

The 19th East Asia Section of SIAM Annual Meeting



EASIAM

Annual Meeting 2026

Full Program Book

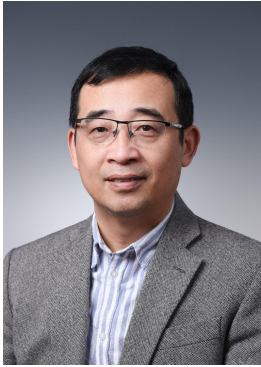
AUGUST 23^{SUN} ~ 27^{THU}, 2026

ORIENTAL HOTEL, JEJU ISLAND, KOREA



TIME	SUN AUG 23 Registration 16:00-20:00	MON AUG 24 Registration 08:00-18:00	TUE AUG 25 Registration 08:00-18:00	WED AUG 26 Registration 08:00-18:00	THU AUG 27 Registration 08:00-18:00
08:00		Opening Ceremony 08:10-08:30			
09:00		Plenary Lecture 1 Shi Jin 08:30-09:20	Plenary Lecture 2 Carol S. Woodward 08:30-09:20	Plenary Lecture 3 Myungjoo Kang 08:30-09:20	Parallel sessions 08:30-09:50
10:00		Group Photo & Coffee Break 09:20-09:50	Coffee Break 09:20-09:50	Coffee Break 09:20-09:50	
11:00		Parallel sessions 09:50-11:10	Parallel sessions 09:50-11:10	Parallel sessions 09:50-11:10	Coffee Break 09:50-10:20
12:00		Parallel sessions 11:20-12:40	Parallel sessions 11:20-12:40	Parallel sessions 11:20-12:40	Parallel sessions 10:20-11:40
13:00		Break	Break	Break	
14:00		Parallel sessions 11:20-12:40	Parallel sessions 11:20-12:40	Parallel sessions 11:20-12:40	Break
15:00		Lunch 12:40-14:00	Lunch 12:40-14:00	Lunch 12:40-14:00	Parallel sessions 11:50-13:10
16:00		Invited Talk 1 Te-Sheng Lin 14:00-14:40	Invited Talk 3 Kenji Kajiwara 14:00-14:40	Invited Talk 5 Zhi Zhou 14:00-14:40	
17:00		Invited Talk 2 Zhenli Xu 14:40-15:20	Invited Talk 4 Guanghui Hu 14:40-15:20	Invited Talk 6 Mikyoung Lim 14:40-15:20	
18:00		Coffee Break 15:20-15:50	Coffee Break 15:20-15:50	Coffee Break 15:20-15:50	
19:00		Parallel sessions + Student Paper Prize (M) 15:50-17:10	Parallel sessions 15:50-17:10	Parallel sessions 15:50-17:10	Excursion 14:00-18:00
20:00		Break	Break	Break	
21:00		Parallel sessions + AC/EC meeting (M) 17:20-18:40	Poster Session Room S 17:20-18:40	Parallel sessions 17:20-18:40	
22:00	Welcome Reception Room I 18:00-20:00		Conference Banquet Room H 18:40-21:00		

PLENARY LECTURES



Shi Jin

Shanghai Jiao Tong University

Date & time	Monday, August 24 2026, 08:30-09:20
Room	H
Chair	Tao Tang

BRIEF BIOGRAPHY

Shi Jin is the Director of Institute of Natural Sciences, and Chair Professor of Mathematics, at Shanghai Jiao Tong University. He also serves as a director of Ministry of Education Key Lab on Scientific and Engineering Computing, and director of Shanghai Jiao Tong University Chongqing Artificial Intelligence Institute.

He received a Feng Kang Prize of Scientific Computing in 2001, a Morningside Silver Medal in 2007, a Shanghai Natural Science Prize (first class) in 2024, a "Frontier of Science" award in International Congress of Basic Sciences in 2025, and a Shanghai Jiao Tong University Ruiyuan Science and Technology Grand Prize in 2026. He is an inaugural Fellow of the American Mathematical Society (AMS) (2012), a Fellow of Society of Industrial and Applied Mathematics (SIAM) (2013), an inaugural Fellow of the Chinese Society of Industrial and Applied Mathematics (CSIAM) (2020), an Invited Speaker at the International Congress of Mathematicians in 2018 and at the International Congress of Industry and Applied Mathematics in 2027. In 2021 he was elected a Foreign Member of Academia Europaea and a Fellow of European Academy of Sciences.

His research interests include kinetic theory, hyperbolic conservation laws, quantum dynamics, uncertainty quantification, interacting particle systems, computational fluid dynamics, machine learning and quantum computing, etc. He has published over 250 papers in Acta Numerica, Comm. Pure Appl. Math., PNAS, Phys. Rev. Lett., etc.

Quantum Computations of nonlinear PDEs and the UnitaryLab Software

ABSTRACT

Quantum computers are designed based on quantum mechanics principle, they are most suitable to solve the Schrodinger equation, and linear PDEs (and ODEs) evolved by unitary operators. Nonlinearity and Nonunitarity are the main challenges for quantum simulations of PDEs.

For linear PDEs (and ODEs) Schrodingerization provides a general method to unitarize them for quantum simulation. For nonlinear problems we first introduce our quantum algorithms for (nonlinear) Hamilton-Jacobi equations, for both multi-valued solutions and viscosity solutions that are needed beyond the formation of caustics. We also introduce quantum algorithms for Young measures associated with nonlinear PDEs, which are effective tools to compute weak solutions to nonlinear PDEs that have singular solutions such as shocks, caustics, physical instabilities or (random) uncertainties.

We also introduce "UnitaryLab", which is an AI-powered research software package of quantum algorithms for scientific computing.



Carol S. Woodward

Lawrence Livermore National Laboratory

Date & time	Tuesday, August 25 2026, 08:30-09:20
Room	H
Chair	Ming-Chih Lai

BRIEF BIOGRAPHY

Dr. Carol Woodward is a Distinguished Member of the Technical Staff at Lawrence Livermore National Laboratory and currently serves as President of the Society for Industrial and Applied Mathematics (SIAM). She received her PhD in Computational and Applied Mathematics from Rice University and has been at Lawrence Livermore National Laboratory in the Center for Applied Scientific Computing since then. She is the Director of the Frameworks, Algorithms, and Software Technologies (FASTMath) Institute, a 10-institution effort to provide numerical algorithms expertise and software to scientists across the United States Department of Energy. She also leads the development and deployment of the SUNDIALS package of time integrators and nonlinear solvers which garners over 100,000 downloads/clones each year. Her research interests include numerical methods for nonlinear partial differential equations, nonlinear and linear solvers, time integration methods, numerical software development, and parallel computing. Dr. Woodward was named to the 2017 Class of Fellows of SIAM and to the 2021 Class of Fellows of the Association for Women in Mathematics. In 2023 Dr. Woodward was a co-winner of the ACM/SIAM Prize in Computational Science and Engineering as part of the SUNDIALS Core Development Team.

Adaptive Time Integration Methods, Software, and Applications

ABSTRACT

Adaptive time integration has become an essential tool for the efficient and accurate simulation of time-dependent science and engineering applications. In this presentation, we examine the value of adaptive stepping strategies for controlling error and reducing computational cost. We then develop the formulation of both fixed step and newly developed adaptive multirate methods, emphasizing how these multirate approaches exploit disparate temporal scales to achieve greater efficiency than standard single-rate schemes. A further focus is on software infrastructure, where robust implementations of adaptive and multirate integrators enable practical deployment in large-scale scientific computing. We highlight how these methods are hardened in reliable software frameworks and discuss their use in applications spanning quantum dynamics, combustion, and nuclear physics. Together, these examples demonstrate the impact of advanced time integration methods on the simulation of complex physical systems and underscore the interplay between numerical analysis, algorithm design, and scientific software development.



Myungjoo Kang

Seoul National University

Date & time	Wednesday, August 26 2026, 08:30-09:20
Room	H
Chair	Hisashi Okamoto

BRIEF BIOGRAPHY

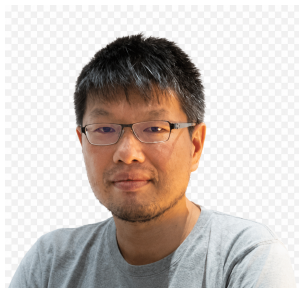
Myungjoo Kang is a Professor in the Department of Mathematical Sciences at Seoul National University (SNU), where he is also affiliated with the Interdisciplinary Programs in Computational Science and Artificial Intelligence. He received his B.S. from Seoul National University, M.S. from KAIST, and Ph.D. in Applied Mathematics from the University of California, Los Angeles (UCLA). His research spans applied mathematics, scientific computing, numerical analysis, and machine learning/deep learning, with a particular focus on optimal transport, physics-informed neural networks (PINNs), and neural operators. A Fellow of the Korean Academy of Science and Technology (KAST), Prof. Kang has published over 150 SCI-indexed papers in premier journals and top-tier AI conferences including ICML, NeurIPS, ICLR, and ICCV. He previously served as Chair of the Department of Mathematical Sciences at SNU and Vice President of KSIAM and EASIAM.

Deep Learning-Based Surface Reconstruction from Point Clouds

ABSTRACT

In this presentation, we introduce an advanced deep learning approach for reconstructing surfaces from unorganized point clouds. By leveraging an implicit surface representation through a level set function, our method ensures watertight results and seamlessly adapts to various topologies. We employ the p-Poisson equation to precisely learn the signed distance function (SDF), improving accuracy through a variable splitting strategy that incorporates the SDF gradient as an auxiliary variable. Additionally, we enforce a curl-free condition on the auxiliary variable to exploit the irrotational nature of conservative vector fields. Our numerical results illustrate that this strategic integration of partial differential equations and key vector field characteristics efficiently reconstructs high-quality surfaces without the need for prior surface knowledge.

INVITED TALKS



Te-Sheng Lin

National Yang Ming Chiao Tung University

Date & time	Monday, August 24 2026, 14:00-14:40
Room	H
Chair	Matthew Lin

BRIEF BIOGRAPHY

Te-Sheng Lin is a Professor in the Department of Applied Mathematics at National Yang Ming Chiao Tung University, Taiwan. He received his Ph.D. in Mathematical Sciences from the New Jersey Institute of Technology in 2012. His research interests include numerical analysis, partial differential equations, scientific computing, fluid dynamics, and scientific machine learning. His recent work focuses on structure-aware computational methods for PDEs and scientific machine learning. He also works on coherent structures and nonlinear pattern formation in fluid dynamics, as well as interdisciplinary data-driven modeling in experimental and biomedical sciences.

Structure-Aware Scientific Machine Learning for Interface Problems

ABSTRACT

Interface problems arise in a broad range of applications, including multiphase flows, materials science, and biological membranes. Their numerical solution is challenging because jumps, derivative discontinuities, singular sources, and geometric constraints are often concentrated near lower-dimensional interfaces. Standard PINNs and neural PDE solvers may fail to resolve these structures accurately due to their smooth and generic representations. In this talk, I will present structure-aware scientific machine learning methods for interface-related PDEs. The main theme is to incorporate interface geometry, jump conditions, singular structures, and classical numerical discretizations into neural solvers. These methods demonstrate how scientific machine learning can move beyond black-box approximation toward neural PDE solvers that respect the analytical structure of interface problems.



Zhenli Xu

Shanghai Jiao Tong University

Date & time	Monday, August 24 2026, 14:40-15:20
Room	H
Chair	Zhiwen Zhang

BRIEF BIOGRAPHY

Zhenli Xu is a distinguished professor at School of Mathematical Sciences, Shanghai Jiao Tong University (SJTU). He received B.S. and Ph.D. degrees from University of Science and Technology of China, and was postdoctoral fellow at University of North Carolina at Charlotte and Humboldt fellow at University of Stuttgart. He joined SJTU in 2010. He was selected in the National Youth Top-notch Talent Program of Central Organization Department of China in 2012, and awarded the National Science Fund for Distinguished Young Scholars in 2023. Professor Xu is in the editorial boards of journals of *Advances in Applied Mathematics and Mechanics*, *Communications in Mathematical Sciences*, and *Mathematical and Computational Applications*. His research fields include fast algorithms and high performance computing, machine learning, molecular dynamics and numerical PDEs.

Machine-Learning Interatomic Potentials for Long-Range Systems

ABSTRACT

Machine-learning interatomic potentials have emerged as a revolutionary class of force-field models in molecular simulations, delivering quantum-mechanical accuracy at a fraction of the computational cost and enabling the simulation of large-scale systems over extended timescales. However, they often focus on modeling local environments, neglecting crucial long-range interactions. We propose a Sum-of-Gaussians Neural Network (SOG-Net), a lightweight and versatile framework for integrating long-range interactions into machine learning force field. The SOG-Net employs a latent-variable learning network that seamlessly bridges short-range and long-range components, coupled with an efficient Fourier convolution layer that incorporates long-range effects. By learning sum-of-Gaussians multipliers across different convolution layers, the SOG-Net adaptively captures diverse long-range decay behaviors while maintaining close-to-linear computational complexity during training and simulation via non-uniform fast Fourier transforms. The method is demonstrated effective for a broad range of long-range systems.



Kenji Kajiwara

Kyushu University

Date & time	Tuesday, August 25 2026, 14:00-14:40
Room	H
Chair	Angeyn Lao

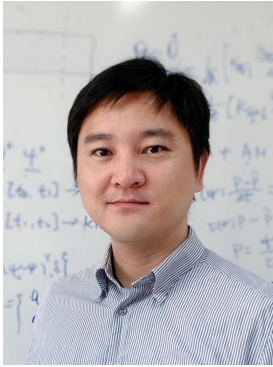
BRIEF BIOGRAPHY

Kenji Kajiwara is a professor and the founding member of the Institute of Mathematics for Industry (IMI), Kyushu University, Japan since 2011. He has been Director of the IMI since 2022. He was awarded a Ph.D. from The University of Tokyo in 1994, then served as a lecturer and an associate professor at Doshisha University, Kyoto, Japan in 1994-2001. In 2001 he moved to the Faculty of Mathematics, Kyushu University and served as an associate professor in 2001-2009, then a professor in 2009-2011. His mathematical expertise is integrable systems and (discrete) differential geometry. He is contributing to the mathematical community in Japan by serving as a Vice President of Japan SIAM for 2020-2022, together with an associate member of the Science Council of Japan since 2023. At the international level, he has been serving as the Council Member of the Asia Pacific Consortium of Mathematics for Industry (APCMfI) since 2021 and also an Officer-at-Large of the International Council for Industrial and Applied Mathematics (ICIAM) since 2023.

Geometric Shape Generation: Integrability, Artisticity and Mechanical Optimality

ABSTRACT

Recently, I have been working with colleagues in differential geometry, architecture, and industrial design to pioneer the field of geometric shape generation where integrable systems play a crucial role. While integrable systems describe universal structures in a sense, the equations and the solutions they define are “special.” In geometric shape generation, this special nature often leads to the definition of meaningful, unique shapes, for example, “aesthetic” shapes, or shapes possessing mechanical optimality. In this talk, while reviewing these special shapes, I will discuss on two topics. The first concerns log-aesthetic curves (LAC), which were introduced in the field of industrial design as a family of curves considered aesthetic by car designers. Recently, their symmetry “self-affinity” (similar to the self-similarity of fractal figures) has been mathematically formulated, and a new family of “aesthetic curves”, including the quadratic curves, has been obtained within the framework of Klein geometry. The second topic concerns classical truss structures in the field of architecture known as the Michell structures, which combine integrability, artisticity and mechanical optimality. I will report on recent results regarding Michell-Prager-type truss structures defined by discrete power functions and discrete logarithmic functions described by the Painlevé VI equation.



Guanghui Hu

University of Macau

Date & time	Tuesday, August 25 2026, 14:40-15:20
Room	H
Chair	Jae-Hun Jung

BRIEF BIOGRAPHY

Dr. Guanghui Hu is a Professor in the Department of Mathematics at the University of Macau and is affiliated with the State Key Laboratory of Internet of Things for Smart City. He received his B.Sc. (2003) and M.Sc. (2006) from Sichuan University, and his Ph.D. (2010) from Hong Kong Baptist University. He served as a postdoctoral researcher at Michigan State University from 2010 to 2012. His research focuses on numerical methods for partial differential equations and computational physics. His work is supported by grants from the National Natural Science Foundation of China and FDCT of Macao SAR, and he has authored over 60 publications. He serves on the editorial boards of Communications in Computational Physics and Advances in Applied Mathematics and Mechanics, as well as the Chinese journal Mathematics Numerica Sinica. He also serves as a member of the Executive Committee of the SIAM East Asian Section and the China Society for Computational Mathematics.

Towards extreme efficiency: numerical methods for PDEs in AI era

ABSTRACT

Partial differential equations (PDEs) are foundational to computational science, but the rise of "AI for Science" demands unprecedented efficiency from traditional numerical methods. Concurrently, the emergence of a new computing paradigm fusing physical mechanisms with data, coupled with rapid hardware advancements, offers fresh opportunities to push the efficiency limits of classical solvers. In this talk, we will review our recent progress in high-performance PDE numerical methods, focusing on the application of adaptive mesh refinement, treecode algorithms, and multigrid techniques in computational physics, highlighting their superior efficiency and accuracy in domains like fluid dynamics. Central to these advancements is AFEPack, an open-source C++ numerical library developed by the speaker and collaborators. We elaborate on its design philosophy, the implementation of these acceleration techniques via low-level data structures, and the development of specialized libraries for targeted physical disciplines. Finally, we present a reinforcement learning framework for airfoil optimization driven by our derivative library, AFVM4CFD, analyzing key implementation challenges and demonstrating its competitiveness through numerical results. Ultimately, this talk highlights viable pathways to extreme efficiency in traditional numerical methods, aiming to inspire next-generation fusion paradigms between physical mechanisms and machine learning.



Zhi Zhou

Hong Kong Polytechnic University

Date & time	Wednesday, August 26 2026, 14:00-14:40
Room	H
Chair	Qianxiao Li

BRIEF BIOGRAPHY

Zhi Zhou is currently a Professor in the Department of Applied Mathematics at The Hong Kong Polytechnic University. Before joining PolyU in 2017, he received his Ph.D. from Texas A&M University in 2015 and conducted postdoctoral research at Columbia University from 2015 to 2017. His research interests include numerical analysis of partial differential equations, scientific computing, nonlocal models, and computational inverse problems. He has published one monograph and more than eighty research papers. His contributions have been recognized with the Early Career Award from the Hong Kong Research Grants Council, the Frontier of Science Award at the International Congress of Basic Science 2024, and his selection as a Highly Cited Researcher in Mathematics by Clarivate.

The Parareal Algorithm Revisited: Toward Parallel-in-Time Integration

ABSTRACT

The parareal algorithm is one of the most widely studied and effective parallel-in-time methods for the numerical approximation of time-dependent problems. Its main idea is to combine a computationally inexpensive coarse solver, which provides a rough prediction of the solution over large time steps, with a more accurate but expensive fine solver, which is applied in parallel on coarse time subintervals to iteratively improve the approximation. In recent years, this approach has attracted considerable attention as a promising strategy for accelerating large-scale simulations of evolutionary partial differential equations. In this talk, I will present some of our recent work on the development, analysis, and application of parareal algorithms for PDEs. I will begin with parabolic equations, where we investigate how to design and optimize the coarse propagator so as to improve the performance of the parareal algorithm and achieve optimal convergence rates. I will then discuss an extension of the framework to linear multistep methods, with particular emphasis on the treatment and correction of initial values on each coarse time subinterval in order to maintain stability and accuracy. Finally, I will turn to the application of parareal algorithms to non-diffusive models, where the absence of smoothing effects introduces additional analytical and computational challenges.



Mikyoung Lim

KAIST

Date & time	Wednesday, August 26 2026, 14:40-15:20
Room	H
Chair	Hiroshi Fujiwara

BRIEF BIOGRAPHY

Mikyoung Lim is a professor in the Department of Mathematical Sciences at KAIST. She received her Ph.D. in mathematics from Seoul National University in 2003. She held postdoctoral and faculty positions at École Polytechnique and Colorado State University before joining KAIST. Her research interests include inverse problems, imaging, composite materials, spectral analysis of integral operators, and data-driven approaches to inverse problems. She received the MediaV Young Researcher Award at the 2014 International Conference on Inverse Problems (ICIP) and was a plenary speaker at the Applied Inverse Problems (AIP) Conference 2025.

Direct and inverse problems for inclusions via layer potentials

ABSTRACT

Inclusion problems arise naturally in materials science and imaging, where one seeks to understand the effects of embedded structures or reconstruct the geometry and material properties of the inclusions. In this talk, I discuss both direct and inverse problems for inclusions governed by partial differential equations. Since inverse problems are closely related to the corresponding direct problems, I first present solution methods based on layer potential techniques and complex analysis. I then discuss several imaging and cloaking results for simply connected and multi-coated inclusions. In particular, I present an analytic inversion formula for planar conductivity inclusions, which provides an explicit reconstruction of the inclusion geometry from exterior measurements. I also discuss homogenization-based approaches to the design of cloaking structures.

MINISYMPOSIA

Monday, August 24 2026

MS06

Locally Conserved and Structure-Preserving Numerical Algorithms for Partial Differential Equations

Main organizer	Shuyu Sun (Tongji University)
Co-organizers	Eun-Jae Park (Yonsei University)

DESCRIPTION

This minisymposium focuses on the design, analysis, implementation, and application of locally conservative, structure-preserving, and physics-constrained numerical methods for partial differential equations (PDEs) arising in engineering and sciences such as fluid dynamics, continuum mechanics, electromagnetism, geophysics, energy systems, and multiphysics coupling. Conventional discretizations often fail to enforce local conservation laws or preserve key physical invariants (mass, momentum, energy, entropy, positivity, divergence constraints, or Hamiltonian structure), leading to unphysical solutions, instability, or inaccurate long-time behavior-especially for under-resolved, nonlinear, or multiscale problems.

The scope includes (but is not limited to) locally conservative finite volume, discontinuous Galerkin, finite element, and compatible discretizations; structure-preserving schemes (energy/entropy-stable, divergence-free, etc); adaptive and high-order methods with physical guarantees; rigorous error analysis; and real-world applications. Machine learning and AI algorithms are increasingly emerging as powerful tools to enhance these numerical methods, and their integration is strongly encouraged in this session; in particular, physics-constrained AI algorithms for PDEs are highly encouraged.

The primary objectives are to bring together researchers from academia and industry to share recent advances, foster cross-fertilization between numerical analysis and applied computational science, highlight open challenges in method design and implementation, and connect early-career researchers with experts in the field-aligning with EASIAM's focus on applied mathematics for real-world impact.

MS06A | 09:50-11:10 | Room H1

09:50-10:10 | Junxiang Yang

Macau University of Science and Technology

Stable auxiliary variable viscosity splitting method for the incompressible Navier-Stokes equations

ABSTRACT

In this talk, we develop an energy-stable, second-order accurate, and stable viscosity splitting method for the penalized incompressible Navier-Stokes equations. At each time step, it is sufficient to solve a Poisson equation to update the pressure and several linear elliptic equations with variable coefficients to update the velocity components. We analytically prove that the time-discretized energy satisfies the unconditional dissipation law. Moreover, we estimate that the L2-norm of velocity at each time step is bounded by the sum of the L2-norm of initial velocity and a constant, the H1-norm of velocity is weakly stable, i.e., it is bounded by a constant which is related to the time step. Extensive numerical experiments are implemented to verify the capability of our proposed method.

10:10-10:30 | Lina Zhao

City University of Hong Kong

A structure-preserving discretization for the coupled Stokes-Biot equations

ABSTRACT

In this talk I will present a structure-preserving discretization for the coupled Stokes--Biot equations. The method is based on a fully-mixed formulation and computes directly the fluid and poroelastic stresses and the Darcy velocity. The scheme employs equal-order polynomial approximations for all unknowns, yet exhibits local momentum conservation, strongly symmetric stress fields, and exactly divergence-free velocity in the fluid domain. Transmission conditions enforcing mass conservation, stress balance, and the Beavers--Joseph--Saffman slip with friction law are incorporated directly into the formulation as natural interface conditions through careful balance of finite element spaces across subdomains. Several numerical experiments are carried out to validate the accuracy and robustness of the proposed scheme.

10:30-10:50 | Xuehai Huang

Shanghai University of Finance and Economics

Superconvergent and Divergence-Free Mixed Finite Element Methods for The Stokes Equation

ABSTRACT

This paper develops superconvergent and divergence-free mixed finite element methods for the Stokes equation. We employ $H(\text{div})$ -conforming finite elements for the velocity and discontinuous piecewise polynomials for the pressure, ensuring that the divergence-free condition is satisfied pointwise. To discretize the vector Laplacian, we introduce a weak deviatoric gradient operator constructed from tangential-normal continuous traceless tensor elements. This approach yields a consistent and stable discretization without the need for additional stabilization terms required in discontinuous Galerkin or virtual element methods. We prove a discrete inf-sup condition and establish optimal-order error estimates for the stress. Notably, we derive superconvergent estimates for the velocity and pressure. The proposed framework provides a unified perspective on nonconforming virtual element methods and pseudostress-velocity-pressure formulations.

10:50-11:10 | Eric Chung

The Chinese University of Hong Kong

An Adaptive Mixed CEM-GMsFEM for Two-Phase Flow in High-Contrast Porous Media

ABSTRACT

In this talk, we present an adaptive physics-preserving multiscale method for incompressible and immiscible two-phase flow in high-contrast porous media. The method couples a physics-preserving implicit pressure explicit saturation scheme (P-IMPES) with a mixed constrained energy minimizing generalized multiscale finite element method. The P-IMPES formulation preserves the conservative structure of the model, treats the wetting and non-wetting phases in an unbiased way, and maintains saturation bounds under a suitable CFL condition. We prove local conservation, unbiased property, bounds preservation, and a saturation error estimate for the multiscale approximation. The work is partially supported by the Hong Kong RGC General Research Fund (Project Nos. 14305423 and 14305624).

MS06B | 11:20-12:40 | Room H1

11:20-11:40 | Meng-Huo Chen

National Chung Cheng University

Parallel Finite Element Simulation of the Quasi-Static Biot Model with Application to Brain Edema Modeling

ABSTRACT

Brain edema can be modeled by Biot-type poroelastic equations coupling tissue displacement and fluid pressure. We present a parallel finite element framework for the quasi-static Biot model as a step toward large-scale simulations on realistic two- and three-dimensional human brain meshes. The method uses a direct displacement-pressure formulation with Taylor-Hood-type (P_2, P_1) elements and Crank-Nicolson time stepping. The mesh is partitioned by METIS, halo degrees of freedom are constructed for the mixed-order discretization, and the resulting systems are solved by Krylov methods with HYPRE-based preconditioning. Manufactured-solution tests verify the expected convergence rates and reveal solver sensitivity in small-storage and low-permeability regimes. The study also provides a computational basis for future dynamic Biot models, where tissue inertia is included through second-order time derivatives of displacement.

11:40-12:00 | Huangxin Chen

Xiamen University

Locally Conserved and Structure-Preserving Numerical Methods for Flows in Porous Media

ABSTRACT

Modeling and simulation of complex flows in porous media are of great interest in the fields of hydrology and petroleum reservoir engineering. In this talk we will introduce a new locally mass-conserved enriched Petrov-Galerkin (EPG) method for flows in porous media, including the applications of EPG method for flows in fractured porous media. The thermodynamically consistent mathematical models for non-isothermal multi-phase flows in porous media, and the structure-preserving numerical methods will also be discussed.

12:00-12:20 | Ruishu Wang

Jilin University

A staggered discontinuous Galerkin method for linear elasticity problem on polytopal meshes**ABSTRACT**

We propose a novel staggered discontinuous Galerkin (SDG) method for linear elasticity, formulated within the Hellinger-Reissner variational principle. The method introduces symmetric stress spaces that ensure normal continuity across element interfaces on arbitrary polytopal meshes, while displacements are approximated using piecewise polynomial functions on the same mesh. The method is locking-free and satisfies a local balance of linear momentum and angular momentum. The formulation also admits a hybridizable structure, which greatly facilitates numerical implementation.

12:20-12:40 | Jiyeon Kim

Ajou University

Co-authors: Dongwook Shin (Ajou University)

Locally Conservative Sparse Neural Operator netWorks**ABSTRACT**

Operator learning is a promising paradigm for parametric partial differential equations (PDEs), yet network parameters grow rapidly with mesh resolution. We present Sparse Neural Operator netWorks (SNOW), a framework that embeds the sparse structure of PDE discretizations into the network architecture. As a primary application, Sparse FEONet restricts each layer's connectivity to the local support of finite element basis functions, supported by a universal approximation theorem and stability analysis, and achieves up to a 98% parameter reduction while maintaining accuracy. In this talk we propose SNOW-HDG, a locally conservative extension based on the Hybridizable Discontinuous Galerkin (HDG) method. The network learns only the skeleton trace λ using HDG connectivity as its sparsity pattern, and element-wise solutions are recovered by the HDG local solver, so the prediction satisfies local conservation property. Poisson experiments confirm accuracy and efficiency.

MS32

Uncertainty Quantification and Mathematical Foundations of Deep Learning: Recent Advances in Methods, Theory, and Applications

Main organizer	Jiahua Jiang (ShanghaiTech University)
Co-organizers	Ling Guo (Shanghai Normal University); Liang Yan (Southeast University)

DESCRIPTION

Uncertainty Quantification (UQ) and Deep Learning (DL) are increasingly interconnected in modern scientific discovery. UQ provides a rigorous framework for probabilistic modeling, error propagation, and reliability assessment, helping transform deep learning models into trustworthy tools for scientific computing. At the same time, deep learning offers powerful surrogate modeling approaches that can significantly accelerate traditional UQ workflows and enable the study of complex high-dimensional systems. This minisymposium will bring together researchers working at the intersection of uncertainty quantification, deep learning, and scientific computing. Topics include uncertainty-aware learning, probabilistic deep models, scientific machine learning, and the mathematical foundations of deep neural networks from the perspectives of approximation theory, numerical PDEs, and geometry. The goal is to promote interaction between methodological, theoretical, and applied advances in this rapidly growing area.

MS32A | 09:50-11:10 | Room H3

09:50-10:10 | Jiahua Jiang

ShanghaiTech University

A warm-basis method for bridging learning and iteration: a case study in fluorescence molecular tomography

ABSTRACT

Fluorescence Molecular Tomography (FMT) is non-invasive but depth reconstruction remains challenging. Conventional iterative methods have poor z-resolution even with advanced regularization, while supervised learning improves accuracy but requires impractical large paired datasets. This raises the question of how to combine learning with iterative schemes. We propose a warm-basis iterative projection method (WB-IPM) with theoretical foundations. It significantly outperforms both learning-based and iterative approaches, and uses a weaker loss function based only on directional differences, reducing training effort. These benefits are supported by error analysis and experiments on simulated and real data.

10:10-10:30 | Ruiyi Yang

Shanghai Jiao Tong University

Functional Multi-Target Detection via Bispectrum Inversion

ABSTRACT

We develop a functional theory for multi-target detection, recovering a compactly supported signal from a single noisy observation containing many unknown translations. Our model permits continuous, off-grid translations and correlated stationary Gaussian process noise, extending beyond standard discrete, grid-aligned white-noise settings. We study two uninitialized autocorrelation-based algorithms. Both first estimate the signal bispectrum using a debiased third-order empirical autocorrelation, then recover the signal either by a functional frequency marching scheme or a Kotlarski-type deconvolution formula. For both methods, we establish non-asymptotic recovery guarantees for compactly supported signals without bandlimiting assumptions. The error bounds depend on signal smoothness and bispectrum estimation accuracy, which is governed by the noise structure and number of signal occurrences. Numerical experiments support the theory and show accurate recovery in low-SNR regimes.

10:30-10:50 | Zhen Gao

Ocean University of China

An Efficient Reduced-Order Model Based on Dynamic Mode Decomposition for Parameterized Spatial High-Dimensional PDEs

ABSTRACT

Accurately constructing a reduced order model (ROM) of parameterized partial differential equations (PDEs) has always been a challenging problem in engineering and applied sciences. Dynamic mode decomposition (DMD) is a popular data-driven method and proposed for the ROM of time-dependent problems. However, it is invalid for the parameterized problems. In this talk, we will first extend the DMD to the parameterized problems and then introduce recent development. We apply the proposed methods to various parameterized PDEs. The results demonstrate the applicability and efficiency of the proposed ROMs. Furthermore, the proposed ROMs show better predictive ability than the POD-based ROMs outside of the training time region.

10:50-11:10 | Sahoqian Zhou

Huazhong University of Science and Technology

Flow-based generative models for amortized Bayesian inference in regression and inverse PDE problems

ABSTRACT

Bayesian inference enables uncertainty quantification in scientific ML, but conventional methods solve a new inference problem per observation set, limiting real-time use in monitoring and digital twins. Many problems involve function-space inference with varying observation counts/locations, challenging amortized methods. We propose Flow-ABI, a flow-based framework for amortized Bayesian inference in regression and inverse PDE problems: (i) a functional prior model learning function-space priors via flow matching, and (ii) a set-conditioned posterior sampler mapping observations to functional posteriors. The model handles varying observation sets, is permutation-invariant, and generalizes across discretizations. Once trained, it enables near-real-time posterior sampling without retraining, and integrates with physics-informed neural networks and neural operators. Experiments show Flow-ABI captures Gaussian/non-Gaussian posteriors with speedups over two orders of magnitude versus HMC.

MS32B | 11:20-12:40 | Room H3

11:20-11:40 | Juncai He

Tsinghua University

Sharp Sobolev Sandwich and Approximation Rates of Shallow ReLU^k Networks

ABSTRACT

We present a Radon-domain framework for analyzing shallow ReLU^k networks, connecting Barron-type spaces, Hilbert integral representations, and L^p Sobolev regularity. The main result is a sharp Sobolev sandwich for L^p ridge integral spaces, with sharpness explained by microlocal analysis. We also derive improved high-probability approximation rates for linearized/random feature networks and illustrate them numerically.

11:40-12:00 | Yanyan Wang

Shanghai Normal University

Deep learning-enhanced reduced-order ensemble Kalman filter for efficient Bayesian data assimilation

ABSTRACT

Bayesian data assimilation for parametric PDE systems is computationally expensive because it requires repeated forward model evaluations. We present a deep learning-enhanced reduced-order ensemble Kalman filter for Bayesian data assimilation in parametric PDE systems. The proposed method combines operator inference with a data-driven model-error correction strategy. A reduced-order model is first learned from long-term coarse-grid simulations to capture the dominant system dynamics. A neural network is then trained to correct the discrepancy between the reduced-order and high-fidelity models. The learned correction is incorporated into the online ensemble Kalman filtering procedure, improving estimation accuracy while maintaining low computational cost. Numerical results demonstrate that the proposed framework provides an effective balance between efficiency and accuracy for nonlinear data assimilation problems.

12:20-12:40 | Xinliang Liu

KAUST

Multigrid Neural Operators for Helmholtz Preconditioning and Diff-ANO Guided UCST Inversion

ABSTRACT

We introduce the Multigrid Neural Operator (MgNO) and the Multigrid Neural Preconditioner (MgNP), a unified framework that integrates classical multigrid methodology with modern deep learning to address complex problems. First, we present a concise neural operator architecture, drawing an analogy to fully connected neural networks. To overcome spectral bias in operator learning, we extend this design into MgNO, built on the MgNet architecture, where multigrid V-cycle structure is embedded. Next, we develop a multigrid-inspired neural preconditioner for challenging problems such as high-wavenumber Helmholtz equations. This preconditioner learns both smoothing and coarsening operators from data. The resulting multichannel neural preconditioner achieves substantial convergence speedups compared to classical alternatives. Finally, we demonstrate the robustness and efficiency of the proposed approaches in applications to ultrasonic computed tomography.

MS27

Propagation, Patterns, and Spatiotemporal Heterogeneity in Reaction-Diffusion Models for Biology

Main organizer	Xiaoqing He (East China Normal University)
Co-organizers	Huicong Li (Sun Yat-sen University)

DESCRIPTION

This minisymposium focuses on recent advances in the analysis of reaction-diffusion-advection equations and related cross-diffusion and chemotaxis systems arising in biology. Particular emphasis will be placed on how spatial and temporal heterogeneity affects invasion, persistence, coexistence, pattern formation, and long-time dynamics. The session will bring together researchers working on propagation phenomena in heterogeneous and periodic media, reaction-diffusion-advection equations, chemotaxis and Keller-Segel type systems, epidemic and population models with cross-diffusion, and nonlinear parabolic equations motivated by ecology, epidemiology, and cell movement. By linking rigorous PDE analysis with biological modeling, this minisymposium aims to promote interaction among researchers in reaction-diffusion theory, dynamical systems, and mathematical biology, and to highlight how heterogeneity and directed movement shape complex biological processes.

MS27A | 09:50-11:10 | Room S1

09:50-10:10 | Mingmin Zhang

University of Science and Technology of China

Sharp asymptotics for the KPP equation with some front-like initial data

ABSTRACT

In this talk, I will present the first PDE proof for Bramson's $\phi(1)$ results established in 1983 concerning the sharp asymptotics for the KPP equation under front-like initial data decaying as $x^{k+1}e^{-\lambda x}$ and $x^{\nu}e^{-\lambda x}$ as x tends to infinity, with $0 < \lambda < \lambda_{*} = \sqrt{f'(0)}$ and with any fixed $k, \nu \in \mathbb{N}$.

10:10-10:30 | Weiwei Ding

South China Normal University

Effects of temporal variations on wave speeds of bistable traveling waves for Lotka-Volterra competition systems

ABSTRACT

This talk is concerned with the bistable traveling waves for two-species Lotka-Volterra competition systems in time periodic environments. We focus especially on the influence of the temporal period, with existence results established for both small and large periods. We also show the existence of, and derive explicit formulas for, the limiting speeds as the period tends to zero or infinity, and provide estimates for the corresponding rates of convergence. Furthermore, we analyze the sign of wave speed. Based on our explicit formulas for the limiting speeds, we construct an example in which the sign of wave speed changes with the temporal period. This example reveals that temporal variations can significantly influence competition outcomes, enabling different species to become dominant under different periods.

10:30-10:50 | Rui Tang

Southeast University

Co-authors: Yuxiang Li (Southeast University)

Global well-posedness and blow-up for a chemotaxis system with indirect signal production in $\mathbb{R}^4$

ABSTRACT

We investigate the chemotaxis system with indirect signal production in $\mathbb{R}^4$:
$$\begin{cases} \partial_t u - \Delta u + \nabla \cdot (u \nabla v) = 0, \\ -\Delta v = w, \\ -\Delta w = u, \\ u(x, 0) = u_0(x). \end{cases}$$
 This system appears as a special case of an attraction-repulsion chemotaxis system describing the motion of microglia in the central nervous system. Some models of this form are also equivalent to certain reaction-cross-diffusion systems with a mechanism termed distributed delayed diffusion, describing the biased movement of animals due to spatial memory. We prove that for every nonnegative initial datum in $L^1(\mathbb{R}^4)$, this system is globally well-posed if and only if the total mass $\int_{\mathbb{R}^4} u_0(x) dx \leq (8\pi)^2$. We show upper bound life span estimates for mild solutions of this system with large initial data.

10:50-11:10 | Yuxiang Li

Southeast University

Critical mass for the Keller-Segel system on closed Riemannian surfaces

ABSTRACT

In this talk, we study the parabolic-elliptic Keller-Segel system on closed Riemannian surfaces. It is known that the critical mass for global existence versus finite-time blow-up is 8π in two-dimensional Euclidean space Blanchet et al (2006) and hyperbolic space Maheux et al (2020). Here, we show a critical mass phenomenon on closed Riemannian surfaces. For any initial mass $M < 8\pi$, the solution exists globally and remains bounded by virtue of Moser-Trudinger inequality on compact surfaces established by Yang (2007). On spheres and ellipsoids of revolution, for supercritical mass $M > 8\pi$, there exist solutions that blow up in finite time, as proved by a refined weighted moment method. Furthermore, for x_0 -zonal solutions on spheres and ellipsoids of revolution, blow-up can only occur at x_0 or its antipodal point.

MS27B | 11:20-12:40 | Room S1

11:20-11:40 | Tian Xiang

Renmin University of China

Boundedness and exponential convergence in a quasilinear chemotaxis-haptotaxis system

ABSTRACT

To fill in gaps and provide new insights for quasilinear chemotaxis only system and chemotaxis-haptotaxis system, we study global dynamics in a Neumann initial-boundary value problem (IBVP) for a three component quasi-linear chemotaxis-haptotaxis system. Under more relaxing conditions than previous studies, we obtain global boundedness of classical solutions to the corresponding IBVP, and then, under further smallness conditions which are independent of masses of cells in the strong diffusion case, we show exponential convergence of such bounded solution towards the constant equilibrium. Our boundedness, based on several subtle energy estimates, significantly extend and improve earlier ones, and our convergence of bounded solutions, relying on a new derived nonlinear Poincaré type inequality, appears to be new even for quasi-linear chemotaxis-only systems.

11:40-12:00 | Jie Jiang

Innovation Academy for Precision Measurement Science and Technology, Chinese Academy of Sciences

On Keller-Segel Models with Signal-Dependent Motility and External Sources

ABSTRACT

In this talk, we report some recent progress on the research of the Keller-Segel model with signal-dependent motility and external sources. By introduction of several auxiliary functions together with applications of comparison techniques and energy methods, we are able to prove in several cases that external sources with super-linear damping term guarantee uniform boundedness of the global classical solution, preventing occurrence of infinite-time blowups in the homogeneous counterpart.

12:00-12:20 | Hongjun Guo

Tongji University

Spreading dynamics for the Lotka-Volterra system with general initial supports: the strong competition

ABSTRACT

This talk concerns the spreading dynamics of a high-dimensional strong competition Lotka-Volterra system where two species initially occupy disjoint measurable (possibly unbounded) subsets in $\mathbb{R}^N$, which are called initial support. Recently, Hamel and Rossi introduced some new geometric notions, such as bounded or unbounded directions and positive-distance interior, for single-species equations with general initial supports. Under these notions and appropriate assumptions, we characterize directional spreading behavior for the two-species system: precise spreading speeds and sets for both species are derived.

MS18

Recent Advances in Computational Science with Machine Learning

Main organizer	Seungchan Ko (Inha University)
Co-organizers	Changhoon Song (Research Institute of Mathematics, Seoul National University)

DESCRIPTION

This mini-symposium focuses on recent advances at the interface between scientific computing and machine learning, two rapidly evolving areas that increasingly complement each other in modern research. Topics of interest include, but are not limited to, numerical algorithms for partial differential equations, machine learning methods for scientific computing, neural operators, physics-informed learning approaches, and the mathematical foundations of machine learning. The session welcomes contributions from a broad range of disciplines, including mathematics, physics, biology, engineering, and related fields, highlighting new perspectives and recent advances in scientific machine learning.

MS18A | 09:50-11:10 | Room S2

09:50-10:10 | Qianxiao Li

National University of Singapore

Learning interpretable dynamics

ABSTRACT

We discuss some recent work on constructing stable and interpretable macroscopic and mesoscopic dynamics from trajectory data using deep learning. We adopt a hypothesis-driven approach: contrary to using generic neural networks as functional approximators for the vector fields driving a dynamical system or operator based learning approaches, we start with a structured hypothesis class in which well-posedness and numerical stability are a priori ensured. Learning on trajectory data then identifies a specific member of this family suitable for capturing the observed dynamical process, from which scientific predictions and analysis can be made. We demonstrate this approach on a variety of macroscopic and mesoscopic modelling problems, including polymer chain dynamics, dynamics of magnetic systems and self-healing in high-entropy alloys.

10:10-10:30 | Youngjoon Hong

Seoul National University

Toward Foundation Models for AI Weather Prediction: Extreme Rainfall, Super-Resolution, and Global Ensemble Forecasting

ABSTRACT

Artificial intelligence is rapidly transforming weather prediction, from regional nowcasting to global ensemble forecasting. In this talk, I will present our recent efforts toward generative weather foundation models across multiple scales. I will first introduce exPreCast, an AI-based model for precipitation nowcasting and extreme rainfall prediction. I will then discuss a generative super-resolution framework that converts low-resolution deterministic forecasts into high-resolution probabilistic predictions, aiming to recover fine-scale rainfall structures and represent uncertainty in extreme events. Finally, I will present our ongoing ERA5-based global medium-range ensemble forecasting model. The talk will highlight key challenges, including spatiotemporal dynamics, uncertainty quantification, physical consistency, and reliable generalization.

10:30-10:50 | Heejae Kwon

Heejae Kwon

Learning Stiff Plasma Global Models with PS-PINNs and DeepONet Surrogates

ABSTRACT

Plasma global models describe low-temperature plasma dynamics as stiff, multi-species ODE systems. Although numerical solvers are reliable, parameter studies require repeated simulations across operating conditions, motivating SciML approaches for efficient solution and surrogate modeling. This talk presents two approaches. First, PS-PINNs improve PINN training for stiff chlorine discharge dynamics through input preprocessing and adaptive residual balancing, and are demonstrated on forward, inverse, and parameter-dependent problems. Second, a DeepONet surrogate learns parameter-to-trajectory maps for gas-specific global models from solver-generated data using time-dependent normalization and a staged hybrid loss. In silane and chlorine examples, the proposed models reproduce transient plasma state trajectories over operating-condition spaces, suggesting SciML as a reusable framework for plasma chemistry simulation.

10:50-11:10 | Myeong-Su Lee

Seoul National University

A Theory-guided Weighted L2 Loss for solving the BGK model via Physics-informed neural networks

ABSTRACT

While Physics-Informed Neural Networks offer a promising framework for partial differential equations, the standard L2 residual loss is insufficient for solving the Bhatnagar-Gross-Krook model of the Boltzmann equation. Specifically, small L2 residuals do not guarantee small errors in macroscopic moments, causing the standard PINN to fail in capturing the true solution. To resolve this, we propose a weighted L2 loss function based on a stability analysis. We obtain that minimizing this weighted loss strictly controls the distance between the exact and approximate solutions. Numerical experiments also show that employing this theoretical guided PINN loss leads to superior accuracy across various benchmarks compared to the standard PINN approach.

MS18B | 11:20-12:40 | Room S2

11:20-11:40 | Kyueon Choi

Yonsei University

Robust training of physics-informed neural networks for p-Laplace problem with rigorous error estimates

ABSTRACT

While physics-informed neural networks (PINNs) are widely adopted, most studies remain confined to linear operators, and a substantial gap persists with classical numerical analysis due to the lack of theoretical error estimation. To bridge these gaps, we propose a robust training framework and establish rigorous error estimates for PINNs solving nonlinear PDEs. In particular, we introduce a dual-norm residual estimation for the p-Laplace equation to overcome challenges posed by low regularity. More precisely, while standard PINNs require strong solutions satisfying the PDE almost everywhere, our framework accommodates cases where solutions exist only in a weak sense. Furthermore, we employ fractional Sobolev norms on the boundary to achieve rigorous estimates. Specifically, within this framework, we derive both a priori and a posteriori error bounds. In addition, the analysis is generalized to a parametric framework. Finally, numerical experiments validate our theoretical estimates.

11:40-12:00 | Jae Yong Lee

Chung-Ang University

Scientific AI for High-Dimensional PDE Learning and Equation Discovery

ABSTRACT

Recent advances in artificial intelligence have opened new opportunities in scientific computing and scientific discovery. In this talk, I present two recent directions in Scientific AI. First, I discuss a BSDE-based learning framework for solving high-dimensional partial differential equations (PDEs), including an unbiased and second-order-free training method that improves computational efficiency while maintaining accuracy. Next, I introduce DoLQ, a framework for discovering ordinary differential equations (ODEs) from observational data by combining symbolic regression with large language model (LLM)-based qualitative reasoning. Together, these works demonstrate how modern AI can contribute to both scalable scientific computing and scientific discovery.

12:00-12:20 | Sho Sonoda

RIKEN AIP

Why Agentic Theorem Prover Works: A Statistical Provability Theory of Mathematical Reasoning Models

ABSTRACT

We develop a statistical theory of LLM-guided theorem proving with proof assistants such as Lean and Rocq. We formulate interactive theorem proving as a finite-horizon deterministic Markov Decision Process, and a tactic-proposing LLM as a stochastic policy with trainable parameters. Statistical provability is defined as the average probability of reaching a proof goal over a distribution of problems.

Although theorem proving is hard in the worst case, modern AI-assisted provers often succeed in practice. We explain this gap by studying biased problem distributions. We formalize two types of bias and show that, when the distribution is sufficiently biased, learning can make statistical provability positive: the model can prove new theorems similar to those it has seen. For hierarchical problems, hierarchical LLMs can improve learning efficiency, giving a principled justification for subgoal decomposition in agentic theorem provers.

Joint work with Shunta Akiyama and Yuya Uezato.

12:20-12:40 | Jinsil Lee

Seoul National University

Combining classical numerical schemes with neural networks for PDEs**ABSTRACT**

This study analyzes the distinct numerical characteristics of standard Partial Differential Equations (PDEs) and Singularly Perturbed PDEs (SPPDEs) and proposes a hybrid numerical-neural framework for their integrated resolution. While conventional numerical methods exhibit high performance in standard PDE analysis, they encounter chronic issues—such as numerical oscillations and solution distortions—in SPPDEs under extreme conditions where the perturbation parameter (ϵ) is very small. These failures arise from the inability to accurately capture sharp gradients within the boundary layer. To overcome these limitations, this research presents a hybrid strategy that synergizes classical numerical techniques with artificial neural networks. Furthermore, a rigorous convergence analysis was conducted to establish the mathematical validity of the proposed methodology. The analysis confirms that the hybrid approach ensures stability.

MS01

Recent Progress in Partial Differential and Difference Equations

Main organizer	Takiko Sasaki (Musashino University)
Co-organizers	Tetsuji Tokihiro (Musashino University)

DESCRIPTION

This mini-symposium presents recent theoretical advances and numerical analysis in partial differential equations and difference equations. It covers a wide range of topics, including integrable systems, exact solutions, singularities in PDE and cellular automata,

The session aims to foster the exchange of ideas on the interplay between continuous and discrete models, highlighting their applications in mathematical models.

MS01 | 11:20-12:40 | Room I1

11:20-11:36 | Kohei Higashi

Musashino University

On lifespan estimates for a discrete Fujita equation

ABSTRACT

We study the lifespan of solutions to a discrete analogue of the semilinear heat equation with power nonlinearity, viewed as a discrete Fujita equation on the lattice. Previous work has shown that this model exhibits finite-time blow-up with the same Fujita critical exponent as in the continuous setting. We investigate how the lifespan depends on the size of small initial data and on the exponent relative to the Fujita critical exponent. We prove that, in both the subcritical and critical cases, the lifespan has the same order as that of the corresponding continuous problem.

11:36-11:52 | Tatsuki Mori

Musashino University

Global solution structure for a cell polarization model with a finite diffusion coefficient

ABSTRACT

We investigate the global bifurcation structure of solutions for a nonlinear boundary value problem with a nonlocal constraint arising in a cell polarization model with mass conservation proposed by Mori, Jilkine, and Edelstein-Keshet. Regarding the shadow system of the stationary problem, a representation formula for the solutions and the global bifurcation diagrams have already been obtained. In this talk, we derive a representation formula for the solutions of the original problem and report on numerical simulations of its global bifurcation diagram. In particular, global bifurcation diagrams include secondary and imperfect bifurcation phenomena.

11:52-12:08 | Paolo Piersanti

The Chinese University of Hong Kong, Shenzhen

Diffuse Adiabatic Flows in Thermally Coupled Grounded Shallow Ice Sheets: Modelling and Analysis

ABSTRACT

In this talk we propose a novel thermodynamical model which couples the evolution of the thickness of a grounded shallow ice sheet with the evolution of its internal temperature. Both the grounded shallow ice sheet surface elevation and the ice internal temperature are subjected to physical constraints. The equations governing the evolution of the grounded shallow ice sheet thickness are degenerate, and the ice internal temperature evolves in a moving domain. First, we formally model the phenomenon under consideration by adopting strategies akin to those employed in the construction of diffuse-interface models. Second, we establish the existence of solutions for one such formal model by means of the penalty method, and we observe that the low regularity of the problem under consideration prevents us from obtaining a standard concept of solution.

12:08-12:24 | TETSUJI TOKIHIRO

Musashino University

A Structure-Preserving Stagewise Rescaling Algorithm for a Two-Dimensional Nonlocal MEMS Equation

ABSTRACT

Nonlocal MEMS equations can exhibit finite-time quenching, or touchdown, which is challenging to resolve numerically. We study a stagewise rescaling algorithm for a two-dimensional nonlocal MEMS equation in an asymptotically constant-feedback touchdown regime. Although the equation is not exactly invariant under the $(A^{3/2})-(A^3)$ scaling used here, the scaling is justified when the reciprocal-integral feedback remains bounded and converges to a positive finite limit, reducing the leading core dynamics to a local MEMS equation with an asymptotically constant coefficient. We prove exact energy dissipation within each fixed stage, derive a discrete energy inequality using a minimizing-movement solver, and quantify switch and outer-update defects. This yields almost monotonicity and a defect-aware criterion for nonexistence of global admissible continuation. Numerical tests illustrate the method and identify diagnostics needed for a posteriori verification.

12:24-12:40 | Takiko Sasaki

Musashino University

Single-Point Touchdown for Radially Symmetric Solutions of a Supercritical Nonlocal MEMS Equation

ABSTRACT

We study finite-time touchdown for a radially symmetric nonlocal MEMS equation in the supercritical regime. Our aim is to construct solutions that touch down only at the origin and whose final profile has a prescribed higher-order algebraic form. The key change of variables is to use $F=(W+\eta)^{-(p+1)}$ together with a contracting radial coordinate z ; in these variables the leading profile becomes $F_B(z)=\alpha_m^{-1}+Bz^m$. This formulation separates the lower-order Taylor modes, the modulation parameter B , and the stable infinite-dimensional remainder. The nonlocal term is controlled by incorporating its leading contributions into a finite-dimensional modulation system for the lower modes and by estimating the remaining stable part. Combining tail estimates, stable remainder estimates, outer barriers, and a degree argument, we obtain smooth radial initial data and the asymptotic profile $(1-v)^{p+1}\sim \Lambda_m(\alpha_m^{-1}(T-t)^{A_m}+B_\infty |x|^m)$.

MS12

Numerical PDEs for scientific machine learning and the vice versa

Main organizer	Hyea Hyun Kim (Kyung Hee University)
Co-organizers	Eric Chung (The Chinese University of Hong Kong)

DESCRIPTION

The scientific machine learning has emerged as a new paradigm to tackle limitations in classical numerical PDEs enhanced with data-driven and physics-informed strategies. The success of physical-AI also highly depends on a profound understanding of the combination of the data-driven and physics-informed machine learning strategies. In this minisymposium, we will consider the following topics; how classical numerical PDEs can be used to deal with problems in the scientific machine learning and physical-AI and the vice versa. The topics include domain decomposition algorithms, multi-scale modeling, reduced-order modeling, and foundation models for numerical PDEs.

MS12A | 15:50-17:10 | Room H1

15:50-16:10 | Youngjoon Hong

Seoul National University

Numerics-Guided Scientific Machine Learning

ABSTRACT

Scientific machine learning provides new tools for solving partial differential equations, but reliable performance often requires incorporating mathematical and numerical structures into the learning process. In this talk, I will discuss numerics-guided SciML methods for challenging PDEs, focusing on approaches that combine neural network-based coefficient learning with classical numerical trial spaces. I will present examples inspired by finite element, discontinuous Galerkin, spectral element, and Müntz-type element methods. These methods exploit problem-adapted approximation spaces and numerical stability mechanisms, making them effective for PDEs with fluid flow, boundary layers, multiscale behavior, discontinuities, or singular perturbations. I will also discuss how numerical analysis helps explain their accuracy, stability, and generalization.

16:10-16:30 | Hyea Hyun Kim

Kyung Hee University

Domain decomposition based iterative algorithms for neural network approximation to PDEs

ABSTRACT

Domain decomposition methods (DDMs) have been extensively developed for fast solutions of algebraic systems obtained from classical finite element discretization of partial differential equations (PDEs). The problem domain is partitioned into overlapping or nonoverlapping subdomains and each local problem to each subdomain is solved iteratively with a suitable interface update to obtain convergent local solutions to the global solution. Each local problem can be solved in parallel and with the addition of a global coarse problem, the iteration convergence can become robust to the number of subdomains in the partition. Recently, DDMs have been also applied to neural network approximation to PDEs in order to improve the solution accuracy and training efficiency. In this talk, Robin iterative algorithms for neural network approximation to PDEs are presented with their convergence theory and numerical results.

16:30-16:50 | Chang-Ock Lee

KAIST

Co-authors: Jun Choi (KAIST); Minam Moon (Korea Military Academy)

Hybrid Least Squares/Gradient Descent Methods for DeepONets

ABSTRACT

We propose an efficient hybrid least squares/gradient descent method to accelerate DeepONet training. Since the output of DeepONet can be viewed as linear with respect to the last layer parameters of the branch network, these parameters can be optimized using a least squares (LS) solve, and the remaining hidden layer parameters are updated by means of gradient descent form. However, building the LS system for all possible combinations of branch and trunk inputs yields a prohibitively large linear problem that is infeasible to solve directly. To address this issue, our method decomposes the large LS system into two smaller, more manageable subproblems - one for the branch network and one for the trunk network - and solves them separately. This method is generalized to a broader type of L^2 loss with a regularization term for the last layer parameters, including the case of unsupervised learning with physics-informed loss.

16:50-17:10 | Jizu Huang

Academy of Mathematics and Systems Science, Chinese Academy of Sciences

Asymptotic Expansion Theory and Methods for Multiscale Hyperelastic Problems

ABSTRACT

In this talk, we study the theory and methods of multiscale asymptotic expansions for hyperelastic problems. Based on the multiscale asymptotic expansion framework, we propose a homogenization method and a first-order asymptotic expansion method for hyperelastic problems. We prove the convergence of the energies of the homogenized solution and the first-order asymptotic approximation. Numerical experiments further verify the accuracy and effectiveness of the proposed methods.

MS12B | 17:20-18:40 | Room H1
17:20-17:40 | Seokjun Ham

Kyung Hee University

Physics-Informed Neural Network Approximations for the Allen-Cahn Equation Using Temporal Decomposition and Levenberg-Marquardt Optimization

ABSTRACT

We propose temporal decomposition strategies for improving the accuracy of physics-informed neural network (PINN) solutions for the Allen-Cahn equation, which is characterized by stiff nonlinearity and sharp interface dynamics. The proposed approaches combine temporal decomposition with the Levenberg-Marquardt (LM) optimization algorithm to enhance the convergence and efficiency of PINN training. Three temporal decomposition strategies are considered: sequential time marching, a time-window approach, and a semi-discrete formulation based on the backward differentiation formula (BDF). Numerical results show that the three strategies achieve comparable accuracy when combined with the LM optimizer.

17:40-18:00 | Wing Tat Leung

City university of Hong Kong

Co-authors: MIN WANG (University of Houston)

Physics-Informed Neural Networks for Multiscale PDEs with Discontinuous High-Contrast Coefficients

ABSTRACT

Physics-informed neural networks (PINNs) are data-driven approaches to solving equations. It is successful in many applications; however, the accuracy of the PINN is not satisfactory when it is used to solve multiscale equations. In this paper, we propose a PINN to solve PDEs with a discontinuous high-contrast coefficient. To find such a solution using a neural network representation, we introduce an additional feature input to the network to retain the inherent solution properties. We train the network using the physics-informed framework in which the loss function comprises the residual of the differential equation. Using the specially designed residual, we can handle the discontinuity of the high-contrast coefficient. Numerical results show that even with a one-hidden-layer (shallow) network and a moderate number of neurons, the present network model can achieve an accurate result using sufficient training data points.

18:00-18:20 | Eric Chung

The Chinese University of Hong Kong

Learning coarse spaces for Darcy flow in heterogeneous media

ABSTRACT

In this talk, we present Darcy flow problems with random permeability using iterative solvers, enhanced by a two-level preconditioner based on a generalized multiscale coarse spaces, which has been demonstrated to be stable for high contrast profiles. To circumvent the need for repeatedly solving spectral problems with varying coefficients, we harness deep learning techniques to expedite the construction of the generalized multiscale coarse spaces. Comprehensive numerical experiments involving diverse random coefficient models, benchmarked against standard algebraic multigrid and ILU preconditioners, demonstrate that the proposed approach substantially reduces the time required to generate the prolongation operator while preserving the preconditioner's original efficacy over traditional methods. The research of Eric Chung is partially supported by the Hong Kong RGC General Research Fund (Projects: 14305624 and 14305423).

18:20-18:40 | Shihua Gong

The Chinese University of Hong Kong, Shenzhen

Power Contractivity and $\mathcal{O}(k)$ Solvers for High-Frequency Helmholtz and Maxwell Problems**ABSTRACT**

High-frequency Helmholtz and Maxwell discretizations produce large, non-Hermitian, and highly indefinite linear systems. This talk presents a power-contractivity convergence theory for overlapping Schwarz methods and its application to scalable frequency-domain wave solvers. For Helmholtz problems, we analyze the power contractivity of RAS-Imp and RAS-PML, leading to a massively parallel RAS-PML solver that exhibits approximately $\mathcal{O}(k)$ runtime for problems with $\mathcal{O}(k^d)$ unknowns. For time-harmonic Maxwell equations, we establish the well-posedness of the parallel overlapping Schwarz iteration, characterize error propagation through impedance-to-impedance maps, and derive a power-contractivity criterion for RAS-Imp. Numerical experiments illustrate the predicted power-contractivity behavior and provide preliminary evidence for the effectiveness of RAS-Imp and RAS-PML for Maxwell problems.

MS14

New developments in numerical verification and analysis for nonlinear problems

Main organizer	Tomoyuki Miyaji (Kyoto University)
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DESCRIPTION

Nearly four decades have passed since the pioneering work by M.T. Nakao on numerical verification methods for partial differential equations. By combining functional-analytic fixed-point theorems with interval arithmetic, these methods bridge the gap between pure mathematical proof and applied scientific computation. Starting from linear elliptic problems, this research field has expanded its scope to a wide range of nonlinear problems through both theoretical and technological breakthroughs. Indeed, the current scope includes not only stationary problems but also nonlinear dynamical systems and singularities, such as the blow-up of solutions. In an era where computer-assisted proofs are opening new horizons in mathematics, the advancement of numerical verification methods for nonlinear problems has become one of the most critical challenges in applied mathematics. Further progress depends on improving the accuracy of numerical schemes, deepening our understanding of numerical analysis, and advancing verification methodologies. For instance, numerical analysis of fourth-order total variation flows and challenges in mathematical fluid dynamics and general relativity require innovations that go beyond the boundaries of conventional theories. This minisymposium shares recent topics, methods, and applications in numerical verification and analysis, including finite element methods, eigenvalue problems, nonlinear phenomena, and emerging ideas in numerical analysis. It aims to provide an opportunity to discuss prospects for the future direction of these research fields over the next decade.

MS14A | 15:50-17:10 | Room H3

15:50-16:10 | Tomoyuki Miyaji

Kyoto University

Numerical verification of unimodal solutions of the generalized Constantin--Lax--Majda equation with viscosity

ABSTRACT

We present a computer-assisted proof of the existence of unimodal solutions of the generalized Constantin--Lax--Majda (gCLM) equation with viscosity and an external force, which is regarded as a one-dimensional model of two-dimensional fluid flow. In the numerical study by Kim et al. (Jpn. J. Ind. Appl. Math. 35 (2018) 1065--1083), it was found that the equation possesses unimodal solutions at sufficiently high Reynolds numbers. In this model, a solution and its second antiderivative are identified with the vorticity and the stream function up to sign, respectively. The solution is said to be unimodal the stream function has exactly one maximum and one minimum in the interval. We apply a fixed-point theorem in infinite-dimensional spaces and interval arithmetic to prove the existence of solutions. This talk is based on joint work with Prof. Yoshitaka Watanabe (Kyushu University).

16:10-16:30 | Yoshitaka Watanabe

Kyushu University

Numerical Verification and Analysis towards Jeffery-Hamel flows related to Navier-Stokes equations

ABSTRACT

Jeffery-Hamel flows are exact solutions of the Navier-Stokes equations in a two-dimensional domain bounded by two semi-infinite lines that meet at a point. It is known that each solution of Jeffery-Hamel flows can be represented in terms of elliptic functions. Hamel's original paper explored a wider class of solutions, and describing all of these solutions in terms of elliptic functions is difficult. We will numerically verify Jeffery-Hamel flows. This approach will avoid the use of elliptic functions and allow extensions to broader solution classes. In this talk, we will introduce Jeffery-Hamel flows and outline future issues. We also plan to discuss new verification examples.

16:30-16:50 | Yuki Ueda

Hokkaido University

Energy dissipation in numerical computation for gradient flows

ABSTRACT

In this talk, we present a numerical scheme for $\mathcal{H}^{-1}$ gradient flows which is based on the backward Euler temporal discretization. The scheme can be interpreted as a minimization problem, and regarded as the minimizing movement with discretized norm. The approximate solutions inherit the energy dissipation property of the continuous system, and this structure can be expected to provide a natural connection to numerical verification. We review the mathematical background of this formulation and demonstrate the application of numerical techniques for solving the associated minimization problems.

16:50-17:10 | Rei Iwamoto

The University of Electro-Communications

Co-authors: Koki Nitta (TDSE Inc.); Hidetomo Hoshino (Waseda University); Nobito Yamamoto (The University of Electro-Communications)

Validated Numerics for ODEs with Conserved Quantities: Application to Black Hole Orbits**ABSTRACT**

Numerical verification methods for ODEs compute rigorous enclosures that are guaranteed to contain the true solutions. In conservative systems, however, such methods may suffer from severe overestimation (the wrapping effect), while conserved-quantity constraints are not explicitly used. We propose a validated integration method that uses multiple first integrals to reduce such overestimation. At each step, we construct a frame that separates directions constrained by the first integrals from directions along the motion. In this frame, we remove regions violating the conservation laws by combining interval reduction and linear prediction. For geodesic motion in Schwarzschild spacetime (a strongly nonlinear system with three invariants), the proposed method extends the validated time horizon by a factor of approximately 21 (from proper time 17,941 to 376,579) and, in high-precision regimes, outperforms standard methods in both accuracy and computational efficiency.

MS14B | 17:20-18:40 | Room H3**17:20-17:40 | Elliott Ginder**

Meiji University

The Surface-Constrained Level Set Method for Multiphase Interfacial Motions**ABSTRACT**

The level set method is one of the most powerful tools of the applied mathematician. It allows one to mathematically express the evolution of shapes and is used throughout the sciences to model phenomena ranging from the free-surface motion of fluids, to the processing of digital images. Nevertheless, the level set method has largely been limited to modeling the evolution of shapes in euclidean spaces. This research extends the level set method to the multiphase surface-constrained setting where surfaces are defined by point clouds.

17:40-18:00 | Ryoki Endo

Niigata University

Co-authors: Xuefeng Liu (Tokyo Woman's Christian University); Phaniel Mariano (Union College)

Sharp Dirichlet Eigenvalue Inequalities on Triangles**ABSTRACT**

This study proves sharp inequalities for the first Dirichlet eigenvalue of the Laplacian on planar triangles. We settle a conjecture of Siudeja on an optimal two-term lower bound involving the area and perimeter, or equivalently a scale-invariant minimization problem formulated by Laugesen and Siudeja. We also prove a Cheeger-type inequality for triangles with the sharp constant conjectured by Parini.

The proof is based on a computer-assisted method. We introduce a computable lower bound for second-order directional derivatives of Dirichlet eigenvalues under vertex perturbations. This is combined with validated finite-element estimates, interval arithmetic, and analytic estimates for nearly degenerate triangles.

18:00-18:20 | Kenta Kobayashi

Hitotsubashi University

A priori error estimates for finite element solutions of the Poisson equation on non-convex domains using graded meshes**ABSTRACT**

We derive an a priori error estimate with explicit error bounds for finite element solutions of the Poisson equation on non-convex domains. On non-convex domains, the reduced regularity of the solution generally prevents the optimal $O(h)$ convergence rate in the H^1 -norm from being achieved with a uniform mesh. To overcome this difficulty, we employ a graded mesh. Unlike conventional graded meshes, which typically require more than $O(h^{-2})$ elements, the graded mesh proposed in our research uses only $O(h^{-2})$ elements, the same order as a uniform mesh, while still achieving the optimal $O(h)$ convergence rate.

MS24

High Order Numerical Methods: Design, Analysis, and Applications

Main organizer	Xinghui Zhong (Zhejiang University)
Co-organizers	Juan Cheng (Capital Normal University); Jie Du (East China Normal University)

DESCRIPTION

High-order numerical methods have become popular tools for solving partial differential equations arising in science and engineering. This minisymposium focuses on recent advances in the field, with an emphasis on discontinuous Galerkin (DG) and weighted essentially non-oscillatory (WENO) schemes.

The goal is to bring together researchers to exchange ideas on the design and analysis of these methods, as well as their applications to complex problems such as gas dynamics, magnetohydrodynamics, shallow water flows, and viscoelastic fluids.

Our confirmed speakers will present their latest work on theoretical developments, numerical analysis, and practical implementations of high-order methods.

MS24A | 15:50-17:10 | Room I1

15:50-16:10 | Xiong Meng

Harbin Institute of Technology

Analysis of the local discontinuous Galerkin method with generalized numerical fluxes for one-dimensional nonlinear fourth-order time-dependent problems

ABSTRACT

In this talk, we study the local discontinuous Galerkin method with generalized numerical fluxes for one-dimensional nonlinear time-dependent fourth-order equations. The numerical flux of the nonlinear convection term is the generalized local Lax-Friedrichs flux, and the generalized alternating fluxes are adopted for the fourth- and second-order terms. A proper numerical initial condition is designed based on a modified projection of the third-order derivative. By using the generalized Gauss-Radau projections, together with sharp bounds of nonlinear and jump terms, optimal error estimates are derived. The results are extended to equations with an additional dispersion term and mixed boundary conditions. Examples including Dirichlet as well as generalized Dirichlet boundary conditions, singularly perturbed problems and two-dimensional problems are also numerically investigated, indicating that the theoretical results hold for more general cases.

16:10-16:30 | Qiang Zhang

Nanjing University

Optimal error estimate of a discontinuous Galerkin method for one-dimensional linear hyperbolic equation with degenerate points moving along space-time curves

ABSTRACT

In this talk, we consider a discontinuous Galerkin method with purely upwind numerical flux to solve one-dimensional linear variable-coefficient hyperbolic equation, where the flow speed has different positive and negative signs when passing through the degenerate points. Our purpose is to give a rigorous proof of the optimal L^2 -norm error estimate when the degenerate points move along smooth curves depending on both space and time. The main difficulty is how to deal with the signs' change of the flow speed regarding time. To this end, we propose a novel analysis framework with the help of a time-dependent projection based on the hybrid application of Gauss-Radau projections and a sharp boundedness concerning the accumulation of all involved jumps on troubled locations.

16:30-16:50 | Yan Jiang

University of Science and Technology of China

High-order inverse Lax-Wendroff procedure for compressible fluid-structure interaction problems**ABSTRACT**

In this talk, we present a global high-order method for fluid-structure interaction (FSI) involving compressible inviscid flows and deformable elastic solids. A partitioned strategy couples the fluid and solid solvers. The fluid is discretized by a high-order finite difference WENO method on fixed Cartesian Eulerian grids, while the solid is solved using a Lagrangian discontinuous Galerkin method on unstructured meshes. To accurately treat the moving interface, we develop a high-order inverse Lax-Wendroff based interface treatment, eliminating mesh regeneration and sub-iterations at each time step. The proposed interface treatment also provides robust stability for challenging cases, including light solids interacting with heavy fluids, as supported by linear stability analysis. Numerical results demonstrate third-order accuracy for smooth solutions, non-oscillatory shock-capturing capability, and stable performance over a wide range of material parameters.

16:50-17:10 | Jianfang Lu

SCUT

An oscillation-free discontinuous Galerkin method for hyperbolic conservation laws**ABSTRACT**

In this talk, we introduce an oscillation-free discontinuous Galerkin (OFDG) method for solving the hyperbolic conservation laws. Typically, the high order linear numerical schemes would generate spurious oscillations in the presence of discontinuous solutions, which can be harmful to the numerical simulation, as they not only generate some non-physical structures but also make the numerical scheme less robust. To overcome this difficulty, we incorporate a numerical damping term into the classic DG formulation to control spurious oscillations. With this modification, the proposed DG method still maintains many good properties, such as the extremely local data structure, conservation, L^2 -boundedness, optimal error estimates, and superconvergence. Several numerical examples are provided to demonstrate the performance of the scheme and confirm the derived theoretical results, thus validating the effectiveness of the proposed DG scheme.

MS24B | 17:20-18:40 | Room I1**17:20-17:40 | Waixiang Cao**

EASIAM 2026

Spectral volume methods for hyperbolic equations**ABSTRACT**

his talk is concerned with the analysis of two spectral volume (SV) methods for hyperbolic equations : one is constructed basing on the Gauss-Legendre points (LSV) and the other is based on the right-Radau points (RRSV). We first prove that for a general nonuniform mesh and any polynomial degree k , both the LSV and RRSV methods are stable and can achieve optimal convergence orders in the L^2 norm. Secondly, we prove that both methods have some superconvergence properties at some special points. For instances, at the downwind points, the solution of RRSV and LSV methods converges with the order of $\mathcal{O}(h^{2k+1})$ and $\mathcal{O}(h^{2k})$, respectively. Moreover, we demonstrate that for constant-coefficient equations, the RRSV method is identical to the upwind discontinuous Galerkin (DG) method. Our theoretical findings are validated with several numerical experiments at the end.

17:40-18:00 | Chunwu Wang

University of Aeronautics and Astronautics

A penalty based conservative interface treating method based on DG framework for multi-medium problems**ABSTRACT**

In this work, a conservative sharp interface treating method is proposed for solving compressible multi-medium flow based on based on DG method for multi-medium flow. To overcome the small cell problem, we introduce the penalty into DG method used in the cells near the interface rather than the complicated cell reconstruction. It is found that this method is stable and conservative. Numerical experiments indicate that the proposed method can capture the shock wave and material interface accurately and sharply even for problems with significant density and pressure gradients.

18:00-18:20 | Juan Cheng

Juan Cheng, Professor, Capital Normal University

A Lax-Wendroff type theorem of doubly conservative schemes for degenerate convection-diffusion equations**ABSTRACT**

It is well known that a conservative numerical scheme may still fail to converge to a weak solution for degenerate diffusion or convection-diffusion equations. We introduce doubly-conservative (DoC) schemes and establish a Lax-Wendroff-type theorem: any convergent DoC scheme converges to the weak solution. We further develop two types of new high order numerical schemes that remain stable and convergent under diffusion degeneracy. Numerical experiments confirm its optimal convergence rates and validate the theoretical results.

18:20-18:40 | Tao Xiong

University of Science and Technology of China

Efficient and energy stable DLRA method for multiscale kinetic transport equations**ABSTRACT**

In this work, we develop an asymptotic preserving dynamic low rank method for multiscale kinetic transport equations. The proposed scheme is unconditionally stable in the diffusive regime, and significantly reduce computational cost via dynamic low rank approximation. Energy stability is established. Numerical experiments confirm the effectiveness and efficiency of the proposed approach.

MS38

Multiscale modeling and numerical methods for multiphysics materials

Main organizer	Luchan Zhang (Shenzhen University)
Co-organizers	Xiang Yang (Hong Kong University of Science and Technology); Qin Xiaoxue (Shanghai University)

DESCRIPTION

Multiphysics materials, characterized by the coupling of multiple physical processes such as mechanics, thermodynamics, and phase transitions, give rise to rich multiscale phenomena that govern their functional and structural properties. The intricate interactions between different physics across scales from atomistic to continuum, present significant challenges for mathematical modeling, numerical analysis, and large-scale simulation. Accurately capturing these coupled effects requires advanced multiscale, multiphysics, and often multi-fidelity models. Speakers in this minisymposium will discuss recent advances in modeling approaches and simulation methods for multiphysics materials, as well as new theoretical and computational findings that deepen our understanding of complex material behaviors.

MS38A | 15:50-17:10 | Room S1

15:50-16:10 | Weiyang Zheng

Chinese Academy of Sciences

Finite element method for the spin-diffusion Landau-Lifshitz-Gilbert (SDLLG) model

ABSTRACT

In this talk, I will present the finite element approximation of the nonlinear spin-diffusion Landau-Lifshitz-Gilbert (SDLLG) model. We first establish the unconditional energy stability for the continuous LLG model independent of the small damping parameter. A fully-discrete finite element method is proposed to solve the LLG model. Unconditional stability for the numerical scheme is proved with respect to the damping parameter. Based on the analysis for the LLG model, we further prove the unconditional stability for the SDLLG model under a very weak and physically reasonable assumption. A decoupled time-marching scheme is proposed for the coupled SDLLG problem.

16:10-16:30 | Yufeng Nie

Northwestern Polytechnical University

Mixed scheme about ROM/FOM with space-adaptive partitioning strategy for quasi-static peridynamic fracture simulation

ABSTRACT

In this talk, we present a mixed reduced-order/full-order model (ROM/FOM) scheme based on space-adaptive partitioning strategy for peridynamics (PD) to efficiently simulate brittle fractures. Generally, the drastic displacement mutation occurs around the crack tip and path, resulting in the ROM more sensitive to high-fidelity snapshots, and even leading to failure of ROM. To overcome this difficulty, the entire computational domain is partitioned into two types of regions: the damage regions are simulated using full-order PD solver, while the sub-system over remaining regions is projected onto low-dimensional subspaces obtained by the proper orthogonal decomposition (POD) method. The domain partitioning is adaptively performed based on bond-breakage data and no a priori knowledge of cracks is required.

16:30-16:50 | Yibao Li

Xi'an Jiaotong University

Reconstruction of phase field model with an EnKF-based restoration framework

ABSTRACT

Incomplete or damaged regions disrupt the consistency of numerical simulations, making both analysis and prediction challenging. In this study, we present an efficient and flexible restoration framework of reconstructed solution for phase field model. To address this challenge, the Ensemble Kalman Filter (EnKF) data assimilation method is employed to estimate optimal model parameters with partial observations sampled from the target phase field states to be reconstructed. The estimated parameters are then incorporated into the governing model to reconstruct the missing morphology. A series of twin experiments are conducted to systematically evaluate the effectiveness and robustness of the method under controlled settings. The results confirm that the EnKF-based restoration framework is capable of reliably restoring structures even with complex reconstructed domains.

16:50-17:10 | Xiaoxue Qin

Shanghai University

3D Continuum Modeling and Simulation of Low-Angle Grain Boundaries**ABSTRACT**

We have developed a range of continuum models that describe the structure and dynamics of low angle grain boundaries in three dimensions. The static model minimizes grain boundary energy according to Frank's formula constraints, while the dynamic model includes the motion and reactions of dislocations. We have developed numerical algorithms based on the projection method. In comparing our simulation results with atomistic simulations, our model accurately predicts the dislocation structure, energy profiles of grain boundaries, and their dynamics. These findings highlight the potential of continuum models to enhance the understanding of material behavior and solid mechanics.

MS38B | 17:20-18:40 | Room S1**17:20-17:40 | Yang Xiang**

HKUST

A unified variational model for grain boundary dynamics incorporating microscopic structure**ABSTRACT**

Recent experiments, atomistic simulations, and theoretical predictions have identified various new types of grain boundary motions that are controlled by the dynamics of underlying microstructure of line defects (dislocations or disconnections), to which the classical motion by mean curvature model does not apply. We propose a unified variational framework to account for all the underlying line defect mechanisms for the dynamics of both low and high angle grain boundaries and the associated grain rotations. The variational formulation is based on the developed constraints of the dynamic Frank-Bilby equation that governs the microscopic line defect structures. The unified variational framework is more efficient to describe the collective behaviors of grain boundary networks at larger length scales. It also provides a mathematically tractable basis for rigorous analysis of these partial differential equation models and for the development of efficient numerical methods.

17:40-18:00 | Jingli Ren

Zhengzhou University

Stacking pattern of short-range order units in binary metallic glasses: A hypergraph approach**ABSTRACT**

This study investigates stacking patterns between short-range order (SRO) units in three binary metallic glasses by establishing a framework combining hypergraph and molecular dynamics simulation. It is found by maximal clique decomposition that SRO unit at 300 K stacking primarily consists of ternary and quaternary maximal cliques, collectively accounting for about 90% of the total. An exponential relationship between maximal clique population and average atomic radius ($\ln N_{mc} = \alpha r + C$) is established, where the absolute value of α is related to atomic radius ratio. We report a close correlation between the dynamic behavior of N_{mc} and the glass transition in metallic glasses. A logistic growth model is presented to reveal the evolution of N_{mc} from initial unlimited growth to hindered growth, with this transition initiating at about 1.16 T_g .

18:00-18:20 | Peicheng Zhu

Shanghai University

A new phase-field model for martensitic phase transitions driven by material forces**ABSTRACT**

We present the existence of weak solutions to an IBVP for a new model of structural phase transitions, in which the order parameter is conserved. Two types of weak solutions will be stated, i.e., usual weak solution (defined by employing the technique of integration by parts), and weak solution defined by combining the usual concept of weak solution and the notion of viscosity solutions. Applications include: To describe martensitic phase transitions in, e.g., Shape Memory Alloys. Numerical results will also be presented.

18:20-18:40 | Luchan Zhang

Shenzhen University

Stochastic Peierls-Nabarro Modeling for Predicting Strength-Optimized Compositions of High-Entropy Alloys**ABSTRACT**

High-entropy alloys (HEAs) exhibit outstanding mechanical properties arising from their complex and heterogeneous atomic environments. However, quantitatively connecting elemental composition to intrinsic strength remains challenging. We develop a composition-dependent stochastic Peierls-Nabarro model that incorporates local compositional fluctuations induced by random site occupancy. Long-range elastic energy is determined by globally averaged material properties, whereas short-range misfit energy depends on local composition. The resulting local Peierls stresses define a statistically constrained optimization problem accounting for both mean lattice resistance and spatial variation. Global elemental fractions are obtained from the optimized local composition field, enabling the prediction of strength-optimized compositions. Numerical results for representative FCC and BCC alloys are compared with experimental data and further used to identify favorable compositions.

MS03

Numerical analysis and applications of nonlocal models

Main organizer Xiaobo Yin (Central China Normal University)

Co-organizers Jiwei Zhang (Wuhan University)

DESCRIPTION

This mini-symposium focuses on numerical analysis and applications of nonlocal models, aiming to gather young scholars and researchers in the fields of computational mathematics, applied mathematics and scientific computing to discuss frontier issues of nonlocal models.

The scope of this mini-symposium centers on the theoretical and practical dimensions of nonlocal models, covering cutting-edge topics and practical bottlenecks in this field. Specifically, it includes: fundamental numerical algorithms for nonlocal equations (such as finite difference methods, finite element methods, collocation methods, spectral methods and meshfree methods); stability, convergence and error analysis of numerical schemes for nonlocal models; efficient numerical implementation and parallel computing techniques for large-scale nonlocal problems; engineering and scientific applications of nonlocal models (including phase field simulation, fracture mechanics, material science, biological diffusion and other practical scenarios); comparison between nonlocal models and classical local models, as well as multi-scale coupling numerical methods; and open challenges in numerical solving and practical promotion of nonlocal models.

MS03A | 15:50-17:10 | Room S2

15:50-16:10 | Lijun Yi

Shanghai Normal University

A unified superconvergent postprocessing technique of the Galerkin methods for solving Volterra integro-differential equations

ABSTRACT

In this talk I shall introduce a unified postprocessing technique of the continuous and discontinuous Galerkin methods applied to solve first and second-order Volterra integro-differential equations. The core idea of this postprocessing technique is to augment the existing Galerkin approximation of degree k with an additional term involving a generalized Jacobi polynomial (multiplied by appropriate coefficients) of degree $k+1$. The theoretical findings suggest that, through postprocessing, the convergence rate of the original Galerkin approximation error can be elevated by one order. Abundant numerical results underscore the effectiveness and high accuracy of the proposed postprocessing technique.

16:10-16:30 | Xiaobo Yin

Central China Normal University

Co-authors: Qiang Du (Columbia University); Hehu Xie (Chinese Academy of Sciences); Jiwei Zhang (Wuhan University)

Error estimates of FEMs for nonlocal problems using exact or approximated interaction neighborhoods

ABSTRACT

In this report, we study the asymptotic error between the finite element solutions of nonlocal models with a bounded interaction neighborhood and the exact solution of the limiting local model. The limit corresponds to the case when the horizon parameter, the radius of the spherical nonlocal interaction neighborhood of the nonlocal model, and the mesh size simultaneously approach zero. Two important cases are discussed: one involving the original nonlocal models and the other for nonlocal models with polygonal approximations of the nonlocal interaction neighborhood. Results of numerical experiments are also reported to substantiate the theoretical studies.

16:30-16:50 | Zhaoxiang Li

Shanghai Normal University

The high accuracy algorithms for finding multiple solutions to nonlinear partial differential systems

ABSTRACT

In this talk, we investigate the computation of multiple solutions to nonlinear partial differential systems, particularly in settings where global variational structures are unavailable. To overcome the limitations of classical methods, we develop a series of computational frameworks based on augmented singular transformations, partial Newton correction techniques and spectral discretizations. For semi-linear systems, we introduce an augmented singular transform and partial Newton correction method for the stable computation of multiple solutions. For multi-component systems with heterogeneous nonlinearities, we develop a modified partial Newton correction method based on a two-parameter scaling strategy to efficiently compute solutions with complex spatial structures. The framework is further extended to quasi-linear systems involving degenerate p -Laplacian-type operators, yielding a generalized partial Newton correction method that effectively addresses operator singularities.

16:50-17:10 | Huajie Chen

Beijing Normal University

Complete Invariants of Symmetric and Self-Adjoint Matrix Families

ABSTRACT

A parameterized matrix family on a configuration domain is determined by its physical content only up to a constant orthogonal change of basis. This gauge ambiguity is intrinsic to data-driven Hamiltonian models, such as tight-binding parameterizations, reduced-order electronic structure methods, or excited states models. It raises a basic inverse problem: what observations suffice to identify the family up to this gauge? The pointwise spectrum is incomplete already for linear families. Here, we prove that, under natural non-degeneracy and connectivity assumptions, augmenting the spectrum with loop products of the coupling matrices in the instantaneous eigenframe yields a complete invariant. We support the theory with numerical experiments.

MS03B | 17:20-19:00 | Room S2

17:20-17:40 | Yufeng Nie

Northwestern Polytechnical University

Co-authors: Shangyuan Zhang (Northwestern Polytechnical University)

Re-derivation and Mathematical Analysis for Linear Peridynamics Model for Arbitrary Poisson Ratio's Material

ABSTRACT

This talk is concerned with the modeling and mathematical analysis of linear peridynamic model for arbitrary Poisson's ratio material. Based on the fundamental laws of dynamics, we re-derive the bond-based peridynamic model for anisotropic materials by relaxing certain assumptions. Through this process, we draw several significant conclusions, such as the relationship between the equivalent strain energy density hypothesis and the convergence of the peridynamic operator to the classical Navier operator. Additionally, the well-posedness of time-dependent peridynamic equations of motion is established. Finally, some necessary conditions for the material stability of anisotropic material are given.

17:40-18:00 | Kuang Huang

The University of Hong Kong

Entropy-consistent numerical methods and singular limit for nonlocal conservation laws

ABSTRACT

We consider a class of nonlocal conservation laws modeling traffic flow, where the velocity depends on a convolution of the density with a rescaled kernel that concentrates as a parameter ϵ tends to zero. A central question is whether solutions converge to the entropy-admissible solution of the corresponding local conservation law, and how to design numerical methods that faithfully capture this transition. We present numerical schemes that are asymptotically compatible: as the mesh size h and ϵ vanish simultaneously, numerical solutions converge to the local entropy solution with an explicit rate of order $\sqrt{\epsilon} + \sqrt{h}$. We also discuss a complementary approach via compensated compactness that resolves the singular limit for rough initial data and kernels.

18:00-18:20 | Dong Wang

The Chinese University of Hong Kong, Shenzhen

A weighted quantile filter based framework for interface optimal design problems

ABSTRACT

We present a robust and efficient numerical framework based on a median filter scheme for solving a broad class of interface optimal design problems, from image segmentation to topology optimization. A key innovation of our work is the extension of the binary scheme into a level-set scheme via a weighted quantile interpretation. Unlike traditional binary iterative convolution-thresholding method (ICTM), this continuous weighted quantile filter scheme effectively overcomes the pinning effect caused by spatial discretization, achieving interface evolution even with small time steps. We also provide a rigorous theoretical analysis, proving the unconditional energy stability of the iterative scheme. Furthermore, we prove that for a wide class of data fidelity terms, the convex relaxation inherently enforces a binary solution, justifying the effectiveness of the method without explicit penalization.

18:20-18:40 | Tomoyuki Oka

Fukuoka Institute of Technology

Two-material optimal design problem governed by the heat equation**ABSTRACT**

In this talk, we shall consider the two-material optimal design problem for the time-averaged duality pairing between a heat source and the weak solution of an initial-boundary value problem for the heat equation with a two-material diffusion coefficient, under a volume constraint. In the elliptic (i.e., time-independent) case, this problem can be relaxed through homogenization, and the relaxation problem has a self-adjoint structure. In this elliptic setting, a direct relaxation with respect to the density is possible, and the convexity of the relaxed problem allows us to construct an optimal density. On the other hand, in the parabolic case, such a structure is in general not ensured due to the time-dependence. In this talk, we shall discuss the direct relaxability and the long-time behavior for the parabolic case in some specific settings.

18:40-19:00 | Kei Matsushima

Hiroshima University

Co-authors: Kosuke Kita (Hokkaido University); Tomoyuki Oka (Fukuoka Institute of Technology)

Optimal design of two-material thermal conductors with thermal radiation**ABSTRACT**

Thermal radiation is important in high-temperature and thermally isolated systems, but it leads to nonlinear boundary conditions beyond standard linear theories for optimal design. This talk presents an optimal design framework for two-material thermal conductors governed by steady-state diffusion equations with nonlinear boundary conditions, including radiation modeled by maximal monotone operators. We discuss a homogenization-based relaxation of the original topology optimization problem and show that the relaxed problem admits minimizers with the same infimum value as the original one. We then introduce a level-set approximation to avoid grayscale material distributions and derive sensitivities for numerical optimization. Numerical examples for radiative heat-dissipating structures illustrate how nonlinear boundary effects and heat-source intensity shape optimal configurations, and show that optimized designs can outperform intuitive fin-like structures.

Tuesday, August 25 2026

MS21

Recent developments in sampling methods, uncertainty quantification, and generative AI

Main organizer	Zhiwen Zhang (The University of Hong Kong)
Co-organizers	Liu Liu (The Chinese University of Hong Kong); Zhongjian Wang (Nanyang Technological University)

DESCRIPTION

This mini-symposium focuses on the latest advances and cross-disciplinary synergies of sampling methods, uncertainty quantification (UQ), and generative AI, which are important areas in applied mathematics. AI-augmented sampling techniques now enable efficient handling of high-dimensional data, while modern UQ frameworks ensure trustworthy AI by quantifying and distinguishing data-driven and model-driven uncertainty. Integrated with mathematical approaches, generative AI improves sample representativeness and enhances the transparency of UQ. This mini-symposium provides a platform for researchers to share cutting-edge results and address emerging challenges in these rapidly evolving fields.

MS21A | 09:50-11:10 | Room H1

09:50-10:10 | YIWEN LIN

Shanghai Jiao Tong University

Asymptotic-Preserving Hybrid UQ Methods for Uncertain Multi-Scale Kinetic Equations

ABSTRACT

This work develops efficient uncertainty quantification methods for multi-scale kinetic equations with random inputs. For the uncertain Boltzmann equation, we propose hybrid-based multi-level Monte Carlo and bi-fidelity approaches that integrate asymptotic-preserving schemes with hydrodynamic limit solvers. For the semiclassical Schrödinger equation, we design multi-fidelity methods adopting grid-based, meshless and level set solvers for its semiclassical limit. We also investigate the multi-phase Navier-Stokes-Vlasov-Fokker-Planck system with random initial inputs, which serves as an application of multi-scale physical problems. Numerical experiments demonstrate that the proposed methods achieve significant computational speedups over standard methods without sacrificing numerical accuracy. Preliminary inverse results for kinetic equations are also presented.

10:10-10:30 | Panchi Li

Soochow University

A multiscale reduced method for the semiclassical Schrödinger problems with random potentials

ABSTRACT

I will present a multiscale reduced-order method for solving the semiclassical Schrödinger equation with random potentials. The proposed approach combines multiscale finite element methods (MsFEM), proper orthogonal decomposition (POD) and the quasi-Monte Carlo (qMC) sampling method. It can be applied to both linear eigenvalue problems and nonlinear time-dependent problems. The total approximation error is controlled by the truncation dimension, the coarse mesh size, the POD error and the qMC sample size. Numerical experiments demonstrate that the method achieves high accuracy while significantly reducing the computational cost compared to standard finite element methods. Additionally, a time-splitting scheme that preserves convergence for discontinuous potentials is introduced for the nonlinear Schrödinger equation. This framework provides an efficient and reliable means of simulating semiclassical quantum systems exhibiting high-dimensional randomness and multiscale features.

10:30-10:50 | Daniel Huang

Peking University

Stable derivative free Gaussian mixture variational inference for Bayesian inverse problems

ABSTRACT

Black-box variational inference (BBVI) with Gaussian mixture families offers a flexible approach for approximating complex posterior distributions without requiring gradients of the target density. However, standard numerical optimization methods often suffer from instability and inefficiency. We develop a stable and efficient framework that combines three key components: (1) affine-invariant preconditioning via natural gradient formulations, (2) an exponential integrator that unconditionally preserves the positive definiteness of covariance matrices, and (3) adaptive time stepping to ensure stability and to accommodate distinct warm-up and convergence phases. Numerical experiments on multimodal distributions, Neal's multiscale funnel, and a PDE-based Bayesian inverse problem for Darcy flow demonstrate the effectiveness of the proposed method.

10:50-11:10 | Guillaume Bal

University of Chicago

Classification and generation in open space communication with structured light**ABSTRACT**

We study the classification of structured-light beams after propagation through a random turbulent medium, with the turbulence-degraded speckle patterns generated by numerical simulation of a stochastic paraxial wave model. The classification task is formulated over a finite alphabet, and two input representations - raw intensity and autocorrelation - are benchmarked using two CNN architectures, SimpleCNN and ResNet-18, with the latter offering a better trade-off between computational cost and classification accuracy. We also present a physics-aware generative augmentation framework based on denoising diffusion probabilistic models, designed to supplement scarce training sets by generating additional class-conditioned speckle images. This is joint work with Aokun Wang, Anjali Nair, and Zhongjian Wang.

MS21B | 11:20-12:40 | Room H1**11:20-11:40 | Yanli Wang**

Beijing Computational Science Research Center

Co-authors: Pei Zhang (Beijing Computational Science Research Center); Zhenning Cai (National University of Singapore)

Accelerated iterative method for solving the steady-state Boltzmann equation**ABSTRACT**

In this work, we propose a modified Newton method equipped with a macroscopic synthetic system (Newton-MS) for the steady-state Boltzmann equation with the quadratic collision operator. In Newton-MS, the modified Newton iteration is utilized as the outer nonlinear solver, while each Newton correction equation is solved by an inner source iteration, where the linearized collision operator is utilized to approximate the quadratic collision model, and it is reduced into a linear iteration. Moreover, a macroscopic synthetic system based on Chapman-Enskog closure is derived to accelerate the convergence of the linear inner iteration in the continuum limit. Several numerical examples, including the 1D Fourier, Couette flow problem, and the 2D cavity flow and thermal-driven cavity flow, are studied to validate the high efficiency of Newton-MS.

11:40-12:00 | LIU LIU

The Chinese University of Hong Kong

Multi-fidelity numerical methods for a class of kinetic models**ABSTRACT**

In this talk, we will discuss about a class of multi-fidelity numerical methods for solving kinetic models. In the first part, we will address the uncertainty quantification for kinetic problems and development of bi-fidelity or tri-fidelity methods for different models, where some error estimates are studied using the hypocoercivity. In the second part, we will study an efficient asymptotic-preserving scheme for solving the Boltzmann equation with bi-fidelity algorithm designed in the velocity discretization. Some applications to deep learning approaches for kinetic models will also be discussed, with the idea of bi-fidelity introduced. These are joint works with Xueyu Zhu, Lorenzo Pareschi, Nicolas Crouseilles, Zhen Hao and Zhenyi Zhu.

12:00-12:20 | Zhongjian Wang

Nanyang Technological University

Posterior learning by Mean Flow**ABSTRACT**

In this talk I will explain how to use the diffusion model, especially mean flow, to construct unbiased, efficient Bayesian posterior sampler. If time permits, I will also talk a bit on the regularity of the mean flow maps.

MS20

Topological data analysis and machine learning

Main organizer	Jae-Hun Jung (POSTECH)
Co-organizers	Shizuo Kaji (Kyoto University); Kelin Xia (NTU)

DESCRIPTION

Recent advances in data science and machine learning increasingly focus on the geometric and topological structures underlying complex datasets, highlighting the importance of studying the “shape of data.” Topological Data Analysis (TDA) provides a novel framework for extracting robust, scale-invariant features of data, such as connectivity and higher-dimensional holes. Its usefulness has been demonstrated through a wide range of applications in science and engineering. More recently, the integration of TDA with machine learning and deep learning has been actively studied to enhance both theoretical understanding and practical performance. For example, topological and geometric analysis plays a key role in structural learning by capturing global representations beyond local structures, and in causal learning by identifying invariant features that are robust to perturbations. This mini-symposium aims to present and discuss recent developments in the topological analysis of data, as well as advances at the interface of topology, geometry, and machine learning. This mini-symposium will invite leading TDA experts, including researchers from East Asia, to promote collaboration and stimulate future interdisciplinary research.

MS20A | 09:50-11:10 | Room H3

09:50-10:10 | Byeongchan Choi

KIAS

Persistent Homology with Path-Representable Distances on Graph Data

ABSTRACT

Persistent homology (PH) is widely applied to graph data, but how the choice of graph distance affects the resulting barcodes has received little attention. We define path-representable distances on graphs and compare their persistent homologies. We identify a nontrivial injection between the 1-dimensional barcodes of the unweighted and weighted shortest-path distances, give sufficient conditions via a subclass, cost-dominated distances, and show it holds in dimensions 0 and 1 but not higher. To quantify these correspondences, we introduce the total persistence difference (TPD), a new measure of the changes between filtrations induced by cost-dominated distances on a fixed graph. We prove a stability result for TPD when the distances admit a partial order, and apply it to the SNAP EU research-institution email dataset. TPD captures both periodic patterns and global trends, and aligns more strongly with classical graph statistics than an existing PH-based measure on the same data.

10:10-10:30 | Yasharth Yadav

NTU

Periodic Topological Deep Learning for Polymer Design and Discovery

ABSTRACT

Polymers are central to energy, healthcare, and materials science, but their vast chemical space makes discovery challenging. Most machine learning models represent polymers as a monomer graph, missing chain periodicity and many-body interactions. I will introduce Periodic-TDL, a deep learning framework using periodic Rips complexes and hierarchical simplicial message passing to capture interactions across spatial scales. Periodic-TDL achieves state-of-the-art performance across electronic, optical, physical, and thermal property prediction tasks. We then use it to test two design principles for thermal stability, ester-to-amide substitution and backbone alpha-methylation. Across 48,208 generated polymers, the model captures systematic changes in glass transition temperature arising from these functional group modifications. Experiments on six novel polymer pairs, including three newly synthesized polymers, confirm the predicted trends, supporting topology-informed polymer design.

10:30-10:50 | Meiyan Kang

Kyoto University

Learning Long-Range Connectivity with Neural Networks**ABSTRACT**

Deep neural networks (DNNs) are highly effective at learning local image features such as texture, yet some image analysis tasks require an understanding of global connectivity. Such information cannot be inferred from local cues alone and is therefore challenging for standard neural networks. In this talk, we propose an auxiliary, or pretext, task for learning connectivity. Given an image and a pair of points, the network predicts whether the two points belong to the same connected component. We also construct a synthetic benchmark dataset whose intricate patterns require long-range connectivity reasoning. Since connectivity is mathematically computable, labels can be generated not only for synthetic images but also for images from arbitrary domains. This makes the method a form of task augmentation rather than data augmentation. We evaluate its effectiveness on several downstream tasks. The results show that connectivity-aware training improves performance.

10:50-11:10 | Hajin Lee

Korea University

Co-authors: Kwangho Kim (Korea University)

Provably Correct k-Means Clustering of Persistence Diagrams**ABSTRACT**

We study k-means clustering of persistence diagrams through their Hilbert-space embeddings, focusing primarily on persistence landscapes. Although persistence landscapes are widely used in practice, it remains unclear when clustering them faithfully reflects clustering in the diagram space. We give simple, verifiable geometric conditions under which (i) nearest-center labels in the landscape space exactly agree with those in the diagram space, and (ii) the landscape k-means objective provably calibrates the diagram-space objective, leveraging tools from modern statistical learning theory. Combined with known fast rates for k-means in Hilbert spaces, our results show that landscape-based k-means provides a statistically and computationally efficient surrogate for diagram-space k-means with explicit performance guarantees and a controllable geometric distortion.

MS20B | 11:20-12:40 | Room H3

11:20-11:40 | Shizuo Kaji

Kyoto University

Topological Regularisation in Basis Learning**ABSTRACT**

We investigate the learning of interpretable bases in non-negative matrix factorisation (NMF) by regularising the topology of the learned basis functions. Many data modalities can be viewed as non-negative functions on structured domains, where basis quality is intrinsically linked to its topology. However, standard methods for incorporating support topology are often hindered by discreteness and threshold dependence, rendering them unsuitable for continuous optimisation. We address these challenges by employing persistent homology as a stable, threshold-free topological quantifier, designing topological scores that integrate into the NMF objective as regularisers. The resulting framework unifies the modelling of spatially coherent image components, periodic time-series structures, and clique-like graph signals.

11:40-12:00 | Jisu Kim

Seoul National University

Topological Data Analysis for Feature Extraction in Machine Learning**ABSTRACT**

Topological Data Analysis (TDA) offers a powerful framework for capturing the shape of data. Its core method, persistent homology, observes data at multiple scales to summarize topological features—such as clusters, loops, and voids—that persistently appear. While these summaries provide noise-robust, coordinate-free insights, integrating such non-Euclidean structures directly into machine learning remains challenging.

This talk explores using TDA as a robust feature extraction tool to bridge this gap. I will examine featurization techniques that map persistence-based information into Euclidean or functional spaces for seamless integration into standard learning algorithms, particularly deep learning. Specifically, I discuss transforming topological summaries into differentiable neural network layers, alongside geometric representations for visualization. Through these methods, I demonstrate how topological features enhance model representation power and interpretability.

12:20-12:40 | Jae-Hun Jung

POSTECH

Persistent Cross Entropy for Causal Inference in Dynamical System**ABSTRACT**

Inferring causal relationships between dynamical system time-series is important in many applications. Topological approaches assume that observed data are measurements of underlying manifolds and that the topology of reconstructed embedding spaces contains information about causal structure. We propose a novel causal inference method based on persistent cross entropy(PCE). We introduce a mathematically consistent probabilistic formulation for comparing persistence diagrams, which remains well-defined even for diagrams of different sizes. This enables principled comparison of topological information from different dynamical systems. Based on this, we develop a topology-based method for causal inference between dynamical system signals. Numerical experiments show that the proposed method captures causality more effectively than methods based on bottleneck and Wasserstein distances, persistence images, and persistence silhouettes.

MS23

Recent Advances in Modeling and Numerical Methods for Interface Problems

Main organizer	Yu-Hau Tseng (National University of Kaohsiung, Taiwan)
Co-organizers	Wei-Fan Hu (Department of Mathematics, National Central University, Taiwan); Hui-Lan Chang (Department of Applied Mathematics, National University of Kaohsiung, Taiwan)

DESCRIPTION

Interface problems arise in a wide range of scientific and engineering applications, including multiphase flows, microfluidics, biological systems, and materials science. These problems are characterized by the presence of moving or stationary interfaces across which physical properties, such as density, viscosity, or pressure, may exhibit discontinuities or sharp gradients. The accurate modeling and efficient numerical simulation of such phenomena remain challenging due to the inherent coupling between interface dynamics and the governing partial differential equations. This minisymposium aims to bring together researchers working on mathematical modeling and numerical methods for interface problems. Topics of interest include, but are not limited to, sharp-interface and diffuse-interface models for discontinuous solutions. In recent years, there has been increasing interest in integrating data-driven and machine learning techniques with traditional numerical methods to enhance accuracy and efficiency. This minisymposium will also highlight emerging approaches that combine physics-based modeling with modern computational paradigms, such as physics-informed neural networks and operator learning methods, particularly in the context of interface problems. The objective of this minisymposium is to foster interdisciplinary exchange and to provide a platform for discussing recent advances, open challenges, and future directions in the field. By bringing together experts from applied mathematics, computational science, and engineering, we aim to promote collaboration and stimulate new research ideas in both modeling and computation perspectives.

MS23 | 09:50-11:10 | Room I1

09:50-10:10 | Chi-Jen Wang

National Chung Cheng University

Triplet approximation in Schloegl's second model for non-equilibrium phase transitions in lattice bistable systems

ABSTRACT

Schloegl's second model involves two processes: spontaneous particle annihilation at a rate p , and autocatalytic particle creation at empty sites with a rate dependent on the neighboring sites. Stochastic kinetic Monte Carlo simulations are commonly used to understand the model behavior, revealing a discontinuous transition when p surpasses a critical value p_e . To improve upon mean-field and pair approximations, this model employs a triplet approximation, which preserves essential local correlations and yields a more accurate description of spatially inhomogeneous configurations.

Our main focus is on analyzing the dynamics of interfaces using discrete reaction-diffusion equations derived from higher-order triplet approximations to the exact master equations for spatially inhomogeneous states. This study contributes to a better understanding of phase coexistence and the discontinuous transition characteristic of such dynamical systems.

10:10-10:30 | Yunchang Seol

Chonnam National University

Discrete Leray projection for solving semi-implicit schemes in fluid-structure interaction problems

ABSTRACT

In this talk, we present an efficient approach for solving semi-implicit schemes of the motion of elastic interfaces in unsteady Navier-Stokes flows, with a focus on immersed boundary methods. In order to solve its original linear system, we transform the 3-by-3 block matrix to a reduced 2-by-2 block matrix after eliminating the fluid pressure term. Such rank reduction is possible by applying the discrete Leray projection operator in a staggered MAC grid. By virtue of this feature, an efficient algorithm for finding two unknowns is suggested using the Schur complement.

10:30-10:50 | Youngjin Hwang

Chonnam National University

Phase-field projection method for multi-component fluid flows**ABSTRACT**

We present a phase-field projection method for the multi-component Navier--Stokes--Cahn--Hilliard system. The Cahn--Hilliard equation is discretized by a convex splitting method, and the Navier--Stokes equations are treated by a fractional step method. Through this decomposition, the coupled system is solved sequentially by several subproblems instead of one fully coupled problem. The proposed method satisfies the discrete incompressibility condition and mass conservation. Various numerical experiments are performed to demonstrate the main idea of the projection method, and the discrete energy dissipation and mass conservation are observed numerically. The method can be further extended to problems with variable mobility and density.

10:50-11:10 | Habin Yim

Chonnam National University

Motion of three geostrophic vortices on a sphere**ABSTRACT**

Accurately approximating and applying geophysical phenomena requires considering geostrophic vortices on spherical or sphere-like curved surfaces. Accordingly, this study explores the dynamics of geostrophic fluid vortices on the surface of a sphere. The geostrophic vortex model incorporates the effects of stratification and planetary rotation and is relevant to large-scale atmospheric phenomena. The governing equations of the model are expressed in terms of the Legendre functions and systematically formulated along with the corresponding Hamiltonian. We focus on the three-vortex case and investigate its dynamics, identifying the fixed and relative equilibria of the vortices. The general dynamics is analyzed using the phase diagram based on trilinear coordinates. Notably, we demonstrate the occurrence of the non self-similar collapse of the three geostrophic vortices. Remarkably, we find a recurring motion of vortices converging toward and diverging from a relative equilibrium.

MS15

Numerical Methods for Semiconductor Device Simulation

Main organizer	Donghang Zhang (Academy of Mathematics and System Science, Chinese Academy of Sciences)
Co-organizers	Weiyang Zheng (Academy of Mathematics and System Science, Chinese Academy of Sciences)

DESCRIPTION

In semiconductor device simulation, mathematical methods are crucial for accurately modeling device behavior, bridging the gap between theory and practice, and forming the foundation of Technology Computer Aided Design (TCAD). This seminar centers on the numerical methods in semiconductor device simulation. Specifically, it delves into special aspects such as discretization methods, stability theory, algebraic solvers, and the parallel implementation techniques for device simulation. The seminar's content includes mathematical analysis techniques, algorithm design, and result implementation, which are crucial for handling related mathematical challenges, and adapting to the development needs of advanced semiconductor devices simulation.

MS15A | 09:50-11:10 | Room S1

09:50-10:10 | Tao Cui

Chinese Academy of Sciences

Multiphysics Simulation and Efficient Numerical Methods for Semiconductor Devices and Circuit Structures

ABSTRACT

As semiconductor devices scale toward three-dimensional and stacked architectures, multiphysics simulation has become increasingly important for understanding device behavior, reliability, and device-circuit interactions. This talk presents our recent progress in multiphysics simulation of semiconductor devices and basic circuit structures, including inverters and ring oscillators. The presentation covers stable and efficient finite-element discretization methods for macroscopic transport, quantum transport, and multiscale coupled transport models, as well as numerical methods for the coupled drift-diffusion and conductor equations used in unified device-interconnect simulation. The talk will also introduce the latest developments of DESIGN (DEvice Simulation Gallery at Nanoscale), a semiconductor device simulation framework developed on the PHG (Parallel Hierarchical Grid) platform for large-scale and high-performance parallel computing.

10:10-10:30 | Chuwen Ma

East China Normal University

Quantum Preconditioning Algorithms for Large Linear Systems via Schrödingerization

ABSTRACT

We present a quantum computational framework for solving linear algebra systems arising from iterative solvers. The framework combines the Schrödingerization technique [S. Jin, N. Liu, and Y. Yu, Phys. Rev. Lett. 133, 230602 (2024)] with preconditioning strategies to achieve near-optimal complexity. Schrödingerization transforms linear differential equations into Schrödinger-type systems with unitary evolution in a higher dimension, making them suitable for quantum computation. In particular, the BPX preconditioner is integrated with Schrödingerization to obtain near-optimal complexity for elliptic problems. Building on this, we extend the method to the Helmholtz equation, incorporating dispersion correction and tailored preconditioning to efficiently address indefiniteness. These results show that quantum preconditioning provides a scalable pathway from well-conditioned systems to challenging wave problems.

10:30-10:50 | Donghang Zhang

Chinese Academy of Sciences

Co-authors: Nuo Lei (Chinese Academy of Sciences); Weiyang Zheng (Chinese Academy of Sciences)

p-multigrid method for high-order discontinuous Galerkin discretization of elliptic problems

ABSTRACT

In this talk, we develop a W-cycle p-multigrid method for elliptic problems, and further extend it to solve elliptic problems with discontinuous coefficients. It adopts hierarchical Legendre bases for SIPDG and SWIPDG discretization. We present unified convergence analysis for this multigrid method. The analysis includes inherited and non-inherited bilinear forms for SIPDG discretization, and relies on piecewise H^2 -regularity for SWIPDG discretization with discontinuous coefficients. The proposed method lowers smoothing complexity from traditional $O(p^2)$ to $O(p)$, where p denotes the polynomial degree. It achieves uniform convergence independent of mesh size, polynomial degree and coefficient jump ratio, showing strong robustness for problems with large coefficient jumps. Numerical experiments validate all theoretical results. Its performance is also verified for elliptic interface problems on C^2 -smooth interfaces via unfitted finite element discretization.

10:50-11:10 | WENHAO LU

National University of Singapore

On The Stationary Electrothermal Drift-Diffusion Model

ABSTRACT

A generalized bipolar electrothermal drift-diffusion model for semiconductor devices is considered. The model couples the electron and hole continuity equations with the Poisson equation for the electrostatic potential and a heat equation whose source terms include Joule heating and heat generated by recombination. The talk will discuss the mathematical well-posedness of the model, including the existence of weak solutions in a general setting with temperature-dependent mobilities that may degenerate at high temperatures. The existence proof is based on a Schauder fixed-point argument, while uniqueness is established under a suitable low-bias condition. Numerical experiments will also be presented to illustrate the coupled electrothermal effects, the influence of temperature-dependent mobilities, and the behavior of the model under different applied bias conditions.

MS15B | 11:20-12:40 | Room S1
11:20-11:40 | Yongyong Cai

Beijing Normal University

Structure preserving schemes for PNP equations

ABSTRACT

We present a novel approach to construct structure preserving approximations for the Poisson-Nernst-Planck equations, focusing on the positivity preserving and mass conservation properties. The strategy consists of a standard time marching step with a projection (or correction) step to satisfy the desired physical constraints (positivity and mass conservation). Rigorous error estimates in L^2 norm are established, which are both second order accurate in space and time. For extensions to the time-independent problem, we construct a HDG scheme for real-world device applications.

11:40-12:00 | Xiaodi Zhang

Zhengzhou University

Numerical discretization of a phase field model in ferroelectric devices

ABSTRACT

In this talk, we present an energy stable scheme for a phase field model in ferroelectric devices. The model is a nonlinear and multi-domain coupled system, which couples the time-dependent Ginzburg-Landau equation for the polarization and Poisson equation for the electric potential. We first deduce the energy estimates for the continuous system and then develop a semi-discrete scheme based on the idea of convex-splitting. The scheme is proved to be unconditionally energy stable and uniquely solvable. Drawing upon the energy argument, error estimates for all variables are established. Several numerical examples including polarization-electric field hysteresis and domain wall dynamics are provided to confirm our theoretical analysis and demonstrate the effectiveness of the proposed method.

MS13

Numerical Optimization and Related Applications

Main organizer Mei-Heng Yueh (National Taiwan Normal University)

DESCRIPTION

Numerical optimization plays a central role in modern scientific computing, providing essential tools for modeling, simulation, and data-driven analysis across a wide range of disciplines. This minisymposium aims to bring together researchers working on theoretical, algorithmic, and applied aspects of numerical optimization, with particular emphasis on emerging methodologies and interdisciplinary applications. Topics of interest include variational formulations, gradient-based optimization methods, large-scale and high-dimensional optimization, and structure-preserving algorithms.

MS13 | 09:50-11:10 | Room S2

09:50-10:10 | Ching-Sung Liu

National University of Kaohsiung

Nodal Newton-Noda Iteration for Computing Eigenstates of Nonlinear Schrödinger Equations

ABSTRACT

We introduce a novel Nodal Newton-Noda Iteration (N-NNI) for efficiently computing the eigenstates of one-dimensional nonlinear Schrödinger equations. Since the K -th state changes sign exactly K times, partitioning the domain at these nodes splits the problem into $K+1$ positive nonlinear algebraic eigenvalue problems (NAEPs); the case $K=0$ gives the ground state. N-NNI employs a two-level iterative structure: an outer iteration that refines the nodal partition via a global Newton step, and an inner iteration that solves the positive subproblems by block-elimination of the coupled Newton system. A key feature of N-NNI is that the subdomain iterates stay strictly positive while the eigenvalue sequence increases monotonically and converges quadratically. The dominant computational cost lies in solving the Newton systems in the inner iterations. Numerical results demonstrate the efficiency and reliability of the proposed method, supporting our theoretical findings.

10:10-10:30 | Yueh-Cheng Kuo

National Chengchi University

The Minimal Solution of Positive Semidefinite Quadratic Programming Problems

ABSTRACT

We study convex quadratic programming problems with positive semidefinite Hessian matrices, for which the set of optimal solutions may be nonunique. We prove that, when the optimal value is finite, there exists a unique minimal solution, defined as the minimizer with the smallest Euclidean norm, and provide a primal-dual characterization of this solution. To compute the minimal solution efficiently, we introduce a regularization framework that yields a sequence of strictly convex quadratic programs and prove that their solutions converge to the minimal solution of the original problem. Based on this analysis, we develop an active-set-based algorithm with a homotopy strategy for tracking the regularization parameter. Numerical experiments demonstrate the effectiveness and robustness of the proposed method.

10:30-10:50 | Tsung-Ming Huang

National Taiwan Normal University

An optimal parameterized Newton-type structure-preserving doubling algorithm for finite-time state-dependent Riccati equation

ABSTRACT

This study develops a high-performance finite-time state-dependent Riccati equation (FT-SDRE) algorithm integrated with structure-preserving doubling algorithms (SDAs). At each state of the FT-SDRE, a modified Newton-Lyapunov method is employed to solve the continuous algebraic Riccati equation (CARE). Furthermore, we introduce a simplified SDA with adaptive optimal parameter selection to efficiently solve the associated Lyapunov equation. Numerical results demonstrate that our accelerated FT-SDRE algorithm is approximately three times faster than standard implementations using MATLAB's `icare` and `lyap` functions.

10:50-11:10 | Mei-Heng Yueh

National Taiwan Normal University

Numerical Optimization for Spherical Area-Preserving Parameterizations

ABSTRACT

Area-preserving surface parameterization is a fundamental problem in computational geometry, with applications to surface registration and shape analysis. In this talk, I will present a numerical optimization framework for computing spherical area-preserving parameterizations of genus-zero closed surfaces. The proposed framework is based on minimizing a spherical authalic energy and introduces a Riemannian bijective correction to guarantee bijective parameterizations. Numerical examples and applications to surface shape analysis will be presented.

MS19

Recent Advances in Matrix Factorization: Theory and Algorithms

Main organizer	Jie Meng (Ocean University of China)
Co-organizers	Zhigang Jia (School of Mathematics and Statistics & RIMS, Jiangsu Normal University); Hyun-Min Kim (Department of Mathematics, Pusan National University)

DESCRIPTION

This mini-symposium focuses on the latest theoretical and algorithmic breakthroughs in Matrix Factorization, a cornerstone of Numerical Linear Algebra (NLA). As datasets grow in complexity and scale, traditional decompositions are being reimagined through the lens of Randomized Numerical Linear Algebra (RandNLA), low-rank approximations, and high-performance computing constraints. This session aims to bridge the gap between abstract algebraic theory and robust numerical implementation. The discussion will center on the mathematical foundations and convergence analysis of structured factorizations, specifically addressing:

- Probabilistic Error Analysis: Investigating the spectral and Frobenius norm error bounds of randomized algorithms, such as sketching and sampling-based SVD, to ensure theoretical reliability in stochastic frameworks.
- Structured & Interpolative Decompositions: Advancing the theory of CUR Decompositions and Interpolative Decompositions (ID), focusing on their ability to preserve data sparsity and interpretability while maintaining numerical stability.
- Optimization on Matrix Manifolds: Analyzing the convergence rates of algorithms operating on Riemannian manifolds, particularly for matrix completion and low-rank recovery under non-convex constraints.
- Multilinear Algebra and Tensor Formats: Extending matrix theory to higher-order tensors, focusing on the stability of Tensor Train (TT) and Tucker decompositions in overcoming the curse of dimensionality.

Objective: To provide a rigorous forum for researchers to present new results on perturbation analysis, complexity bounds, and the algebraic properties that define the next generation of matrix-based computational tools.

MS19A | 11:20-12:40 | Room I1

11:20-11:40 | Susana López-Moreno

Pusan National University

Linear-map-based tensor CUR decomposition for robust video foreground-background separation

ABSTRACT

The factorization of three-dimensional data continues to gain attention due to its relevance in representing and compressing large scale datasets. The linear-map-based tensor-tensor multiplication is a matrix-mimetic operation that extends the notion of matrix multiplication to higher order tensors, and which is a generalization of the T-product. Under this framework, we introduce the tensor CUR decomposition, show its performance in video foreground-background separation for different linear maps and compare it to a robust matrix CUR decomposition, a tensor CUR decomposition, other tensor approximations and the slice-based singular value decomposition. We also provide a theoretical analysis of our tensor CUR decomposition, extending classical matrix results to establish exactness conditions and perturbation bounds.

11:40-12:00 | Jie Meng

Ocean University of China

Component-wise accurate computation of the square root of an M-matrix

ABSTRACT

Component-wise accurate algorithms for computing the principal square root of an M-matrix are designed in terms of triplet representations. A triplet representation of an M-matrix A is the triple $(P, \mathbf{u}, \mathbf{v})$, where the matrix P is such that $p_{ij} = -a_{ij}$ for $i \neq j$, $p_{ii} = 0$, and $\mathbf{u} > 0$, $\mathbf{v} \geq 0$ are two vectors such that $A\mathbf{u} = \mathbf{v}$. It is shown that if A is an M-matrix representable by a triplet, then its principal square root exists and is an M-matrix represented by a triplet as well. New versions of the Cyclic Reduction and the Incremental Newton iterations are provided in terms of triplets, to compute the principal matrix square root of A . Structure-preserving doubling algorithm and fixed-point iterations are also provided. It is shown that these algorithms are component-wise numerically stable independently of the singularity of A and of its condition number. Numerical experiments are shown to confirm the component-wise stability.

12:00-12:20 | Taehyeong Kim

Kyungpook National University

Co-authors: Hayoung Choi (Kyungpook National University); Jeong-Hoon Ju (University of Copenhagen)

Numerical methods approach to discovering low-rank tensor decompositions**ABSTRACT**

Exact low-CP-rank decompositions of structured tensors are central problems in algebraic complexity. Numerical decompositions are useful in this setting only when they can be converted into exact symbolic identities. We introduce several numerical approach framework based on sparse optimization and Sigma-Pi-Sigma neural networks for this task. Notably, in the determinant case, we prove $\text{rank}(\det_4) \leq 12$ and $\text{rank}(\det_5) \leq 42$ by finding their exact new formula over fields of characteristic not equal to 2.

12:20-12:40 | Zhigang Jia

Jiangsu Normal University

A Novel Adaptive Low-Rank Matrix Approximation Method for Image Compression and Reconstruction**ABSTRACT**

Low-rank matrix approximation plays an important role in various applications such as image processing, signal processing and data analysis. The existing methods require a guess of the ranks of matrices that represent images or involve additional costs to determine the ranks. A novel efficient orthogonal decomposition with automatic basis extraction (EOD-ABE) is proposed to compute the optimal low-rank matrix approximation with adaptive identification of the optimal rank. By introducing a randomized basis extraction mechanism, EOD-ABE eliminates the need for additional rank determination steps and can compute a rank-revealing approximation to a low-rank matrix. Experimental results demonstrate the superior speed, accuracy and robustness of EOD-ABE and indicate that EOD-ABE is a powerful tool for fast image compression and reconstruction and hyperspectral image dimensionality reduction in large-scale applications.

MS19B | 15:50-17:10 | Room I1**15:50-16:10 | Ling Si-Tao**

China University of Mining and Technology

Generalized singular value decompositions of dual quaternion matrices and beyond**ABSTRACT**

In high-dimensional data processing and data analysis related to dual quaternion statistics, generalized singular value decomposition (GSVD) of two or more dual quaternion matrices is an essential numerical linear algebra tool for an elegant problem formulation and numerical implementation. In this talk, building upon the existing singular value decomposition (SVD) of a dual quaternion matrix, we put forward several types of GSVD of dual quaternion data matrices in accordance with their dimensions. Due to the peculiarity of containing infinitesimal part for dual quaternion matrices, the obtained series of GSVD of dual quaternion matrices dramatically distinguish from those in the real field, the complex field, and even the quaternion ring, but can be treated as an extension of them in some sense.

16:10-16:30 | Meiyue Shao

Fudan University

On Two-Stage Householder Orthogonalization**ABSTRACT**

Two-stage orthogonalization is essential in numerical algorithms such as Krylov subspace methods. For this task we need to orthogonalize a matrix A against another matrix V with orthonormal columns. A common approach is to employ the block Gram-Schmidt algorithm. However, its stability largely depends on the condition number of $[V, A]$. While performing a Householder orthogonalization on $[V, A]$ is unconditionally stable, it does not utilize the knowledge that V has orthonormal columns. To address these issues, we propose a two-stage Householder orthogonalization algorithm based on the generalized Householder transformation. Instead of explicitly orthogonalizing the entire V , our algorithm only needs to orthogonalize a square submatrix of V . Theoretical analysis and numerical experiments demonstrate that our method is also unconditionally stable.

MS08

Recent advances in analysis and numerical methods for wave scattering problems

Main organizer	Tao Yin (Academy of Mathematics and Systems Science, Chinese Academy of Sciences)
Co-organizers	Weiyang Zheng (Academy of Mathematics and Systems Science, Chinese Academy of Sciences)

DESCRIPTION

The wave scattering problems appear in many practical applications in science and engineering. Developing comprehensive mathematical analysis and efficient numerical schemes for the related problems of Helmholtz, Navier and Maxwell's equations is among the most dynamic research fields in applied and computational mathematics. The goal of this mini-symposium is to discuss unresolved challenges and exchange recent advances in analysis and numerical methods for wave scattering problems, including, but not limited to, analysis of direct and inverse problems of wave propagation, finite element method, high-order integral equation solver, preconditioning for large-scale problems and quantum algorithm.

MS08A | 11:20-12:40 | Room S2

11:20-11:40 | Xue Jiang

Beijing University of Technology

Wave-number-explicit analysis for maxwell's equation with Dirichlet-to-Neumann truncation

ABSTRACT

This work is focused on the propagation of electromagnetic waves in $\mathbb{R}^3$ described by Maxwell's equation with large wave number and Silver-Müller radiation condition. The model problem is approximated by truncating the exact Dirichlet-to-Neumann (DtN) operator into a finite sum of vector spherical harmonics. We prove the well-posedness and wave-number-explicit $H(\text{curl})$ -stability of the solution to truncated problem by assuming that the truncation number N satisfies $N \geq \alpha k R$ for some $\alpha > 1$, where k represents the wave number and R is the radius of the physical domain. Additionally, we demonstrate that the truncated solution is exponentially close, in terms of N , to the true scattering solution. Finally, we present the hp-finite element method (hp-FEM) for the truncated problem, along with its asymptotic error estimate. Some numerical experiments are provided to validate the theoretical findings.

11:40-12:00 | Tao Yin

Academy of Mathematics and Systems Science, Chinese Academy of Sciences

Nanoscale electromagnetic scattering: well-posedness and adaptive FEM

ABSTRACT

This talk will present our recent work on the mathematical analysis and numerical method for the nanoscale electromagnetic scattering problem with mesoscopic boundary conditions whose TM polarization leads to a transmission problem of Helmholtz equations with boundary conditions involving the Laplace-Beltrami surface differential operator. In particular, a nonstandard Sobolev space involving the jumps across the boundary is introduced to establish the well-posedness of the variational formulations for the reduced problems truncated by the Helmholtz Dirichlet-to-Neumann operator. The a priori and a posteriori error estimates of the finite element discretization are derived by means of some carefully designed local error estimators that are related to the mesoscopic boundary conditions. Numerical experiments will be presented to validate the theoretical results and verify the convergence and efficiency of the proposed adaptive method.

12:00-12:20 | □ □ □

中科院数学与系统科学研究院

Wave-number-explicit stability and preasymptotic error analysis of a UPML finite element method

ABSTRACT

This talk presents a wavenumber-explicit stability and preasymptotic error analysis for the two-dimensional Helmholtz exterior scattering problem with a uniaxial perfectly matched layer (UPML) truncation. The UPML formulation is obtained by Cartesian complex stretching, and the analysis relies on estimates of the stretched Green kernel. We prove stability estimates for the whole-space and truncated UPML problems. In particular, the truncated formulation has an inf-sup constant bounded below by Ck^{-1} in a natural k -weighted H^1 norm, equivalently a stability bound of order $O(k)$. We also obtain exponential decay of the PML truncation error. Based on this framework, we study a linear CIP-FEM. A key ingredient is a piecewise H^{1+s} -regularity result for any $0 < s < 1$, accounting for coefficient jumps and corner singularities. This yields wavenumber-explicit preasymptotic error estimates, illustrated by numerical experiments.

12:20-12:40 | Yicheng Huang

Academic of Mathematics and System Science, Chinese Academy of Science

A Robust Multigrid Method for the High Wavenumber Helmholtz Equation via Ray Equation Correction**ABSTRACT**

Solving the high-wavenumber Helmholtz equation with impedance boundary conditions remains a computational challenge due to the indefiniteness of the resulting discrete systems. In this work, we propose an efficient multigrid framework designed to achieve robust, weakly wavenumber-dependent convergence. Our approach utilizes a ray equation correction, $\mathbf{u} = \mathbf{a} \mathbf{e}^{i \mathbf{w} \cdot \mathbf{x}}$ to reformulate the original problem into a complex-coefficient convection-diffusion equation for the amplitude variable $\mathbf{a}$. We solve this transformed system using a specialized geometric multigrid algorithm. Theoretical analysis and numerical experiments confirm that our methodology maintains optimal $\mathcal{O}(N)$ computational complexity, with iteration counts exhibiting slow growth as the wavenumber k increases.

MS08B | 15:50-17:10 | Room S2**15:50-16:10 | Shipeng Mao**

Academy of Mathematics and Systems Science, Chinese Academy of Sciences

Structure-Preserving and Helicity-Conserving FEMs For MHD Systems**ABSTRACT**

Designing numerical methods that accurately preserve mathematical structures and physical properties has become a critical research topic in MHD computations. For incompressible MHD, we propose the fully discrete finite element exterior calculus (FEEC) method that simultaneously and exactly preserves key physical properties-including mass conservation, magnetic flux conservation, current density conservation, energy conservation, and the conservation of magnetic helicity and fluid helicity-even under their respective physical limits. For the ideal compressible MHD system, we develop a Lagrangian FEEC algorithm that achieves high-order accuracy in both space and time, preserves positivity of density, ensures a divergence-free magnetic field, and conserves magnetic helicity. To address mesh distortion issues, we design and develop a structure-preserving, helicity-conserving ALE FEEC algorithm.

16:10-16:30 | Wangtao Lu

Zhejiang University

The PML-BIE method: numerics and theories**ABSTRACT**

In this talk, I will briefly review the progresses of the PML-BIE method for wave scattering problems, and then will talk about the convergence theory of such method for a particular scattering problem.

MS10

Modeling Health and Disease in the Age of AI

Main organizer Eunha Shim (Department of Mathematics, Soongsil University)

DESCRIPTION

This minisymposium explores recent advances in mathematical and statistical modeling, complemented by artificial intelligence (AI), for understanding health and disease across a wide range of applications, including infectious diseases and chronic conditions. As modern healthcare becomes increasingly data-rich, there is a growing need for integrative frameworks that combine mechanistic insight with data-driven approaches to enable accurate prediction and effective decision-making.

The session brings together experts in mathematical epidemiology, biomedical data science, and AI-based modeling. The presentations will cover both methodological developments and real-world applications, highlighting how models can be used not only to understand disease dynamics but also to guide intervention strategies and health policy.

Key topics include: (1) dynamic transmission modeling and optimization of vaccination strategies for infectious diseases; (2) integration of large-scale healthcare and cohort data for risk prediction of chronic diseases; (3) multimodal data analysis combining genomic, imaging, and clinical data to improve predictive performance; (4) adaptive and data-driven approaches, including reinforcement learning, for decision-making in complex and evolving health systems.

Particular emphasis will be placed on translating modeling results into actionable insights. By linking mathematical models with real-world data, the session aims to provide quantitative evidence for policy decisions, such as vaccination strategies and resource allocation in healthcare systems.

This minisymposium is supported by the G-LAMP (Global-Learning & Academic research institution for Masters, PhD students, and Postdocs) at Soongsil University, which promotes interdisciplinary and international collaboration. Through contributions from researchers across mathematics, AI, and biomedical sciences, this session seeks to foster new collaborations and advance the development of next-generation approaches to health data analysis and disease modeling.

MS10 | 15:50-17:10 | Room H1

15:50-16:10 | Minjin Kim

Soongsil university

Cost-effectiveness of female-only and gender-neutral HPV vaccination strategies in Japan

ABSTRACT

This study evaluated the cost-effectiveness of female-only vaccination (FOV) and gender-neutral vaccination (GNV) strategies using 4-valent (4vHPV) and 9-valent (9vHPV) HPV vaccines among Japanese adolescents aged 12-16 years. An age- and sex-structured dynamic transmission model simulated HPV transmission and disease progression over a 100-year period. Six strategies were assessed: no further vaccination; FOV with 4vHPV; FOV with 9vHPV; GNV with 9vHPV for females and 4vHPV for males; GNV with 4vHPV for both sexes; and GNV with 9vHPV for both sexes. Both FOV with 4vHPV and FOV with 9vHPV produced ICERs below the willingness-to-pay threshold. GNV with 9vHPV for both sexes generated the greatest health benefits while remaining cost-effective. These findings indicate that both female-only 4vHPV and 9vHPV vaccination strategies are cost-effective under Japan's economic standards, while GNV with 9vHPV offers greater health gains and overall cost-effectiveness.

16:10-16:30 | Wonil Chung

Soongsil University

Statistical Hazard Models for Mendelian Randomization in Large-scale Survival Data

ABSTRACT

Mendelian randomization (MR) with survival outcomes commonly relies on the Cox proportional hazards (CoxPH) model, despite limitations arising from the proportional hazards assumption and the non-collapsibility of the hazard ratio. This paper compares CoxPH and additive hazards models for survival-based MR in terms of causal interpretation, estimator behavior, and model adequacy. We develop a simulation framework based on restricted mean survival time (RMST) to enable fair comparison across hazard structures. When the hazard model is correctly specified, CoxPH is more efficient for multiplicative hazards, whereas additive hazards provide stable inference on a collapsible scale; under misspecification, CoxPH exhibits systematic bias, while additive hazards generally maintain smaller bias at the cost of higher variance. An application to colorectal cancer survival highlights heterogeneity in hazard-model suitability.

16:30-16:50 | Hyeongki Park

Pusan National University

Analysis of longitudinal antibody titers measured after COVID-19 mRNA vaccination**ABSTRACT**

A key challenge in the post-COVID-19 era is optimizing repeated vaccination against circulating and emerging SARS-CoV-2 variants while efficiently managing medical resources. Identifying poor responders with low sustained antibody titers may help prioritize revaccination. We analyzed longitudinal antibody titer data from 2,526 participants in Fukushima, Japan, collected between April 2021 and November 2022. Using mathematical modeling and machine learning, we stratified antibody trajectories after two primary doses and one booster dose of mRNA vaccines into three groups: durable, vulnerable, and rapid-decliner. The rapid-decliner group experienced earlier infections than the others. In addition, early post-booster spike-specific IgA titers were lower in participants who later developed SARS-CoV-2 infection. This framework may help guide vaccine distribution strategies to maximize population-level immunity.

MS36

Machine Learning Methods for Stochastic Dynamics

Main organizer	Li Zeng (Fuzhou University)
Co-organizers	Xiaodong Feng (Beijing Normal-Hong Kong Baptist University)

DESCRIPTION

Recent years have witnessed growing interest in machine learning methods for stochastic dynamics. These methods provide new tools for representing probability distributions, learning dynamical structures from data, performing inference for stochastic models, and analyzing complex behaviors in high-dimensional systems. This minisymposium focuses on recent advances in machine learning for stochastic dynamics, including topics such as generative modeling, Bayesian inference, identifiable learning of dissipative systems, and related applications in uncertainty quantification and complex dynamical systems. The aim of the minisymposium is to bring together researchers from scientific computing, stochastic analysis, and machine learning, and to promote discussion on recent progress and challenges in this rapidly developing area.

MS36 | 15:50-17:10 | Room H3

15:50-16:10 | Aiqing Zhu

National University of Singapore

Identifiable learning of dissipative dynamics

ABSTRACT

Complex dissipative systems appear across science and engineering, from polymers and active matter to learning algorithms. These systems operate far from equilibrium, where energy dissipation and time irreversibility govern their behavior but are difficult to quantify from data. In this work, we introduce a universal and identifiable neural framework that learns dissipative stochastic dynamics while ensuring interpretability, expressiveness, and uniqueness. Our method identifies a unique energy landscape, separates reversible from irreversible motion, and allows direct computation of the entropy production, providing a principled measure of irreversibility and deviations from equilibrium. Applications to polymer stretching in elongational flow and to SGLD reveal new insights, including super-linear scaling of barrier heights and sub-linear scaling of entropy production rates with the strain rate, and the suppression of irreversibility with increasing batch size.

UPDATED - CANCELLED - no replacement talk

16:10-16:30 | Xintong Wang

Shanghai Normal University

Flow-based joint Bayesian state and parameter inference for nonlinear stochastic dynamical systems

ABSTRACT

Bayesian state and parameter inference for nonlinear stochastic dynamical systems is fundamental but challenging across science and engineering. Gaussian filters struggle with non-Gaussian distributions, while sequential Monte Carlo methods are costly and suffer from particle degeneracy in high dimensions. Although deep generative approaches can model complex distributions, they still face difficulties in balancing accuracy and computational efficiency. To address these challenges, we develop a unified framework built upon the flow-based Bayesian filter, which integrates normalizing flows to construct a novel latent linear Gaussian state-space model. This framework enables efficient data-driven filtering, smoothing, and parameter sampling without requiring explicit knowledge of system dynamics and observation models. Numerical experiments show that the proposed method achieves higher accuracy and efficiency than existing approaches.

16:30-16:50 | Li Zeng

Fuzhou University

Flow-Based Adaptive Density Approximation for Fokker--Planck Type Equations**ABSTRACT**

Fokker--Planck type equations describe the evolution of probability densities arising from stochastic dynamical systems, but their numerical solution remains challenging in high dimensions, on unbounded domains, and in the presence of nonlocal operators. In this talk, we present flow-based methods for adaptive density approximation of such equations. The main idea is to represent the unknown density by an invertible neural transformation, so that positivity and mass conservation are naturally encoded. We first discuss temporal normalizing flows for time-dependent Fokker--Planck equations, and then describe extensions to fractional Fokker--Planck equations with nonlocal operators on unbounded domains. Finally, we introduce B-KRnet, a bounded-domain normalizing flow, and discuss its applications to density estimation and PDE-based density approximation. Together, these works demonstrate the effectiveness of flow-based neural models for probability-density evolution equations.

16:50-17:10 | Yaobin Wang

Beijing Normal-Hong Kong Baptist University

Operator Learning for Solving Fokker-Planck Equations with Various Initial Conditions**ABSTRACT**

The Fokker-Planck equation (FPE) describes the evolution of probability density functions for stochastic dynamical systems. We propose a conditional normalizing-flow physics-informed neural network (PINN) for approximating the FPE solution operator over a family of initial conditions. Using the Chapman-Kolmogorov equation, we reformulate the task as learning the transition density from a Dirac mass at an arbitrary initial point. To avoid the singular map induced by the Dirac initial distribution, we use the density of a linearized stochastic differential equation (SDE) as the flow base distribution, which gives an accurate small-time approximation to the target density. We further introduce a time-weighted residual loss to reduce small-time instability while preserving the causal structure of the dynamics. Numerical experiments demonstrate the accuracy, robustness, and efficiency of the proposed method.

Wednesday, August 26 2026

MS04

Dispersive PDEs: Modeling, Analysis and Numerical Simulations

Main organizer	Yue Feng (Xi'an Jiaotong University)
Co-organizers	Weizhu Bao (National University of Singapore)

DESCRIPTION

Dispersive partial differential equations (PDEs) serve as essential tools in a wide array of scientific disciplines from engineering to physics. The proposed minisymposium is dedicated to recent developments in the field of dispersive PDEs including mathematical modeling, rigorous analysis, and numerical simulations. It will bring together experts to cover new theoretical results concerning the properties of solutions, the design of efficient and accurate numerical methods, and the modeling of real-world wave phenomena. The goal is to exchange ideas between pure and applied mathematicians and foster collaborations that drive the field forward.

MS04A | 09:50-11:10 | Room H1

09:50-10:10 | Weizhu Bao

National University of Singapore

Multiscale methods and analysis for the Dirac equation in nonrelativistic regime

ABSTRACT

In this talk, I will review our recent works on multiscale methods and analysis for solving the highly oscillatory (nonlinear) Dirac equation including the nonrelativistic regime. In this regime, the solution is highly oscillating in time and the energy becomes unbounded and indefinite. Rigorous error bounds are obtained for finite difference time domain methods, time splitting Fourier pseudospectral method and exponential wave integrator Fourier pseudospectral method, which depend explicitly on the mesh size, time step and the small parameter. Then based on a multiscale expansion of the solution, we present a multiscale time integrator Fourier pseudospectral method for the Dirac equation and prove its error bound which uniformly accurate in term of the small dimensionless parameter. This is a joint work with Yongyong Cai, Yue Feng, Xiaowei Jia, Qinglin Tang and Jia Yin.

10:10-10:30 | Xiang-Ke Chang

Academy of Mathematics and Systems Science, Chinese Academy of Sciences

On a class of low regularity solutions to the Camassa-Holm equation

ABSTRACT

The Camassa-Holm equation is a nonlinear wave equation that has attracted much attention because of the existence of peaked solitons (peakons) and being a meaningful model for wave breaking. We describe a class of conservative low regularity solutions to the Camassa-Holm equation on the line by exploiting the moment problem and generalized indefinite strings to develop the inverse spectral method. In particular, we identify explicitly the solutions that are amenable to this approach, which include solutions made up of infinitely many peakons. As an application, our results are then used to investigate the long-time behavior of solutions. We also present numerics for these solutions with certain step-like and asymptotically eventually periodic initial data, etc.

10:30-10:50 | Jeongho Kim

Kyung Hee University

Hydrodynamics limit and numerical simulation for the Chern-Simons-Schrodinger equations

ABSTRACT

In this talk, I present the analytical and numerical results on the Chern-Simons-Schrodinger (CSS) equations. In the first part of the talk, we rigorously prove the semi-classical limit of the CSS equations when the Planck constant converges to zero. The resulting equation is the pressure-less Euler equation. In the second part of the talk, we discuss the numerical methods for solving the CSS equations, including finite difference method and time-splitting method, and verify the analytical result via numerical experiments.

MS04B | 11:20-12:40 | Room H1

11:20-11:40 | Yoshio Tsutsumi

Kyoto University

Four-Fermion Interaction Approximation of the Intermediate Vector Boson Model**ABSTRACT**

I will talk about the approximation of the Dirac-Proca equations to the cubic Dirac equation when the mass of the Proca field is large enough. This justifies the four-fermion interaction approximation of the intermediate vector boson model in a mathematically rigorous sense. The proof is based on the Strichartz estimate of the Proca sector with mass parameter. My talk is based on the paper published in Bull. Braz. Math. Soc., New Series, 56-3 (2025).

11:40-12:00 | Yue Feng

Xi'an Jiaotong University

Explicit Symmetric Low-Regularity Integrator for the Nonlinear Schrodinger Equation**ABSTRACT**

The numerical approximation of low-regularity solutions to the nonlinear Schrodinger equation (NLSE) is notoriously difficult and even more so if structure-preserving schemes are sought. In this work, we introduce the first fully explicit (multi-step) symmetric low-regularity integrators for NLSE. We demonstrate the construction of an entire class of such schemes which notably can be used to symmetrise (in explicit form) a large amount of existing low-regularity integrators. We provide rigorous convergence analysis of our schemes and numerical examples demonstrating both the favourable structure preservation properties obtained with our novel schemes, and the significant reduction in computational cost over implicit methods.

MS25

Numerical Methods and Computational Modeling for Complex Physical Systems

Main organizer	Shuo Zhang (Academy of Mathematics and Systems Science, Chinese Academy of Sciences)
Co-organizers	Xia Ji (Beijing Institute of Technology); Hehu Xie (Academy of Mathematics and Systems Science, Chinese Academy of Sciences)

DESCRIPTION

This minisymposium collects new advances in computational science on developing and applying advanced numerical algorithms to model complex phenomena across physical scales. It integrates classical techniques with modern machine learning to introduce high-performance simulation methods and gain decisive insights into challenging physical processes. By bridging algorithm development with scientific applications, it aims to expand the limits of discovery to understand and engineer complex matter.

MS25A | 09:50-11:10 | Room H3

09:50-10:10 | Haijun Yu

Academy of Mathematics and Systems Science, Chinese Academy of Sciences

Fast Jacobi Spherical Harmonic Spectral Methods for the FENE Fokker--Planck Equation with Applications to Closure Modeling

ABSTRACT

We develop efficient spectral methods for the spatially homogeneous Fokker--Planck equation associated with the finitely extensible nonlinear elastic (FENE) dumbbell model. To address the boundary singularities induced by FENE potential, we construct Jacobi-spherical harmonic spectral methods to incorporate the correct boundary behavior through suitably weighted Jacobi polynomial bases, resulting in sparse linear systems that can be solved efficiently. For time discretization, we employ a semi-implicit BDF2 scheme and establish its energy stability. Numerical experiments demonstrate the accuracy and efficiency of the proposed solvers. Using the high-fidelity solutions as benchmarks, we further assess several commonly used closure approximations, including the Peterlin model (FENE-P) and the quasi-equilibrium approximation (FENE-QE). We also propose a neural-network-based implementation of the FENE-QE closure that significantly reduces computational cost while maintaining high accuracy.

10:10-10:30 | Xiaobo Yin

Central China Normal University

Neural network methods for fractional Laplacian: from quadrature-enhanced MC fPINN to fTNN

ABSTRACT

This talk presents two methods on the neural networks for fractional Laplacian. They all adopt a spatially varying radius, yielding a geometry-adaptive three-part decomposition of the fractional Laplacian: singular near-field, regular interior far-field, and analytical exterior far-field. Then, for the first method called quadrature-enhanced Monte Carlo fPINN, Gauss-Jacobi quadrature is used for the singular near-field radial integral, Gauss quadrature for the regular interior radial integral, and Monte Carlo sampling for the angular variables, combined with a feature-enhanced PINN trial space, achieving 1-3 orders of magnitude improvement over existing baselines on problems up to 10000 dimensions. The second method is a fully deterministic method, called fTNN, which replaces the angular Monte Carlo sampling by deterministic directional quadrature, reaching relative errors on the order of 10^{-4} to 10^{-6} in 1D/2D/3D.

10:30-10:50 | Xiaoying Dai

Academy of Mathematics and Systems Science, Chinese Academy of Sciences

Orthogonality Preserving Methods for Electronic Structure Calculations

ABSTRACT

To obtain convergent numerical approximations without orthogonalization operations is of great importance in electronic structure calculations. In this talk, we will introduce an extended gradient flow based Kohn-Sham DFT model, for which we prove that the flow is orthogonality preserving and that the solution evolves to the ground state. With the help of the extended gradient flow based Kohn-Sham DFT model, we propose some iteration schemes for the discretized Kohn-Sham model, which are proved to preserve the orthogonality of the Kohn-Sham orbitals automatically. With our schemes, the iterative approximations are guaranteed to converge to the Kohn-Sham orbitals without any orthogonalization operations when the initial orbitals are orthogonal.

10:50-11:10 | Fei Xu

Beijing University of Technology

Effective Approximations for Hybrid Density Functional Theory Calculations**ABSTRACT**

A novel adaptive finite element algorithm is proposed for hybrid density functional theory to address the high complexity and large dense eigenvalue problems induced by the nonlocal Fock exchange operator. The algorithm adopts the multilevel correction framework to decompose high-dimensional nonlinear eigenvalue problems into linear boundary value problems and low-dimensional subspace problems. A general low-rank approximate exchange operator is constructed, which maintains Hermiticity, guarantees calculation accuracy and avoids matrix singularity. A three-level nested SCF iteration strategy is also introduced to cut the cost of repeated operator construction. This method effectively breaks the computational bottleneck of traditional approaches and offers an efficient numerical solution for electronic structure simulations.

MS25B | 11:20-12:40 | Room H3**11:20-11:40 | Jie Xu**

Academy of Mathematics and Systems Science, Chinese Academy of Sciences

Quasi-entropy: in free energies and closure approximations**ABSTRACT**

Molecular-theory-based tensor models of liquid crystals typically contain an explicit entropy term deduced from the maximum entropy state. For dynamic models, high-order tensors also appear in the model, for which a classical closure approximation is also given the maximum entropy state. The maximum entropy state is able to maintain the essential properties and structures of the molecular theory in tensor models, but leads to high computational cost. Quasi-entropy is a class of elementary functions to substitute the terms deduced from the maximum entropy state, which can be incorporated both in free energies and in closure approximations. It not only keeps the desired properties and structures of the models, but also reduces the complexity of dealing with implicit functions involving three dimensional integrals to $O(1)$. We present a few representative results in equilibrium states and dynamics.

11:40-12:00 | Manting Xie

Tianjin University

Numerical computation of Bogoliubov collective excitations in Bose-Einstein condensates**ABSTRACT**

Bogoliubov collective excitations represent a distinctive quantum state in Bose-Einstein condensates, which mathematically correspond to a class of linear response eigenvalue problems known as the Bogoliubov-de Gennes equations (BdGEs). This report presents an efficient, robust, and high-precision numerical method for solving such BdGEs. It covers the fundamental underlying mathematical theories and the numerical analysis framework. The superiority of the proposed method in terms of accuracy and computational efficiency is validated via numerical experiments. Numerical results demonstrate that the implemented algorithm can precisely characterize the low-energy excitation spectra, thereby providing reliable numerical support for investigating macroscopic quantum phenomena in ultracold quantum gases.

12:00-12:20 | Jiarong Chen

Beijing Institute of Technology

Dirichlet Harmonic Solutions via Neumann-Type Curl Potentials: A Unified Natural Deep Ritz Framework on the de Rham Complex**ABSTRACT**

Deep neural networks show great promise for high-dimensional PDEs, yet enforcing Dirichlet boundary conditions remains a core challenge. This work builds on a key geometric insight: Dirichlet harmonic solutions admit a curl-driven Neumann-type representation, circumventing the case-by-case tuning and convergence imbalance of standard penalty-based methods in high dimensions. Based on the de Rham complex, our unified Natural Deep Ritz Method (NatDRM) for all $d \geq 2$ converts Dirichlet constraints into three coupled Neumann subproblems via dimension-adaptive curl potentials, with unified discrete losses, lightweight boundary gauge-fixing regularizations, and extensions to variable-coefficient and semilinear Poisson cases. Numerical experiments up to 6D show the method matches or outperforms optimally tuned DRM and PINN in most cases, with stable convergence and synchronous interior-boundary error decay.

12:20-12:40 | Huaijia Zhang

Beijing Institute of Technology

Tensor Neural Network Based Machine Learning Method for Elliptic Multiscale Problems**ABSTRACT**

In this work, we present a machine-learning method based on tensor neural networks for solving elliptic multiscale problems. Thanks to their special structure, tensor neural network functions allow direct, highly-accurate high-dimensional integration without resorting to Monte-Carlo sampling. Using homogenization techniques, the original multiscale problem is first transformed into a high-dimensional limit problem with satisfactory accuracy. We then construct a machine-learning approach based on tensor neural networks to solve this resulting high-dimensional limit problem. The proposed framework offers a new avenue for developing high-accuracy numerical methods for more general multiscale problems. Several numerical examples are presented to verify the performance of our numerical scheme.

MS29

Recent advances on kinetic theory and continuum mechanics

Main organizer	Hiroshi Fujiwara (Kyoto University)
Co-organizers	Daisuke Kawagoe (Kyoto University)

DESCRIPTION

Kinetic theory and continuum mechanics are deeply interconnected disciplines within physics, engineering, and various fields, both concerned with the description of basic and complex physical phenomena through mathematically rigorous frameworks. Rooted in phenomenological modeling, these fields lead to the formulation and analysis of a wide range of integral equations and differential equations to understand and application of nature. Over time, their study has not only advanced our understanding of physical systems but has also stimulated the development of diverse areas in mathematics. In particular, the analysis of such equations has given rise to significant progress in mathematical analysis, including both forward and inverse problems. At the same time, challenges arising from real-world applications have driven innovations in numerical analysis and scientific computing, leading to increasingly sophisticated algorithms and simulation techniques capable of handling nonlinear problems. Despite a long history of research, these fields remain highly active, with ongoing efforts to address unresolved theoretical questions and to improve computational methodologies. Recent advances continue to bridge gaps between theory and application, fostering new connections across disciplines. This symposium aims to provide a platform for researchers to exchange ideas and share recent developments in kinetic theory, continuum mechanics, and related areas. By bringing together perspectives from mathematical analysis, numerical analysis, and data science, it seeks to promote deeper understanding and stimulate further progress in these fundamental and evolving fields.

MS29A | 09:50-11:10 | Room S1

09:50-10:10 | In-Jee Jeong

Korea Institute for Advanced Study

Stability of traveling waves on the half-plane without sign condition on the vorticity

ABSTRACT

We establish Lyapunov stability of a family of traveling waves without the sign condition on the vorticity, for the two-dimensional incompressible Euler equations on the half-plane. This is done by combining variational principles with Lagrangian bootstrapping arguments which carefully track the location of the negative part of the vorticity. This seems to be the first stability result which does not require the sign condition in the half-plane. This is based on joint works with Ken Abe, Kyudong Choi, Guolin Qin, and Yao Yao.

10:10-10:30 | Masaki Imagawa

Academia Sinica

Stability and Boundary Interaction of Viscous Shock Waves for the Burgers Equation

ABSTRACT

We study the stability and boundary interaction of viscous shock waves for the Burgers equation on the half-line. The initial data are assumed to be close to a viscous shock profile located far from the boundary. We treat both cases where the shock moves away from the boundary and where it moves toward the boundary. In the outgoing case, pointwise estimates for the perturbation of the shock profile are obtained by introducing a suitable shift of the shock location. In the incoming case, the same analysis remains valid only while the shock is sufficiently far from the boundary. After the shock approaches the boundary, we use the Green's function for the linearized equation around a Riemann solution, which is explicitly described via the Hopf-Cole transform. This enables us to capture the transition from a shock layer to a boundary layer.

This talk is based on joint work with Shih-Hsien Yu (Academia Sinica, Taiwan).

10:30-10:50 | Yong-Gwan Ji

Korea Institute for Advanced Study(KIAS)

The transmission problem with imperfect interfaces of small resistance**ABSTRACT**

We consider the transmission problem in presence of interfaces with imperfect bonding. The imperfect bonding condition is characterized by the positive resistance along the interface, which causes discontinuity of the potential across the interface while the flux is continuous. If the interface resistance is zero, then the interface is of perfect bonding, where both the potential and the flux of the solution are continuous across the interface. In this paper, we first construct using layer potentials the solution to the transmission problem with imperfect interfaces. We then prove that the solutions converge in various Sobolev spaces to the solution to the transmission problem with perfect interfaces as the interface resistance tends to zero. In particular, it is shown that the gradient of the solution converges in the uniform norm if the boundary is sufficiently regular. This is joint work with Shota Fukushima and Hyeonbae Kang.

10:50-11:10 | Evan Miller

University of Maine

The global regularity problem for the axisymmetric, swirl-free Euler equation in four and higher dimensions.**ABSTRACT**

In this talk, I will discuss some recent progress on the regularity problem for axisymmetric, swirl-free solutions of the Euler equation in four and higher dimensions. This problem is more singular than the classical three dimensional case, because the transported quantity may be unbounded initially.

MS29B | 11:20-12:40 | Room S1**11:20-11:40 | Chun-Hsiung Hsia**

National Taiwan University

On the existence and regularity of weakly nonlinear stationary Boltzmann equations : a Fredholm alternative approach**ABSTRACT**

This is joint work with I-Kun Chen and Daisuke Kawagoe. In this talk, we demonstrate a generalized Fredholm theory in the setting of identity power compact operators, which was suggested in Cercignani and Palczewski in 1987 to solve the existence of the stationary Boltzmann equation in a slab domain. We carry out the detailed analysis based on this generalized Fredholm theory to prove the existence theory of the stationary Boltzmann equation in bounded three-dimensional convex domains. To prove that the integral form of the linearized Boltzmann equation satisfies the identity power compact setting requires the regularizing effect of the solution operators. Once the existence and regularity theories for the linear case are established, with suitable bilinear estimates, the nonlinear existence theory is accomplished.

11:40-12:00 | Hiroshi Fujiwara

Kyoto University

Schlieren tomography of density in transparent media as the inverse source problem**ABSTRACT**

The Schlieren method is a well-established flow visualization technique that captures the deflection of light caused by refractive index variations in transparent media. By detecting such variations, it enables us to visualize density gradients in fluids, and is widely used, for example, to reveal shock-wave structures. Conventional Schlieren imaging generally produces two-dimensional projections from a single viewing direction. Tomographic Schlieren techniques, which acquire images from multiple view angles, enable the reconstruction of the internal structure of fluid fields. In this study, we develop a novel reconstruction method based on the A-analytic theory. Unlike conventional approaches relying on the Radon transform, the reconstruction problem is formulated as an inverse source problem for the transport equation. Numerical simulation results are presented to demonstrate the effectiveness of the proposed method.

12:00-12:20 | Junha Kim

Ajou University

Uniqueness for alpha-SQG in critical Hölder space**ABSTRACT**

In this talk we establish uniqueness for the alpha-SQG equation in the Hölder space C^α . This space is critical in the following sense: a C^α -solution barely admits a log-Lipschitz velocity, and its associated flow map is uniquely determined. On the other hand, the equation is strongly ill-posed in C^α , and existence of solutions is not guaranteed for all C^α -data. Assuming a hypothetical C^α -Lagrangian solution, we prove that it is unique within the class $L^\infty_t C^\alpha_x$.

12:20-12:40 | Peiran Zhang

Kyoto University

Coefficient Reconstruction in Elliptic and Parabolic PDEs Without Adjoint Problems Using Continuous Data Assimilation**ABSTRACT**

In this talk we present a method to reconstruct the spatially distributed diffusion coefficient in elliptic and parabolic partial differential equations (PDEs) from discrete interior measurements of the solutions. The proposed method is derived by the minimization of an error functional. By applying the technique of continuous data assimilation (CDA), an approximate gradient of the error functional is derived, which circumvents the computation of adjoint problems to obtain the gradient required by the conventional approach. We then consider the error analysis of the method using the proposed approximate gradient in a semi-discrete setting. Since the proposed gradient formula is explicit, we are able to investigate directly the descent of reconstruction error, and a Hölder stability is obtained. Finally, some numerical results are also presented, exhibiting the accuracy and stability of the proposed method.

MS31

Low-Rank Tensor Approximation and Neural Sampling Methods for High-Dimensional Scientific Computing

Main organizer	Kejun Tang (Great Bay University)
Co-organizers	Qifeng Liao (ShanghaiTech University)

DESCRIPTION

High-dimensional and large-scale problems are central to scientific computing, arising in the numerical partial differential equations (PDEs), stochastic systems, and high-dimensional approximation of functions and operators. The curse of dimensionality poses fundamental challenges to both representation and computation.

This minisymposium focuses on two complementary mathematical frameworks for addressing high-dimensional problems. The first is based on low-rank tensor approximation, including tensor train (TT), hierarchical Tucker (HT), and related formats, which provide compressed representations of high-dimensional objects and enable efficient numerical algorithms for high-dimensional problems. The second is rooted in neural network-based approaches, which offer flexible function approximation schemes and are closely connected to probabilistic formulations and sampling methods for high-dimensional distributions. Particular emphasis will be placed on the mathematical foundations and computational aspects of these approaches, including approximation theory in high dimensions, low-rank structure of solution manifolds, tensor-based discretizations and solvers, as well as neural sampling techniques such as transport-based methods, and generative models.

MS31A | 09:50-11:10 | Room S2

09:50-10:10 | Zhihang Xu

Shanghai Institute of Technology

Weak TransNet: a Petrov-Galerkin based method for partial differential equations

ABSTRACT

We propose Weak TransNet (WTN), a Petrov-Galerkin method for solving PDEs with singular solutions or without strong formulations. WTN combines weak formulations with TransNet, a shallow neural network that builds a predetermined neural feature space. The PDE solution is approximated as a linear combination of these features, with coefficients obtained by minimizing a weak-form loss. By decoupling basis construction from coefficient computation, WTN alleviates non-convexity and ill-conditioning in neural training. Numerical experiments demonstrate its robustness and efficiency.

10:10-10:30 | Heechang Kim

POSTECH

Physics-Informed Laplace Neural Operator: Data-Efficient and Out-of-Distribution Robust PDE Surrogate Modeling

ABSTRACT

Neural operators provide fast surrogate solvers for parametric PDEs, but purely data-driven training often requires large datasets and can be unreliable in small-data or out-of-distribution settings. In this talk, I will present the Physics-Informed Laplace Neural Operator (PILNO), which extends the Laplace Neural Operator by enforcing PDE, boundary condition, and initial condition losses during training. PILNO also uses unlabeled "virtual" inputs for physics-only supervision and temporal-causality weighting to emphasize early-time dynamics. Benchmarks on Burgers' equation, Darcy flow, reaction-diffusion, and forced KdV show that PILNO improves accuracy in small-data regimes and generalizes better beyond the training distribution.

10:30-10:50 | Kejun Tang

Great Bay University

Solving high-dimensional partial differential equations with deep learning requires rethinking sample generation

ABSTRACT

This work studies the role of random collocation points in deep learning methods for solving high-dimensional partial differential equations. Although deep neural networks have shown remarkable performance in data-driven methods, the selection of random collocation points remains a critical issue in solving high-dimensional partial differential equations (PDEs). From the perspective of error analysis, random sampling introduces statistical errors into the discretization of the loss functional, and the geometric properties of high-dimensional spaces may cause these statistical errors to dominate the final approximation error. We propose a new min-max formulation that simultaneously optimizes the approximate solution and the training samples. The main idea is to adjust the distribution of random samples such that the residual induced by the neural network maintains a nearly uniform profile during training.

10:50-11:10 | Xiang Zhou

City University of Hong Kong

Generative Modelling and Probability Flow : from A to B

ABSTRACT

In this talk, I will demonstrate the impact of the generative modelling to some longstanding challenges in computational mathematics and statistical physics and new opportunities for scientific computing. The specific topics are (1) How weak form of the PDE significantly reduces the cost of flow-based transport map (normalizing flow) to solve Kolmogorov forward equation (2) How the perspective of probability flow equivalence defines the Levy score function for the non-Gaussian Levy-Ito SDE, and its application to Onsager-Machlup functional and transport-based particle algorithm and in stochastic thermodynamics for non-Gaussian active matter. (3) How the flow-based generative method solves the gradient flow of free energy in Wasserstein space in geometric Dawson-Gartner framework. : 2604.11519; 2504.06628 [PRL 2026]; 2412.19520 Levy Score Function [SINUM2026]; 2409.01340[SIAP2025]; 2405.19256 : Weak Generative Sampler[SISC2026]; 2306.02063 [NeurIPS 2023].

MS31B | 11:20-12:40 | Room S2

11:20-11:40 | Chuanfu Xiao

Xiangtan University

Low-rank analysis of the inverse of the discretized Laplace operator

ABSTRACT

Solving high-dimensional partial differential equations often leads to extremely large structured linear systems, for which direct matrix inversion is computationally prohibitive. Tensor representations provide an efficient framework for compressing and manipulating such large-scale operators. A fundamental question is whether the inverse of a structured matrix, arising from the discretization of a differential operator, can still be accurately represented in a low-rank tensor format. In this talk, we investigate the low-rank structure of the inverse of discretized Laplace operator. We prove that it admits an accurate low-rank TT/QT approximation. This result provides both a theoretical explanation for the low-rank behavior of inverse operators and practical guidance for designing efficient numerical algorithms based on tensor representations.

11:40-12:00 | Chupeng Ma

Great Bay University

Multiscale model reduction based on local low-rank approximations

ABSTRACT

I will present a multiscale model reduction method based on local low-rank approximations for elliptic PDEs with heterogeneous coefficients. The low-rank approximations are built from the singular value decomposition of a restriction operator defined on generalized harmonic spaces. Rigorous convergence analysis of the method as well as numerical experiments will be provided.

12:00-12:20 | Fenglei Fan

Cornell

Model Compression via Dynamic System**ABSTRACT**

Recently, the escalating demand for memory and computational resources by large models has presented formidable challenges for their deployment in resource-constrained environments. One prevalent way to serve large models is to develop effective model compression approaches that crop the size of large models while maintaining acceptable performance levels. In this talk, we introduce a novel and general-purpose approach, referred to as hyper-compression, that redefines model compression as a problem of parameter representation. Specifically, we extend the concept of hypernets into what we term a 'hyperfunction'. Then, the hyperfunction is designed based on dynamic systems.

MS22

Learning-Based Scientific Computation: Theory, Algorithms, and Applications

Main organizer	Aiqing Zhu (Department of Mathematics, National University of Singapore)
Co-organizers	Qianxiao Li (Department of Mathematics, National University of Singapore); Yue Zhao (Institute for Functional Intelligent Materials, National University of Singapore)

DESCRIPTION

This mini-symposium focuses on recent advances in learning-based methods for scientific and engineering problems, spanning mathematical foundations, algorithmic developments, and practical applications. A central challenge across many disciplines is how to extract governing laws, predictive models, and efficient computational representations from data while incorporating physical principles and structural constraints. With the rapid growth of observational and simulation data, machine learning is becoming an increasingly important tool for scientific modeling, computation, and discovery. These developments are driving fruitful interactions among machine learning, applied mathematics, computational science, and physical and biological sciences. At the same time, they raise fundamental questions on approximation, generalization, stability, interpretability, and structure preservation, making this active and rapidly developing area of research. This session will highlight both foundational and application-oriented advances in learning-based scientific computation. Topics include data-driven modeling and system identification, operator learning, physics-informed and structure-preserving methods, learning-augmented numerical methods for differential equations, and scientific applications in diverse areas of science and engineering.

MS22 | 11:20-12:40 | Room I1

11:20-11:40 | silu Yan

Great Bay University

Co-authors: Jinchang Feng (Great Bay University); Hong-Kun Zhang (Great Bay University); Yixian Gao (Northeast Normal University); Tiantian Sun (Northeast Normal University); Jian Zu (Northeast Normal University)

Rhythm-ONet: A query-conditioned neural operator for high-fidelity emulation of multiscale rhythm transitions in neurological disorder modeling

ABSTRACT

Mechanistic neural mass models (NMMs) are essential for digital twins in neurological disorders, but their dynamics can vary sharply with synaptic connectivity, making parameter sweeps costly and challenging for standard neural operators due to spectral bias. We propose Rhythm-ONet, a query-conditioned neural operator with a time-conditioned coefficient generator in the branch pathway. Inspired by attention, it dynamically reweights branch features according to query points, while a Fourier-embedded trunk improves reconstruction of multiscale rhythms. Tested on the Jansen-Rit model for Alzheimer's-like activity and the Wendling-Chauvel model for seizure-like dynamics, Rhythm-ONet achieves lower relative L2 error than DeepONet, Fourier-DeepONet, and DeepONet-Bt, with better time-frequency agreement across connectivity regimes. Once trained, it enables rapid mapping of connectivity-dependent rhythm transitions, including rhythm slowing in AD and ictal-like discharges.

11:40-12:00 | Liyao Lyu

University of Science and Technology of China

Learning and Data Assimilation McKean-Vlasov Dynamics from Particle Data

ABSTRACT

Learning interaction laws in collective systems and incorporating partial observations into mean-field dynamics are two closely related challenges. We propose a unified framework that addresses both. First, we introduce a measure-valued neural network (MVNN) that learns measure-dependent interaction (drift) terms directly from particle trajectories, using scalable distribution-to-vector embeddings. We establish well-posedness, propagation of chaos, and universal approximation with quantitative rates under a low-dimensional structure. Second, we develop Multiscale Nudge, a data assimilation method that injects macroscopic observations into microscopic dynamics via a Wasserstein gradient-based nudging term with a tractable particle implementation. Under suitable assumptions, we prove exponential decay of the L^2 error up to a model-misspecification bias.

12:00-12:20 | Peijie Zhou

Peking University

Simulation-Free Dynamic Unbalanced Optimal Transport**ABSTRACT**

The Wasserstein-Fisher-Rao (WFR) metric extends dynamic optimal transport to systems with both displacement and mass variation, but existing solvers are often unstable and costly. We introduce WFR Flow Matching (WFR-FM), a simulation-free method that learns a transport vector field together with a scalar growth rate for birth-death dynamics. We prove that minimizing the WFR-FM objective recovers WFR geodesics. In single-cell applications, WFR-FM reconstructs trajectories involving proliferation and apoptosis, estimates time-dependent growth fields, and supports generative modeling under imbalanced data. Across benchmarks, it improves efficiency, stability, and reconstruction accuracy over existing methods. WFR-FM thus provides a scalable framework for learning continuous dynamics from unbalanced snapshots in which both states and mass evolve.

12:20-12:40 | Zhuoyuan Li

National University of Singapore

Hypothesis-driven construction of mesoscopic dynamics**ABSTRACT**

Traditional scientific modeling typically begins with fixed, instance-wise effective equations and then carries out equation-specific analysis and computation, a procedure that becomes exceptionally challenging in complex applications such as multiscale systems. We propose an alternative paradigm by learning mesoscopic dynamics within a mathematically constrained hypothesis class. Building upon a generalized Onsager principle, we introduce a unified framework encompassing both dissipative and conservative mesoscopic dynamics. We establish uniform and a priori theoretical guarantees, including global well-posedness, asymptotic stability, unique factorization identifiability, and discrete energy dissipation, applicable to all spatio-temporal evolution equations within this hypothesis class prior to all learning stages. We empirically validate that the proposed approach acts as an effective dynamics learner and offers vital interpretable diagnostics of the underlying physics.

MS09

Advances in Computational Mathematics and Machine Learning for Scientific Computing

Main organizer	BingZe Lu (Department of mathematics, National Chung Cheng University)
Co-organizers	Yu-Chen Shu (Department of Mathematics, National Cheng Kung University, Taiwan)

DESCRIPTION

Recent years have witnessed a rapid convergence between computational mathematics and machine learning, leading to new paradigms for scientific computing. This minisymposium aims to highlight recent advances at the interface of numerical analysis, differential equations, integral equations, and modern neural network methodologies, with particular emphasis on learning-based solvers for computational science and engineering problems. One of the primary objectives of this minisymposium is to explore how machine learning-particularly neural networks-can be systematically integrated with modern numerical methods to accelerate, approximate, and enhance classical solvers for scientific computing problems. Rather than treating neural networks as purely black-box models, we emphasize principled integration with structure-aware discretizations and operator-based formulations. Another central objective is to present pioneering computational methodologies for challenging scientific problems. Related topics include algorithmic efficiency, computational effectiveness, scalability on modern hardware architectures, stability and convergence analysis, and rigorous comparisons with established numerical solvers. Through these discussions, we aim to clarify the mathematical foundations, computational trade-offs, and practical implications of learning-enhanced scientific computing. A central theme of this minisymposium is the interplay between conventional numerical methodologies and data-driven approaches. Scientific computing problems typically possess an intrinsic operator structure. Rather than replacing classical methods, we emphasize principled integration that respects underlying mathematical structure. We aim to bring together researchers in numerical analysis, applied mathematics, and machine learning to foster meaningful dialogue and collaboration. The minisymposium seeks to promote deeper integration between mathematical theory and modern data-driven methodologies.

MS09A | 15:50-17:10 | Room H1

15:50-16:10 | Axel Turnquist

Beijing Institute of Mathematical Sciences and Applications

Convergence Theory for Monotone Finite-Difference Schemes Solving Prescribed Jacobian Equations on Unbounded Subsets of $\mathbb{R}^n$

ABSTRACT

Consider two probability measures μ and ν in $\mathbb{R}^n$ with unbounded supports and with density functions f, g and a pushforward map T such that $T_{\#}\mu = \nu$. If T is smooth enough, it satisfies the Jacobian equation $f(x) = g(T(x)) |\det DT(x)|$. In many applications, T is related to the gradient of a so-called potential function u . In many cases of optimal transport and freeform optics problems, $T(x) = F(x, u(x), Du(x))$. In this case, the PDE for u is called a prescribed Jacobian equation (PJE).

We aim to solve PJE with monotone finite-difference methods on unbounded subsets of $\mathbb{R}^n$, where we cut off the problem at a radius $R > 0$. We present explicit convergence rates for the potential function in the quadratic cost optimal transport case as $R \rightarrow \infty$. We then present results on the convergence of monotone discretizations for PJE, given that the potential function u is locally Lipschitz or Hölder continuous.

16:10-16:30 | JUANMING YUAN

Providence University

Particle trajectories in 1D Boussinesq equation

ABSTRACT

In this work, we consider particle trajectories beneath soliton solutions described by the Boussinesq equation, a model for bidirectional, weakly nonlinear, long surface waves. The Boussinesq equation admits many exact soliton solutions. We analyze the particle drift induced by both single-soliton and various two-soliton solutions. Our results provide insight into the Lagrangian behavior of fluid particles under these nonlinear wave fields.

16:30-16:50 | Bingze Lu

National Chung Cheng University

Artifacts of Numerical Integration in Learning Dynamical Systems**ABSTRACT**

When learning a dynamical system from data, you fit a model by minimizing mismatch with observed trajectories - but this requires a numerical integrator, and the choice of integrator shapes what you learn. This talk shows the integrator can corrupt identified dynamics: a damped oscillation can be "learned" as anti-damped and oscillating in the wrong direction, yet still fit the data perfectly. The culprit is the integrator's stability region, which distorts which dynamics appear consistent with observations. The obvious fixes don't help: smaller step sizes or higher-order explicit methods make things worse, since higher-order explicit integrators have larger stability regions reaching further into the "wrong" part of the complex plane. The remedy: the implicit midpoint method, which provably preserves conservative or dissipative structure from discrete data - a principled default even when the only assumption is that the system is autonomous.

16:50-17:10 | Takaharu Yaguchi

Kobe University

Conformal Symplectic Neural Operators for Hamiltonian Partial Differential Equations in Complex Domains**ABSTRACT**

Hamiltonian partial differential equations include the wave equation and the Maxwell equations, and typically describe wave phenomena. To efficiently compute solutions to such equations on complex domains, some techniques for handling domain geometry are required. The Brinkman method is an example of such methods. In this talk, we explain that equations obtained by applying the Brinkman method to the Hamilton partial differential equations possess a conformal symplectic structure. Based on this fact, we propose an operator learning method that preserves this structure.

MS09B | 17:20-18:40 | Room H1**17:20-17:40 | Yu-Chen Shu**

National Cheng Kung University

Neural Initialization and Local Search for Accelerating Digital and GPU Annealers in QUBO Problems**ABSTRACT**

Quadratic unconstrained binary optimization (QUBO) is a common framework for modeling large-scale combinatorial optimization problems in scientific computing, scheduling, manufacturing, and resource allocation. This talk presents a neural initialization and local search strategy for accelerating QUBO solvers based on digital and GPU annealers. From each QUBO matrix, bit-wise structural features are extracted and used by a neural network to predict variable-wise probabilities. Candidate binary solutions are generated by thresholding and Bernoulli sampling, refined by local search, and used as warm-starts for annealing. Experiments on random QUBO matrices and synthetic subset-sum instances show that the proposed approach reduces solve time while maintaining final objective quality.

17:40-18:00 | Ming Cheng Shiue

National Yang Ming Chiao Tung University

Multivariate Müntz-Szász Neural Networks for Learning with Adaptive Power-Law Bases**ABSTRACT**

Building upon the Müntz-Szász Network (MSN) in the literature for univariate function approximation, we propose Multivariate Müntz-Szász Neural Networks (MMSNs) for learning high-dimensional functions. The proposed architecture employs adaptive multivariate power-law basis functions with trainable exponents, providing an efficient and interpretable representation of multiscale and anisotropic features. We present the mathematical foundation of MMSNs together with numerical experiments demonstrating their approximation accuracy and effectiveness for high-dimensional function learning.

18:00-18:20 | Isao Ishikawa

Kyoto University

Finite-dimensional approximation of push-forwards via jets and data**ABSTRACT**

Jets are canonical local objects, and they provide finite-dimensional models for operators induced by analytic maps, in particular push-forwards. In this talk, I will explain how this yields finite-dimensional approximations of push-forwards, explicit error bounds, and reconstruction of analytic vector fields from data from a dynamical system. This provides a novel mathematical framework for data-driven analysis of dynamical systems, including Koopman-type approximations from sampled data. The main point is that approximation and reconstruction both arise from the same jet structure. I will describe how local jet information can be used to build finite-dimensional models, quantify their accuracy, and recover analytic dynamics from observations. Time permitting, I will briefly comment on how the same viewpoint also leads to local dynamical restrictions through operator-theoretic properties.

MS28

Geometric Shape Generation (I)

Main organizer	Yoshiki Jikumaru (Toyo University)
Co-organizers	Taiki Yamada (Shimane University)

DESCRIPTION

Geometric shape generation plays a central role in many areas of applied mathematics, computer science, and engineering, including computational geometry, architectural design, robotics, and digital fabrication. Recent developments in discrete differential geometry and geometric analysis have provided powerful mathematical frameworks for modeling, analyzing, and generating complex geometric structures. In particular, curvature-based methods, integrable systems, and discrete (differential) geometric techniques have enabled new approaches to shape design that combine rigorous mathematical theory with practical computational tools. This mini-symposium focuses on recent advances in geometric shape generation from both theoretical and applied perspectives. The scope includes discrete curvature methods, integrable geometric systems, discrete differential geometry, and discrete geometric analysis, as well as their applications to robotic motion planning, deployable structures, and architectural geometry. By bringing together researchers from mathematics, engineering, and computational design, the session aims to highlight how geometric theory can inform practical shape generation problems and how real-world constraints can motivate new mathematical developments. It will feature two sessions with a total of eight speakers. The objectives of the mini-symposium are threefold. First, it aims to provide a forum for exchanging recent research results on geometric methods for shape generation. Second, it seeks to foster interdisciplinary dialogue between communities working on geometry, mechanics, robotics, and structural design. Finally, the session aims to identify emerging research directions at the intersection of discrete geometry, integrable systems, and engineering applications, thereby strengthening collaboration between theoretical and applied researchers.

MS28A | 15:50-17:10 | Room H3

15:50-16:10 | Taiki Yamada

Shimane University

Discrete curvature analysis of the multiplex network

ABSTRACT

Network analysis increasingly requires tools beyond classical centrality, especially for multilayer systems where entities interact through several types of connections. This talk is based on my paper that extends Forman curvature, a combinatorial analogue of Ricci curvature, to multiplex graphs. After introducing a compile-graph framework for doubly-weighted multilayer networks, I defines Forman curvature for both intra-layer and inter-layer edges, and establishes explicit upper and lower bounds. A key invariant, the comprehensive evaluation of a vertex, aggregates inter-layer curvature into a scalar that complements classical centrality by capturing how a node's structural role varies across layers. A three-step algorithm identifies such layer-dependent vertices, validated on Erdős-Rényi compile graphs. Classification experiments further show that curvature-based descriptors achieve high accuracy and combine effectively with graph kernels.

16:10-16:30 | Kentaro Hayakawa

College of Industrial Technology, Nihon University

Co-authors: Takashi Maekawa (Waseda Research Institute for Science and Engineering); Makoto Ohsaki (College of Science and Engineering, Ritsumeikan University)

Optimization Approach for Generating Developable or Nearly Developable Strips Forming Spatially Curved Beams of Architectural Surfaces

ABSTRACT

Geometric and structural design of supporting frames for architectural doubly curved free-form surfaces has been intensively studied, yet balancing geometric complexity and manufacturability remains challenging. While the majority of research and implementations rely on straight or planar curved structural elements, we propose a method for constructing spatially curved beams with developable or nearly developable strips, enhancing both aesthetic quality and structural consistency. Our approach enables the fabrication of spatially curved beams through standard bending processes, such as rolling or press bending, without twisting. An optimization method is introduced to generate developable strips forming beam geometries while preserving near-orthogonality between ruling directions and directrix curves. Continuity of beam surface normals and ruling directions is also ensured at intersections, improving both structural integrity and visual coherence.

16:30-16:50 | Yoshiki Jikumaru

Toyo University

On the governing equations of membrane O surfaces

ABSTRACT

Shapes that utilize curvature to efficiently transmit stress play a crucial role in fields such as shell structures and membrane structures in architectural surface design. Rogers and Schief demonstrated that shapes in which a constant load acts in the normal direction of the membrane, and the principal curvature lines and principal stress lines coincide and are in equilibrium, form an integrable system known as an O surface. A representative example is the constant mean curvature surface, known as a mathematical model of a soap bubble that achieves isotropic and homogeneous stress state for the pressure. In this talk, we show the system of differential equations governing membrane O surfaces and demonstrate that they contain known 'solitonic' equations and constitute a truly 'good' system of equations.

16:50-17:10 | Wayne Rossman

Kobe University

A discretization principle via permutability

ABSTRACT

Many classes of surfaces have geometric characterizations, including special coordinate properties or curvature properties, that admit a description using integrable systems. The viewpoint of discrete differential geometry often hovers around the definition of integrable-systems-based discrete versions of these surfaces, reflecting the various coordinate and curvature properties. Such discretization has been carried out in a wide variety of cases, including, for example, pseudospherical surfaces, constant mean curvature surfaces, isothermic surfaces, or Ω -surfaces. Here we consider the case of discrete isothermic surfaces arising from the permutability of Darboux transformations of smooth isothermic surfaces so that they are circular nets, and we show the following: permutability of transforms of smooth surfaces with particular characteristics leads to discrete surfaces with discrete analogues of the same characteristics. This is joint work with J. Cho and M. Pember.

MS28B | 17:20-18:40 | Room H3

17:20-17:40 | Shun Kumagai

Hachinohe Institute of Technology

Co-authors: Kenji Kajiura (Kyushu University)

Geometry of aesthetic curves based on self-affinity in Klein geometries

ABSTRACT

Log-Aesthetic Curve (LAC) is a family of curves proposed by Harada et al. in 1995 as a reference for shapes in industrial design; while offering limited controllability, it was intended as a consistent shape element. The consistency is formulated as invariance under a one-parameter family of affine deformations of its Euclidean Frenet frame, called "self-affinity". Its variation in affine geometry yields a special case of Klein-Lie W-curve that includes the quadratic curve, power function graph, logarithmic spiral, etc. In this talk, we present the result that the LAC meets the "affine W-curve" in the framework of Möbius geometry based on self-affinity, and discuss deformations of them.

17:40-18:00 | Kazuki Hayashi

Kyoto University

Design and fabrication workflow for kagome gridshells via curvature optimization and curve partitioning

ABSTRACT

Kagome geometric patterns are widely used for design, valued for both their aesthetic appeal and structural stability. However, design processes for large-scale Kagome structures that account for surface rigidity, member strength, and fabricability remain underdeveloped. To address this, we present a novel design workflow for Kagome gridshells. First, the vertical equilibrium of a flat triangulated mesh is determined via the force density method, and a Kagome pattern is generated through mid-edge subdivision. Next, the equilibrium configuration is obtained using a surface-constrained B-spline curve optimization algorithm that minimizes discrete Darboux-frame elastic energy through finite-difference gradient descent. Furthermore, we propose an algorithm to partition the grid curves into three groups, considering singularities to avoid internal intersections. For two groups, integrating a scissors mechanism enables flat-plane joint pre-assembly, significantly simplifying fabrication.

18:00-18:20 | Noriyasu Iwamoto

Shinshu University

Low-Dimensional Shape Modeling of Robotic Surfaces**ABSTRACT**

Robotic control requires prediction of the robot's state from actuator inputs and estimation from sensor measurements. Both rely on kinematic models that must represent shape accurately and remain efficient enough for real-time use. This talk focuses on robotic surfaces, thin sheet-like robots whose many spatially distributed degrees of freedom make modeling difficult. Although finite element simulations and boundary-value methods can describe deformation in detail, their computational cost limits their use in control. We therefore explore low-dimensional models that exploit surface geometry to represent shape with few parameters. Two robotic surfaces developed by the speaker are presented: a sheet-like robot composed of interconnected frustum-shaped actuators modeled by conformal mapping, and a boundary-actuated robotic surface using a soap film modeled as a minimal surface. A piecewise constant-mean-curvature model and its applications to shape design and control are also introduced.

UPDATED - New talk added**18:20-18:40 | Yohei Yokosuka**

Kagoshima University

Equilibrium Surfaces of Pneumatic Structures Based on Willmore Surfaces**ABSTRACT**

This study focuses on the geometric analysis and stress-strain analysis of Willmore surfaces. In tension structures, particularly membrane structures, there is a very close relationship with geometric quantities. It is well known that minimal surfaces distribute uniform tension stress, and numerous numerical analysis methods have been proposed to find stationary points of functionals based on geometric quantities. These methods have yielded significant results in determining the initial surface geometry of tension structures.

Although the curved surfaces of expression and methods are different, many of these methods employ area functionals or area functionals with additional constraints. On the other hand, it has long been known in the fields of geometry and mathematics that minimal surfaces can be obtained by finding the critical points of functionals based on geometric quantities. In this paper, we consider geometric functionals for membrane surfaces that are not uniform tension stress.

MS39

PINNs and AI Agents for Engineering Applications

Main organizer	Hyunseok Oh (GIST)
Co-organizers	Jae-Hyuk Lim (Kyunghee University); Seungchul Lee (KAIST)

DESCRIPTION

This mini-symposium explores the integration of Physics-Informed Neural Networks (PINNs) and AI Agents as core technologies for innovating structural analysis, virtual sensing, simulation acceleration, and system diagnosis. As modern engineering challenges increase in complexity, existing numerical methods often struggle to provide real-time responsiveness and computational efficiency. Consequently, this session provides an in-depth discussion on combining PINNs—which embed physical laws directly into deep learning architectures to ensure physical consistency—with AI Agents capable of autonomous reasoning and executing complex engineering workflows. From a technical perspective, PINNs maintain high predictive reliability even with sparse data by incorporating partial differential equations (PDEs) as constraints within the loss function. Simultaneously, AI Agents and agentic workflows offer the autonomy to invoke these physics-based models, iteratively optimize design parameters, and establish multi-step plans based on large-scale engineering data. The synergy between these two technologies transcends purely data-driven AI, forming the foundation for a next-generation computational framework that merges engineering domain knowledge with autonomous decision-making capabilities.

MS39 | 15:50-17:10 | Room S1

15:50-16:06 | Seungchul Lee

Korea Advanced Institute of Science and Technology

Geometry-Aware Spatially-Adaptive Operator Learning for Accelerated PDE Simulation

ABSTRACT

Operator learning accelerates PDE simulations, but handling geometry variations remains challenging due to localized boundary phenomena that reshape solution fields in spatially non-uniform ways. Existing geometry-aware operators encode shape into a single global descriptor injected at one trunk layer, limiting their ability to capture spatially varying geometric effects near boundaries. We propose GASA-DeepONet, which embeds geometric information spatially and at every trunk layer. A convolutional encoder-decoder produces a spatially resolved basis over the output grid, while a SPADE-inspired module applies position-dependent modulation at each layer. Validated on acoustic wave scattering and jet-impingement cooling, GASA-DeepONet consistently outperforms existing baselines, especially near boundaries with sharp gradients. Combined with CMA-ES, it also enables efficient reliability-based shape optimization under geometric uncertainty.

16:06-16:22 | Jae Lim

Kyung Hee University

Co-authors: Jeong-Hoon Park (Jeonbuk National University); Hong-Kyun Noh (KAIST); Ah-Jeong Seong (Kyung Hee University)

Sparse Sensing-Guided Physics-Informed Operator for Real-Time Real-to-Sim Visualization of High-Frequency Vibration Fields

ABSTRACT

This study proposes a sparse sensing-guided physics-informed operator for real-time Real-to-Sim visualization of high-frequency vibration fields from sparse sensor measurements. The proposed framework learns a sensor-to-field operator that maps limited physical sensor signals to simulation-like full-field vibration responses. Ordered sensor histories sampled on a uniform temporal grid are used as an implicit representation of time, enabling full-field reconstruction without explicitly inputting the physical time coordinate. During training, fixed-time-increment numerical differentiation is used to construct physics residuals and impose temporal consistency. To enhance the representation of high-frequency responses, Fourier feature embedding and spectral proper orthogonal decomposition (SPOD)-based modal features are incorporated. The method is evaluated in terms of reconstruction accuracy, phase consistency, noise robustness, and extrapolation stability.

16:22-16:38 | Jeong-Hoon Park

Jeonbuk National University

Co-authors: Jae Hyuk Lim (Kyung Hee University)

A Physics-Informed Machine Learning Framework for DIC-Based Physical Field Reconstruction with Robust Data Loss Strategies**ABSTRACT**

This study proposes a physics-informed machine learning framework for mechanically consistent reconstruction of noisy and partially reliable DIC-based displacement fields. The framework reconstructs full-field displacements from spatial coordinates and selected DIC measurements while enforcing quasi-static linear elasticity and boundary conditions. Robust data-loss strategies are introduced to address large residuals and spatially nonuniform measurement reliability. Strain and stress fields are subsequently derived using automatic differentiation and the linear elastic constitutive relation. The method was evaluated using two noisy numerical DIC-like examples and an experimental crack-growth DIC dataset. The numerical examples showed good agreement with clean finite element references despite 10% Gaussian noise, while the experimental application demonstrated that the framework can regularize noisy measured displacement fields and recover mechanically plausible derivative fields.

16:38-16:54 | Minseok Choi

GIST

Co-authors: Donghyun Lee (KIMM); Hyunseok Oh (GIST)

Physics-Informed Neural Network for Journal Bearing Defect Severity Quantification Using Temperature Sensor Measurements**ABSTRACT**

Tilting pad journal bearings are critical components in rotating machinery whose wear progression directly affects system reliability and remaining useful life. Real-time wear quantification is challenging due to limited accessibility, and traditional data-driven approaches yield only scalar severity estimates without physical consistency. This work develops a Verification-Conditioned Physics-Informed Neural Network (VC-PINN) to predict the wear-depth landscape from pad-temperature measurements. The Reynolds lubrication and thermohydrodynamic equations serve as physics constraints, with multi-location pad temperatures as data constraints. The wear depth is parameterized with five thermohydrodynamic variables as learnable outputs, trained via a two-phase verification-and-validation strategy with an output-level bias-correction estimator. The approach achieves consistent accuracy and noise robustness, providing a foundation for digital twin and remaining useful life prediction.

16:54-17:10 | Jong Moon Ha

Ajou University

Co-authors: Dohun Lee (Ajou University); Minhyuk Cho (Ajou University); Inwhan Jung (Ajou University)

PHM Foundation Models and Multimodal Diagnostic Agents for Overcoming the Interpretation Barrier of High-Frequency Time-Series Signals**ABSTRACT**

In rotating-machinery PHM, high-frequency vibration holds the richest health data, yet foundation models and autonomous agents pretrained on language and vision cannot interpret raw waveforms—a modality gap. We propose four complementary ways to make such signals tractable for these models. First, a diagnostic agent couples multi-level signal-processing tools with multimodal reasoning, autonomously deciding when further analysis is needed and synthesizing retrieval-augmented, physics-grounded evidence into a report. Second, a PHM foundation model pretrained on large-scale time-series enables zero-shot fault classification. Third, an interpretation agent describes signal patterns in natural language as a backbone for the diagnostic agent. Fourth, vibration signals are rendered into images where faults become visually salient, diagnosed via a vision-language model (VLM). Components are validated on benchmarks including CWRU, matching expert-based reliability.

MS30

Non-linear Wave Phenomena: From Quantum Interactions to Stochastic and Transonic Flows

Main organizer	Ying-Chieh Lin (Department of Applied Mathematics, National University of Kaohsiung)
Co-organizers	Shih-Wei Chou (Department of Financial Engineering and Actuarial Mathematics, Soochow University)

DESCRIPTION

The proposed mini-symposium brings together four talks that explore how non-linear interactions shape wave behaviour in dispersive and hyperbolic partial differential equations, ranging from microscopic quantum systems to macroscopic fluid dynamics under uncertainty. Although the physical scales differ, all contributions employ modern analytical or variational techniques-often in combination with carefully designed numerical schemes-to uncover existence, multiplicity and stability of solutions that exhibit concentration, coupling or dissipation effects invisible to linear theory.

We open with coupled Schrödinger equations that model many-body quantum states. The first two speakers present complementary perspectives: the multiplicity of vector solutions generated by three-wave interactions, and positive semiclassical states in a Hartree-Fock type system with interspecies repulsion. Together they highlight how the geometry of the potential landscape and the strength of inter-component coupling determine where and how wave packets concentrate as the semiclassical parameter tends to zero.

The focus then shifts to conservation-law systems driven by stochastic or geometric forcing. The third talk studies shallow-water equations perturbed by fractional Brownian noise and irregular bed topography. A Hurst-dependent “regularisation by noise” mechanism, proved via a Glimm-type scheme, delineates the range $1/4 < H \leq 1/2$ required for global entropy solutions. Numerical experiments confirm the theoretical interaction estimates and demonstrate the robustness of the algorithm.

The closing talk addresses Fanno-Rayleigh flow in time-dependent nozzles. By introducing a nonlinear characteristic dilation into an extended Glimm-Goodman framework, the speaker derives sharp thresholds that govern the onset of transonic entropy solutions and supplies explicit lower bounds for the Mach number and power flux. The results reveal a quantitative interplay between friction, heat transfer and duct geometry.

Taken together, the session emphasises three unifying themes:

1. Variational and entropy methods tailored to strongly coupled, inhomogeneous or noisy environments;
2. Thresholds and concentration mechanisms that separate qualitatively different flow or state regimes;
3. Hybrid analytical-numerical frameworks that validate theory and guide applications, from quantum chemistry to geophysical hydraulics and aerodynamics.

The diversity of equations and techniques will stimulate cross-disciplinary discussion among analysts, probabilists and computational scientists interested in the frontier of non-linear wave phenomena.

MS30 | 15:50-17:10 | Room S2

15:50-16:06 | Tomoharu Kinoshita

Waseda University

On the existence and the multiplicity of vector solutions to nonlinear Schrödinger equations with three wave interaction

ABSTRACT

In this talk, I would like to talk about the nonlinear Schrödinger equations with three wave interaction. For large interaction, Pomponio (2010) showed that there exists a ground state which is a vector solution. On the other hand, for small interaction the existence of vector solutions is not even known. The purpose of this talk is to establish the existence and the multiplicity of vector solutions of the system for small and large three wave interaction.

16:06-16:22 | Ying-Chieh Lin

National University of Kaohsiung

Semiclassical States in Hartree-Fock Type Systems with Interspecies Repulsion

ABSTRACT

In this talk, we consider a class of Hartree-Fock type systems consisting of two coupled nonlinear Schrödinger equations with Coulomb interaction terms. We focus on the regime where the interaction between different components is repulsive.

We establish the existence and multiplicity of positive semiclassical solutions and analyze how these solutions are influenced by the structure of the underlying potential functions, in particular their minima. Special attention is devoted to the concentration behavior of solutions in the semiclassical limit, where we identify the locations and profiles of concentrating states.

In addition, we discuss the variational characterization of these solutions and examine whether they correspond to least energy states. The results reveal a rich interplay between repulsive interactions and concentration phenomena, leading to qualitative differences from the attractive case.

16:22-16:38 | □ □ □

National Kaohsiung Normal University

The System of Nonlinear Schrodinger Equations with Linear Coupling

ABSTRACT

In this talk, we will undertake a comprehensive study for a system of nonlinear Schrodinger equations with linear coupling. The type of systems arises in the study of nonlinear optics. We will address questions related to local and global well-posedness, finite time blowup, and scattering in the energy space.

16:38-16:54 | ShihWei Chou

Soochow University

Global Transonic Entropy Solutions of Fanno-Rayleigh Flow Through Time Dependent Nozzles

ABSTRACT

In this talk we investigate the initial boundary value problem for the one-dimensional compressible Euler equations with friction and heat transfer effect, a model describing Fanno-Rayleigh flow in a time dependent, variable area nozzle. We identify a sharp threshold expressed in terms of the friction coefficient and the geometric properties of the duct that admit the existence of transonic solutions. In addition, we derive explicit lower bounds for both the Mach number and the power flux of the gas, through a nonlinear dilation of the characteristic fields; these bounds allow us to determine whether a feasible solution remains purely supersonic or make a transition to transonic flow. To conduct our investigation, an innovative variant of the generalized Glimm scheme is developed.

16:54-17:10 | Po-Chih Huang

National Chung Cheng University

Global Existence for Stochastic Shallow Water Equations with irregular topography and Hurst-dependent Noise

ABSTRACT

In this talk, we consider initial-boundary value problem for shallow water model with stochastic source term. We propose a generalized Glimm scheme. We construct approximate solutions for both interior and boundary Riemann problems, carefully estimating the corresponding residuals to ensure consistency. By introducing a modified Glimm functional that accounts for wave interactions and stochastic perturbations, we prove that the total variation of the approximate solutions remains uniformly bounded, yielding the global existence of entropy solutions. Furthermore, by exploring the evolutionary dynamics of the stochastic waves, we derive physically meaningful dissipative initial and boundary conditions that effectively control non-physical oscillations.

MS17

Verified and High-Performance Numerical Computation: Nonlinear Problems, Iterative Methods, and Matrix Multiplication Emulation

Main organizer Katsuhisa Ozaki (Shibaura Institute of Technology)

DESCRIPTION

This minisymposium focuses on recent advances in numerical computation that address both mathematical reliability and high performance on modern computing architectures. The proposed talks will cover three closely related themes: verified numerical computation, iterative methods for solving systems of linear equations, and emulation techniques for matrix multiplication. Verified numerical computation plays an essential role in scientific and engineering applications where reliability, reproducibility, and mathematically rigorous results are required. In addition to linear algebraic problems, this area also includes nonlinear topics such as nonlinear equations, fixed-point problems, and related computational frameworks with guaranteed accuracy. Recent developments in interval methods, rigorous error analysis, and verification techniques have expanded the applicability of such methods to a broader class of problems while maintaining practical usefulness. Iterative methods for large-scale systems of linear equations remain a central topic in scientific computing. Their efficiency, scalability, and robustness are crucial in many applications, especially when combined with modern preconditioning strategies and mixed-precision techniques. This minisymposium will include both theoretical and practical aspects of iterative solvers, with emphasis on convergence behavior, numerical stability, and efficient implementation on modern hardware. Another important direction is matrix multiplication emulation, which seeks to exploit the high throughput of low-precision hardware while delivering results of higher accuracy. This direction is particularly relevant in the post-Moore era, where the performance gap between low-precision and high-precision arithmetic continues to widen. Emulation methods based on arithmetic decomposition, residue systems, and related algorithmic ideas provide promising approaches for accelerating core numerical kernels without sacrificing computational quality. By bringing together these topics, the minisymposium aims to highlight a common objective: achieving both speed and reliability in modern numerical computation. The session will promote interactions among researchers in numerical analysis, scientific computing, high-performance computing, and verified computation, and is expected to stimulate discussion on new algorithms, theoretical foundations, and practical implementations for next-generation computational science.

MS17 | 17:20-18:40 | Room I1

17:20-17:40 | Katsuhisa Ozaki

Shibaura Institute of Technology

Co-authors: Yuki Uchino (RIKEN); Takeshi Terao (Waseda University); Toshiyuki Imamura (RIKEN)

Matrix Factorizations Using Preconditioning and Ozaki Schemes

ABSTRACT

This talk discusses Ozaki schemes for high-precision matrix multiplication and their applications to numerical linear algebra on NVIDIA GPUs. Motivated by the widening performance gap between low-precision Tensor Core operations and native FP64 arithmetic, we show how emulated matrix multiplication can exploit fast INT8 Tensor Cores to obtain FP64-like accuracy. We introduce the idea of repeatedly using high-speed GEMM engines and compare two approaches: the slice-based Ozaki-I scheme and the CRT-based Ozaki-II scheme. Benchmark results demonstrate the potential performance of these schemes for large DGEMM problems. Finally, we discuss preconditioning strategies for Cholesky, LU, and QR factorizations, where preconditioners are used to avoid inefficient products of tall-and-skinny and short-and-wide matrices and to expose larger GEMM-dominant computations.

17:40-18:00 | Yuki Uchino

RIKEN Center for Computational Science

Co-authors: Katsuhisa Ozaki (Shibaura Institute of Technology); Toshiyuki Imamura (RIKEN Center for Computational Science)

A Library for Emulating BLAS-like Matrix Operations Using the Ozaki-II Scheme

ABSTRACT

Modern computing architectures feature low-precision matrix multiplication units that achieve substantially higher throughput than their high-precision counterparts. Motivated by this architectural trend, we proposed the Ozaki-II scheme, a high-throughput emulation method for high-precision matrix multiplication using low-precision matrix multiplication units. In this talk, we introduce GEMMul8, a library that provides emulation of BLAS-like matrix operations based on the Ozaki-II scheme. We also present performance evaluations on modern GPUs of the proposed library.

18:00-18:20 | Kensuke Aihara

Tokyo City University

Co-authors: Akira Imakura (University of Tsukuba); Keiichi Morikuni (University of Tsukuba)

Shifted Bi-CG method combined with the cross-interactive residual smoothing**ABSTRACT**

We consider solving shifted linear systems with a large sparse nonsymmetric matrix using Lanczos-type iterative methods. Cross-interactive residual smoothing (CIRS) is an effective technique for obtaining a smooth convergence behavior of residual norms, and results in a smaller residual gap (the difference between the recursively updated residual and the explicitly computed residual), when solving the standard single linear systems. In this talk, we propose applying CIRS to the shifted bi-conjugate gradient (Bi-CG) method. Several implementations of combining CIRS with the seed and shifted parts of algorithms are presented, and their computational efficiency and the residual gap are evaluated through numerical experiments.

18:20-18:40 | Akitoshi Takayasu

University of Tsukuba

An improved scheme for rigorous integration of semilinear parabolic PDEs**ABSTRACT**

In this talk, we present a rigorous integrator for the study of initial and boundary value problems for semilinear parabolic PDEs. Our method is based on a non-autonomous semigroup approach, in which the solution operator of the linearized PDE along a numerically computed time-dependent approximate solution is rigorously controlled. In particular, we introduce a multi-stepping scheme based on a new construction of the multi-step propagator via direct backward iteration, allowing rigorous integration over much longer time intervals. For each time step, the dynamics are decomposed into a signed finite-dimensional bare propagator and a finite-tail coupling correction. The bare propagators are composed at the signed matrix level, preserving cancellation effects and significantly reducing the wrapping effect. As a result, the proposed method enables long-time rigorous integration of the Ohta-Kawasaki equation. This is joint work with Jean-Philippe Lessard (McGill University).

MS26

Bridging AI and Scientific Computing

Main organizer	Cheng Yuan (Wuhan University)
Co-organizers	Lican Kang (Wuhan University); Yuling Jiao (Wuhan University)

DESCRIPTION

The synergy between artificial intelligence and classical numerical methods is fostering a dynamic new paradigm in computational science. This mini-symposium explores the "collision and convergence" of these two worlds, highlighting the transformative interaction between deep learning and first-principles modeling. Discussion topics encompass a broad spectrum of research-from multi-scale modeling and quasicrystal calculations to DL-based molecular dynamics and data assimilation. We focus on how AI can transcend long-standing computational bottlenecks while preserving the mathematical rigor of classical solvers. By facilitating this cross-disciplinary dialogue, the symposium seeks to define robust, hybrid strategies for the next generation of scientific discovery.

MS26 | 17:20-18:40 | Room S1

17:20-17:36 | Yanming Lai

The Hong Kong Polytechnic University

Standard Transformers Achieve the Minimax Rate in Nonparametric Regression with $C^{\{s, \lambda\}}$ Targets

ABSTRACT

The tremendous success of Transformer models in fields such as large language models and computer vision necessitates a rigorous theoretical investigation. In this work, we show that standard Transformers can approximate Hölder functions $C^{\{s, \lambda\}}([0, 1]^d)$ with arbitrary precision. Building upon this approximation result, we demonstrate that standard Transformers achieve the minimax optimal rate in nonparametric regression for Hölder target functions. It is worth mentioning that, by introducing two metrics: the size tuple and the dimension vector, we provide a fine-grained characterization of Transformer structures, which facilitates future research on the generalization and optimization errors of Transformers with different structures. These findings provide theoretical justification for the powerful capabilities of Transformer models.

17:36-17:52 | Zhao Ding

Hong Kong Polytechnic University

Score-Based Sequential Langevin Sampling for Data Assimilation

ABSTRACT

This talk introduces score-based sequential Langevin sampling (SSLS), an approach to nonlinear data assimilation within a recursive Bayesian filtering framework. It decomposes the assimilation process into alternating prediction and update steps, using dynamic models for state prediction and incorporating observational data via score-based Langevin Monte Carlo during the updates. Theoretically, we establish convergence guarantees for SSLS in total variation distance, yielding concrete insights into the algorithm's error behavior with respect to key hyperparameters. Crucially, our derived error bounds demonstrate the asymptotic stability of SSLS, guaranteeing that local posterior sampling errors do not accumulate indefinitely over time. Numerical experiments across challenging scenarios, including high-dimensional systems, strong nonlinearity, and sparse observations, highlight the robust performance of the proposed method.

17:52-18:08 | CHEN CHEN

Shanghai Jiao Tong University

Learning Arbitrary Long-Range Tails for MLIPs with SOG-Net

ABSTRACT

Long-range (LR) interactions remain a critical bottleneck for machine-learning interatomic potentials (MLIPs) due to their non-local and slowly decaying nature. We present a sum-of-Gaussians neural network (SOG-Net), a lightweight and modular framework that learns general LR tails directly from energy/force data without assuming a predefined decay exponent. The architecture connects local atomic descriptors to multidimensional latent variables and applies trainable sum-of-Gaussians multipliers in reciprocal space, evaluated via nonuniform fast Fourier transforms at near-linear cost. This design adaptively captures arbitrary LR behaviors and is backend-agnostic, seamlessly integrating with short-range descriptors such as DP, CACE, and NEP. Extensive benchmarks across diverse systems-from molecular dimers and molten salts to electrolytes and ferroic interfaces-show that NEP-SOG consistently outperforms both purely local and Ewald-based models.

18:08-18:24 | Shifeng Li

Mathematics and Statistics College of Chengdu University of Technology

Numerical Methods and Analysis of Computing Quasiperiodic Systems**ABSTRACT**

Quasiperiodic systems are important space-filling ordered structures, without decay and translational invariance. How to solve quasiperiodic systems accurately and efficiently is of great challenge. A useful approach, the projection method (PM) [J. Comput. Phys. , 256: 428, 2014], has been proposed to compute quasiperiodic systems. However, there is a lack of theoretical analysis of PM. In this report, we present a rigorous convergence analysis of the PM by establishing a mathematical framework of quasiperiodic functions and their high-dimensional periodic functions. We also give a theoretical analysis of the quasiperiodic spectral method (QSM) based on this framework. Moreover, we investigate the accuracy and efficiency of PM, QSM and periodic approximation method in solving the linear time-dependent quasiperiodic Schrödinger equation.

MS11

Statistical Learning for Inverse Problem: Methodologies and Applications

Main organizer	Hongqiao Wang (Central South University)
Co-organizers	Qiuqi Li (Hunan University); Xiang Sun (Ocean University of China)

DESCRIPTION

This minisymposium focuses on the integration of statistical learning techniques for solving inverse problems, which arise in a wide range of scientific and engineering applications, including medical imaging, ocean science, fluid dynamics, and electromagnetics. Inverse problems are often ill-posed, meaning that solutions may be non-unique or unstable with respect to data perturbations, posing significant challenges for traditional numerical methods. These classical approaches are typically computationally expensive and may lack robustness in the presence of noise, model uncertainty, or limited data.

In recent years, statistical learning has emerged as a powerful framework for addressing these challenges by incorporating data-driven methodologies. Techniques such as deep learning, Bayesian inference, and probabilistic modeling enable more stable, efficient, and robust reconstruction and inference. These approaches not only improve predictive performance but also provide mechanisms for uncertainty quantification and model adaptation.

This minisymposium aims to bring together researchers and practitioners working at the intersection of statistical learning and inverse problems to present recent advances, share practical insights, and discuss emerging challenges. Topics of interest include, but are not limited to, learning-based inverse solvers, data-driven regularization, uncertainty quantification, and real-world applications. The symposium seeks to highlight the critical role of statistical methodologies in enhancing the accuracy, efficiency, and reliability of inverse problem solutions, thereby fostering innovation across diverse application domains.

MS11 | 17:20-18:40 | Room S2

17:20-17:36 | Yuanhong Chen

Qingdao University of Science and Technology

Co-authors: Yifan Lin (Nanjing Tech University); Xiang Sun (Ocean University of China); Chunxin Yuan (Ocean University of China); Zhen Gao (Ocean University of China)

Tensor decomposition-based neural operator with dynamic mode decomposition for parameterized time-dependent problems

ABSTRACT

DeepONets have gained attention for modeling PDEs but often fail to accurately predict solutions outside the training time interval due to poor extrapolation. To address this, we propose TDMD-DeepONet, a novel framework combining tensor train decomposition (TTD) and dynamic mode decomposition (DMD). We first show the mathematical consistency between TTD and DeepONet. TTD is applied to a higher-order tensor of spatiotemporal snapshots across parameter values, yielding parameter-, space-, and time-dependent cores. DMD then models the evolution of the time core, which together with the space cores forms the trunk net. The branch net is a neural network taking parameters as inputs, and its outputs are merged with the trunk net for prediction. We further propose ETDMD-DeepONet, which adds a linear layer to the branch net, taking projected initial conditions as input. Numerical examples show that both proposed methods outperform standard DeepONet in forecasting accuracy.

17:36-17:52 | YUMING BA

Guangdong Polytechnic Normal University

A sensitivity analysis-based variable-separation method for eigenvalue problems with random inputs

ABSTRACT

In this presentation, we present a Variable-separation (VS) method based on sensitivity analysis for solving eigenvalue problems with random inputs. The method employs an offline-online strategy. During the offline stage, deterministic functions are precomputed for a training set and stored, then repeatedly used for parametric eigenvalue problems (PEVPs) with new parameters. In applications, small parameter variations can cause dramatic changes in the eigenvalues and eigenvectors. Therefore, a sensitivity analysis is essential to ensure its effectiveness. For low-sensitive regions, only a single global VS model is required. For highly sensitive regions, the parameter domain is divided into several subregions, and multiple local VS models are constructed. Furthermore, the Grassmann distance of eigenspaces is used to evaluate the performance of the proposed method. Finally, we apply the proposed method to a parametric matrix based on Karhunen-Loève expansion.

17:52-18:08 | Haibo Li

Huazhong University of Science and Technology

Data-adaptive RKHS regularization for learning convolution kernels**ABSTRACT**

Learning convolution kernels in operators from data arises in numerous applications and represents an ill-posed inverse problem. In this talk, I will present a Data-Adaptive RKHS (DA-RKHS) regularization framework for learning convolution kernels from data. We show that the input data and forward operator themselves induce a data-adaptive RKHS, and there is a finite set of automatic basis functions to represent the estimators in the DA-RKHS when the observation data is discrete and finite. We propose Tikhonov regularization, iterative regularization, and divide-and-conquer methods for small, large, and huge data, respectively. Theoretical results show that the DA-RKHS estimator can achieve optimal minimax convergence rate under certain source conditions. Numerical experiments confirm that our automatic RKHS regularization outperforms standard Gaussian process methods with preselected kernels.

18:08-18:24 | Xiaomin Wang

Yonsei University

Co-authors: Jung-Il Choi (Yonsei University)

Non-Intrusive POD-ME-gPC Reduced-Order Modeling for Parameterized Nonlinear Dynamical Systems**ABSTRACT**

We propose a non-intrusive reduced-order modelling framework for uncertainty quantification and surrogate evaluation in parameterized nonlinear systems. The method combines two-stage Proper Orthogonal Decomposition (POD) with adaptive Multi-Element generalized Polynomial Chaos (ME-gPC). POD extracts low-dimensional spatial and temporal structures from full-order snapshots, while ME-gPC approximates the parameter-dependent coefficients by local polynomial expansions on an adaptively partitioned stochastic space. This avoids the global smoothness assumption of standard POD-PCE and improves robustness for parameter-sensitive dynamics. The framework is tested on the Kraichnan-Orszag system, stochastic advection-diffusion, flow past a circular cylinder, and a flexible flapping filament. Results show accurate reconstruction, long-time prediction, and uncertainty bands at unseen parameters, indicating its potential for repeated forward solves in statistical inverse problems.

18:24-18:40 | Jinchao Feng

Great Bay University

Recovery of pairwise interaction kernels from noisy position trajectories with structure-aware neural ODEs**ABSTRACT**

Recovering pairwise interaction kernels from particle trajectories is a central inverse problem in computational physics. It arises in molecular dynamics, soft matter, coupled oscillators, and collective-motion modeling. Existing kernel-learning methods often rely on velocity data, which may be unavailable and must then be approximated from noisy position observations. However, such finite-difference approximations strongly amplify noise under sparse temporal sampling. To overcome this limitation, we propose a structure-aware Neural ODE framework for learning pairwise interaction kernels directly from noisy trajectory data. We also establish well-posedness of the inverse problem and provide an error estimate for the learned kernel. We test our method on different types of systems and on a real pedestrian-trajectory dataset. All examples show improved robustness over finite-difference baselines on noisy annotated data.

Thursday, August 27 2026

MS02

Recent Topics in Applied Mathematics and Computation

Main organizer Peter Chang-Yi Weng (National Chiayi University)

DESCRIPTION

Applied mathematics and computational science span a wide range of disciplines, including scientific computing, machine learning, image processing, control theory, and quantum mechanics. These areas play a vital role in advancing both theoretical understanding and practical applications across science and engineering.

This mini-symposium at the 19th East Asia SIAM (EASIAM) Annual Meeting aims to bring together researchers who focus on the development, analysis, and implementation of efficient computational algorithms and advanced numerical methods. By gathering experts from diverse yet interconnected fields, the symposium seeks to highlight recent progress in computational techniques and their applications to complex real-world problems.

The mini-symposium will provide a forum for the exchange of ideas, discussion of current challenges, and exploration of emerging research directions in computational mathematics. It also offers valuable opportunities for participants to establish new collaborations, strengthen existing research networks, and promote interdisciplinary interactions within the East Asia SIAM community.

MS02A | 08:30-09:50 | Room H3

08:30-08:50 | Peter Chang-Yi Weng

National Chiayi University

The refining estimates of invariant subspaces through projected nonsymmetric algebraic Riccati equations in high dimensionality reduction and image compression

ABSTRACT

In this talk, we provide an efficient and accurate method, which is the numerical solution of the projected nonsymmetric algebraic Riccati equations (pNAREs) arisen in the refinement of estimates of invariant subspaces (REIS). The theoretical contribution of our paper is threefold. Firstly, we introduce how to apply SVD to do image compression. Secondly, the core of this paper is to adapt REIS and find the first singular values to do image compression. Thirdly, we describe some measurement tools like compression ratio, mean square error, peak signal to noise ratio and structural similarity index to evaluate the performance of the compression factors and the quality of the compressed images. Furthermore, the operation counts and computational complexity are also provided. Finally, we present some numerical experiments about some real world image dataset to show the feasibility of our proposed algorithm.

08:50-09:10 | Chun-Yueh Chiang

National Formosa University

Geometric spectral separation and algebraic dichotomy for critical Stein matrix equations

ABSTRACT

This talk considers the critical Stein matrix equation $AX - XB = C$ with $\rho(A)\rho(B) = 1$, which causes the r -Smith iteration to fail. We propose two structure-preserving preconditioning strategies to resolve this challenge.

First, a geometric approach utilizes Moebius transformations to map the problem into a contractive domain. Under spectral separability, convergence is related to Apollonius circles. For interleaved eigenvalues on the unit circle, a power iteration strategy reorganizes the spectra into disjoint arcs to restore separability.

Second, for pathological configurations, we develop a three-region algebraic dichotomy. The system is converted into a Sylvester equation via Cayley transform. By integrating shifted matrix sign functions with optimal even polynomials, we partition the spectra into orthogonal regions and shift imaginary eigenvalues into stable half-planes without subspace extraction.

09:10-09:30 | Matthew Lin

National Cheng Kung University

Quantum Channel Reconstruction

ABSTRACT

In this work, we propose a manifold-constrained optimization framework for quantum channel reconstruction using only a single input-output pair. By employing projected gradient dynamics on the Stiefel manifold and the probability simplex, we recover the underlying channel parameters while preserving the intrinsic geometric constraints of the problem. Convergence of the proposed method is established. Numerical experiments demonstrate the effectiveness and flexibility of the approach, including its extension to multiple input-output pairs.

09:30-09:50 | Nai Zhu Huang

National University of Kaohsiung

A Characterization of Positive Entropy of Markov Tree-Shifts

ABSTRACT

Topological entropy is often considered as an indicator of complexity. However, there is no finitely checkable algorithm to determine the positive entropy of multidimensional shifts of finite type. Indeed, it is right recursively enumerable. In this presentation, we will present the characterization of positive entropy in Markov tree-shifts by adjacency matrices.

MS02B | 10:20-11:40 | Room H3

10:20-10:40 | Louis Kao

Fu Jen Catholic University

The Kelmans Transformation and the Largest Real Eigenvalue of Nonnegative Matrices

ABSTRACT

The Kelmans transformation is originally defined on graphs and their adjacency matrices, which has some nice properties on the spectrum of graphs. For a nonnegative square matrix C of order n and fix a 2 -subset $\{a, b\} \subseteq [n]$ with certain constraints, we define $C'(a, b)$ to be a general version of the Kelmans transformation of C . In this talk, we will show that the largest real eigenvalue of C is at most the largest real eigenvalue of $C'(a, b)$. Furthermore, we will apply this tool to discuss the Hamiltonicity of mixed graphs, whose adjacency matrix is not necessarily symmetric.

10:40-11:00 | Hung-Hsun Chen

Fu Jen Catholic University

Co-authors: Wen-Pei Tsai (National Kaohsiung University of Science and Technology); Chia-Lee Yang (National Center for High-performance Computing)

Nonlinear Modeling of Fishery Resources via Kolmogorov-Arnold Networks and Latent Variable Frameworks

ABSTRACT

Reversing biometric relationships to predict shark length from weight is crucial for fisheries management, as market data often lacks size records. Standard neural networks (ANNs) capture these nonlinearities but act as black boxes. We propose a mathematically rigorous framework integrating Kolmogorov-Arnold Networks (KANs) with a latent variable formulation to reconstruct length from weight. We model ten Northwest Pacific shark species independently. Since practical market data lacks sex classification, sex is excluded as an input. To capture unobserved physiological dynamics like sexual dimorphism and age, a latent layer models these hidden covariates within the KAN. KANs employ learnable splines on edges, dramatically improving parameter efficiency and interpretability. Our KAN-latent framework matches ANN accuracy while enabling symbolic equation discovery for sustainable ecological management.

11:00-11:20 | CHIEN-CHANG YEN

Mathematics, Fu Jen Catholic University

Co-authors: Yong-Shiuan Lee (Department of Applied Mathematics, Feng Chia University, Taichung City 407102, Taiwan (R.O.C.)); Tsung-Jui Chiang-Lin (Department of Aerospace and Systems Engineering, Feng Chia University, Taichung City, 407102, Taiwan (R.O.C.)); Ting-Fu Chen (Department of Mathematics, National Central University, 32037, Taiwan(R.O.C.))

State Transformation of Stock Prices and Its Applications**ABSTRACT**

A state on the time zone $[t_0, t_1]$ is defined by two successive values, $S_0=S(t_0)$ and $S_1=S(t_1)$ and the imposed equilibrium A . A state transform is to represent a discrete stock time series by determining the state at each time zone. We simulate four simple/fundamental states of a time series, increasing, decreasing, white noise, and random walk of time series, for revealing the relation between time series and states. The analysis of state transform for the aforementioned time series are shown in theoretical approach. It is significant that the behavior of white noise and random walk can be distinct by the state transform. The application on predicting state is used the weighted probability sample, which is also used in the two-gram language model, and the simulations show that the nearest future states could be reasonably acceptable through our simulations of financial markets data.

11:20-11:40 | Yung-Ta Li

Fu Jen Catholic University

Numerical Methods and Closed-Form Solutions for Structured Sylvester Equations in Pseudospectral Discretizations**ABSTRACT**

In this talk we first review the Bartel-Stewart algorithm that numerically solve the Sylvester equation and a closed-form finite series representation of the unique solution. Then we derive a structured Sylvester equation by discretizing a two dimensional advection equation using a pseudospectral method with penalty. To solve the structured Sylvester equation, we propose a numerical method that takes advantage of the skew-symmetric structure and we aim to seek for a closed-form solution to the structured Sylvester equation with particular right hand sides.

MS37

Numerical Methods for Phase-Field Models: Advances, Challenges and Applications

Main organizer	Chaoyu Quan (The Chinese University of Hong Kong (Shenzhen))
Co-organizers	Jiang Yang (Southern University of Science and Technology); Wei Zhang (Beijing Normal-Hong Kong Baptist University)

DESCRIPTION

This minisymposium focuses on numerical methods for phase-field models, which are essential tools for simulating interfacial dynamics and pattern formation in materials science, physics, engineering, and biology. Phase-field models avoid explicit interface tracking but pose key numerical challenges, including stiffness, nonlinearity, high-order derivatives, and computational cost for large-scale simulations. The speakers will showcase state-of-the-art advances in structure-preserving schemes, high-order spatial discretization, parallel/GPU computing, and hybrid data-driven-physics-based approaches. This session unites numerical analysts, computational mathematicians, and applied scientists to foster cross-community dialogue, advancing reliable, efficient tools that unlock phase-field modeling's potential for science and industry.

MS37 | 08:30-09:50 | Room I1

08:30-08:50 | Chaoyu Quan

The Chinese University of Hong Kong

Energy Dissipation Analysis of Implicit-Explicit Linear Multistep Methods for Gradient Flows Using General Multipliers

ABSTRACT

A unified framework is proposed to establish the energy dissipation of implicit-explicit linear multistep methods (IMEX-LMMs) applied to gradient flows. Given a fixed IMEX-LMM, it is shown that finding an appropriate multiplier for constructing the dissipative energy can be formulated as a feasibility problem over the multiplier coefficients, where the involved positivity inequalities on the unit circle are relaxed to a finite-dimensional linear programming problem after discretization. Within this framework, two specific multipliers are obtained to establish the energy dissipation of the sixth-order IMEX backward differentiation formula (IMEX-BDF6) and a seventh-order IMEX weighted and shifted BDF, and a new eighth-order energy-dissipative IMEX-LMM is developed together with its multiplier. To the best of our knowledge, these are the first energy-dissipation results for the IMEX-BDF6 method and the IMEX-LMMs of order higher than six.

08:50-09:10 | Zhonghua Qiao

The Hong Kong Polytechnic University

Efficient Structure-Preserving Exponential Time Differencing Schemes for the Gradient Flow of Q-tensor Model

ABSTRACT

The Landau-de Gennes Q-tensor theory provides a fundamental framework for modeling nematic liquid crystals. Numerical simulations of the corresponding Q-tensor gradient flows are challenging due to the presence of stiff nonlinear terms and the need to preserve essential physical constraints, in particular the energy dissipation law and the maximum bound principle (MBP). In this work, we propose a class of first- and second order stabilized exponential time differencing (ETD) schemes for the Q-tensor flow. We rigorously prove that the proposed schemes unconditionally preserve the discrete MBP and the original energy dissipation law. Moreover, optimal-order error estimates are established for both schemes. Numerical experiments are presented to validate the theoretical results, demonstrating that the proposed schemes achieve high-order temporal accuracy while strictly preserving the physical bounds and energy dissipation property, even for relatively large time step sizes.

09:10-09:30 | Jiang Yang

Southern University of Science and Technology

Length- and Energy-Preserving Numerical Schemes for Projected Gradient Flows of Vector Fields**ABSTRACT**

Developing numerical schemes that simultaneously preserve length constraints energy dissipation for projected gradient flows of vector fields is a long-standing challenge, particularly for high-order or decoupled formulations.

In this talk, we present a novel structure-preserving numerical framework based on a newly developed class of product-type implicit-explicit Runge-Kutta (PRK) methods. For unit vector fields with Dirichlet energy, we propose a linear, second-order time-stepping scheme that unconditionally guarantees both unit-length preservation and original energy dissipation without requiring computationally expensive nonlinear algebraic solvers. To the best of our knowledge, this represents the first second-order linear scheme to achieve dual structure preservation for harmonic map heat flows. Furthermore, we discuss the extension of this framework to more general nonlinear potentials and complex manifold constraints using the Scalar Auxiliary Variable (SAV) approach.

09:30-09:50 | Jie Shen

Eastern Institute of Technology, Ningbo

Efficient spectral methods for solving incompressible Navier-Stokes equations in complex domains**ABSTRACT**

In this talk, we will present an efficient, fully decoupled, divergence-free spectral method for the incompressible Navier-Stokes equations in two-dimensional complex domains. The method combines a circular embedding technique with a pressure reconstruction strategy. The physical domain is embedded into a disk, where the geometric boundary constraints are separated from the governing equations through an appropriate decomposition. The pressure is then decomposed into a particular component determined by the forcing term and a homogeneous component whose coefficients act as Lagrange multipliers enforcing the incompressibility constraint. Numerical experiments demonstrate the spectral accuracy, computational efficiency, and robustness of the proposed method in complex geometries.

MS07

Mathematics and AI for Scientific Computing

Main organizer	Yuqing Li (East China Normal University)
Co-organizers	Xiaofei Zhao (Wuhan University); Zhiping Mao (Eastern Institute of Technology, Ningbo)

DESCRIPTION

This minisymposium aims to convene researchers at the interface of computational mathematics and machine learning to examine some recent advances in deep learning methodologies for scientific computing. Computational mathematics provides some essential tools for modeling, simulation, and numerical analysis across the physical sciences and engineering. Classical techniques, including finite element methods, spectral methods, and stochastic simulation techniques, have achieved great success in solving partial differential equations, inverse problems, and large-scale optimization tasks. However, some contemporary applications often involve inherently high-dimensional or multi-scale structures, presenting formidable challenges for conventional computational techniques.

Recently, deep learning has emerged as a promising paradigm for overcoming these limitations. Neural networks based methods are increasingly employed to accelerate numerical solvers, construct surrogate models, approximate solution operators of differential equations, and develop algorithms tailored for the high-dimensional problems. These developments, in turn, raise fundamental questions in approximation theory, optimization, and generalization-questions that are pivotal for the theoretical understanding and further advancement of deep learning methods. Motivated by these challenges, this minisymposium will explore topics including neural network approximation theory, operator learning for partial differential equations, dynamical perspectives on training algorithms, and deep learning strategies for multiscale modeling and high-dimensional computation. By bringing together these complementary perspectives, the symposium seeks to foster dialogue and collaboration at the forefront of computational mathematics and machine learning.

MS07A | 08:30-09:50 | Room S1

08:30-08:50 | Chaozhen Wei

University of Electronic Science and Technology of China

A JKO approach for gradient flows

ABSTRACT

In this talk, I will present a novel numerical approach based on minimizing movement (also known as JKO) schemes for a class of gradient flows arising widely in applications in material science and biology such as porous medium, tumor growth, phase separation, crystal defects migration, surface-diffusion-driven dynamics. By leveraging the underlying variational structure and its intrinsic connection to optimal transport, we construct structure-preserving fully discrete JKO scheme that ends up with a series of linearly constrained convex optimization problems, which can be solved by tailored primal dual operator splitting methods. Our method has built-in strictly positivity or bounds preserving, mass conservation, and entropy decreasing properties, and overcomes stability issue due to the strong nonlinearity and degeneracy. I will show a suite of simulation examples to demonstrate the effectiveness and applicability of our approach.

08:50-09:10 | Qi Meng

Chinese Academy of Sciences

SPDEBench: A Benchmark for Learning Regular and Singular Stochastic PDEs

ABSTRACT

Stochastic partial differential equations model rough spatio-temporal phenomena across turbulence, quantum dynamics, materials, and other complex systems, yet machine learning for SPDEs lacks unified evaluation tools that handle stochasticity, discretization, and singular behavior with sufficient care. This keynote introduces SPDEBench, a benchmark for learning both regular and singular SPDEs through controlled data generation, renormalization-aware simulation, representative baselines, and metrics that go beyond pointwise error. We will discuss what SPDEBench reveals about current neural operators and SPDE-aware models, where existing methods succeed or fail, and how principled benchmark design can guide the next generation of learning methods for rough, noisy, and physically significant dynamical systems.

09:10-09:30 | Fei Wang

Xi'an Jiaotong University

Randomized Neural Network Methods for Partial Differential Equations

ABSTRACT

In this talk, we introduce Randomized Neural Network (RaNN) methods as a unified framework that combines random feature-based neural representations with traditional numerical methods for solving partial differential equations. Within this framework, we develop a series of structure-preserving schemes, including RaNN-Petrov-Galerkin, local RaNN-discontinuous Galerkin, local RaNN-hybridizable discontinuous Petrov-Galerkin, and local RaNN-finite difference methods. Adaptive growing RaNN strategies are further developed to enhance approximation capability for complex solution structures, and RaNN-based operator learning approaches are explored for efficient parameterized PDE simulations. Numerical results demonstrate that RaNN methods achieve high accuracy with reduced degrees of freedom while maintaining computational efficiency, structural consistency, and scalability, providing a promising direction for the integration of numerical analysis and machine learning in scientific computing.

09:30-09:50 | Yan Wang

Central China Normal University

Numerical methods for Dirac equation

ABSTRACT

This talk is devoted to numerical methods for highly oscillatory and low-regularity Dirac equations. In the nonrelativistic regime, the solution to Dirac equation is highly oscillatory in time, severe time-step size restriction is required to resolve the solution. With rough initial data, traditional methods usually suffer from order reduction. In this talk, we introduce the operator separation and nested Picard iteration technique to construct efficient numerical methods for this two kinds of problems.

MS07B | 10:20-11:40 | Room S1

10:20-10:40 | Zhenye Wen

Wuhan University

Deep Onsager Operator Learning: An Unsupervised Framework for Dissipative Equations

ABSTRACT

Most existing operator learning methods rely on supervised training with high-fidelity simulation data, introducing significant computational cost. In this work, we propose the deep Onsager operator learning (DOOL) method, a novel unsupervised framework for solving dissipative equations. Rooted in the Onsager variational principle (OVP), DOOL trains a deep operator network by directly minimizing the OVP-defined Rayleighian functional, requiring no labeled data, and then proceeds in time explicitly through conservation/change laws for the solution. Another key innovation here lies in the spatiotemporal decoupling strategy: the operator's trunk network processes spatial coordinates exclusively, thereby enhancing training efficiency, while integrated external time stepping enables temporal extrapolation. Numerical experiments on typical dissipative equations validate the effectiveness of the DOOL method, and systematic comparisons demonstrate its enhanced performance.

10:40-11:00 | Yuqing Li

East China Normal University

Condensation Phenomena and Stochastic Methods: From Neural Networks to Particle Systems

ABSTRACT

We study condensation phenomena driven by stochasticity in neural network training and interacting particle systems. In neural networks, we characterize a phase diagram of condensation in two-layer and convolutional models, where training induces concentration of weights along finitely many directions, improving generalization. We further show that Dropout admits a stochastic modified equation description, which captures its dynamics and explains its role in promoting and stabilizing condensation at late training stages. In a second direction, we develop a quasi-Ewald splitting method for charged particles in nanoscale confinement. By combining importance sampling with random batch techniques in Fourier space, we obtain an $O(N)$ algorithm for electrostatic interactions. The method also reveals dielectric boundary effects and anisotropic diffusion induced by confinement. dimensional structures in learning systems and efficient computation in complex physical systems.

11:00-11:20 | Xiaofei Zhao

武汉大学

On action ground state of NLS**ABSTRACT**

In this talk, we first review the definition of action ground state of NLS. Some equivalent formulations are then introduced. Based on each, different computational methods are designed and compared. With the simulation and analysis, the relation between action and energy ground states are explored.

11:20-11:40 | Haozhe Xu

Eastern Institute of Technology, Ningbo

Co-authors: Zhiping Mao (Eastern Institute of Technology, Ningbo)

NN-WGF: A Neural Ritz Flow-Map Method for Two- and Three-Dimensional Porous Medium Flows**ABSTRACT**

We present NN-WGF, a neural Ritz discretization of a Lagrangian flow-map variational scheme for Wasserstein gradient flows. Unlike PINNs, the method does not fit PDE residuals or solution data. At each implicit time step, a residual neural network represents the transport map and directly minimizes a weighted movement cost plus the porous-medium internal energy. The density is reconstructed by $\rho(T(X),t)=\rho_0(X)/\det(DT(X))$, so discrete Lagrangian mass is conserved by construction. We evaluate the method on the compactly supported Barenblatt benchmark with $m=5$, $dt=0.01$, and 400 steps to $T=4$. Against the exact self-similar scaling, the final relative density errors are 1.94% in 2D and 1.72% in 3D, with map errors of 0.40% and 0.55%. Both runs exhibit energy dissipation, zero reported mass drift, and positive sampled Jacobians. The results support neural flow-map optimization for long-time free-boundary Wasserstein dynamics in three dimensions.

MS34

High-Order Numerical Methods for Hyperbolic Conservation Laws

Main organizer	Jiaxi Gu (Pohang University of Science and Technology)
Co-organizers	Bao-Shan Wang (Ocean University of China)

DESCRIPTION

This mini-symposium brings together researchers to discuss recent advances in the design, analysis, and implementation of high-order numerical methods for hyperbolic conservation laws. The focus will be on both theoretical developments and practical computational techniques. Topics include high-order schemes such as weighted essentially non-oscillatory (WENO) and discontinuous Galerkin (DG) methods, along with their stability, efficiency, and error analysis. Applications will include compressible fluid dynamics, shock-interface interactions, and related multiphysics problems governed by hyperbolic systems. By fostering interaction among researchers from diverse areas, the mini-symposium aims to encourage the exchange of ideas, identify emerging research directions, and promote interdisciplinary collaboration. The session is expected to feature four invited speakers.

MS34 | 08:30-09:50 | Room S2

08:30-08:50 | Bao-Shan Wang

Ocean University of China

Foliation Structures and Numerical Validation of Scalar Hyperbolic Conservation Laws on Manifolds

ABSTRACT

This talk presents a theoretical and computational framework for scalar (nonlinear) hyperbolic conservation laws on closed regular 2D manifolds (e.g., sphere and torus), demonstrating how kernel-style embedding techniques, specifically the Closest Point Method, can be effectively combined with high-order numerical schemes to solve surface PDEs with shocks on complex geometries. A geometry-compatible flux formulation is introduced, which induces a natural foliation of the manifold forming regular leaves, singular points, and separatrices. The foliation decomposes the surface PDEs into a family of 1D conservation laws along the leaves, enabling global flow dynamics to emerge from their collective evolution, as validated by 2D-1D reduction tests. The Closest Point Method coupled with high-order WENO scheme (cp-WENO) is employed to simulate the hyperbolic equations on both spherical and toroidal geometries, confirming the geometry-induced structures.

08:50-09:10 | Kwanghyuk Park

POSTECH

Co-authors: Jiaxi Gu (POSTECH); Jae-Hun Jung (POSTECH)

A data-driven third-order WENO schemes based on conservative approximation to the derivative

ABSTRACT

We propose a feedforward neural network based on a conservative approximation to the derivative from point values for WENO schemes applied to hyperbolic conservation laws. The network replaces the classical WENO weighting procedure by mapping three-point stencil values to two nonlinear weights. For supervised training, we construct a labeled dataset in which numerical fluxes are determined so that their differences provide high-order approximations to the derivative. The loss function encourages the neural network to satisfy ENO property and the symmetry shared by WENO3-JS and WENO3-Z. The resulting WENO3-CADNN schemes generalize robustly across benchmark problems and grid resolutions, outperforming WENO3-Z.

09:10-09:30 | Pei Fu

Nanjing University of Aeronautics and Astronautics

Structure preserving unfitted discontinuous Galerkin method for hyperbolic conservation laws

ABSTRACT

This talk will present a family of high order cut finite element methods based on the discontinuous Galerkin (DG) framework for hyperbolic problems. To avoid the small-cut-cell issue, a ghost penalty stabilization is employed to stabilize the scheme. The strong stability-preserving Runge-Kutta method is used for time discretization, in which the time step is chosen independently of the size of the cut elements. We show that the proposed methods possess stability and accuracy properties as the standard DG methods on fitted meshes. We also prove and verify that the scheme preserves the bound-preserving property for scalar conservation laws when a flux limiting work is applied. Finally, numerical experiments will be given to demonstrate that the proposed methods achieve high-order accuracy for smooth solutions and perform well for problems with discontinuities.

09:30-09:50 | Li Yuan

AMSS

A modified WENO-Z+ scheme based on the unnormalized nonlinear weights of the rewritten fifth-order adaptive order WENO scheme**ABSTRACT**

This paper proposes a modified fifth-order WENO-Z+ type scheme by comparing the unnormalized weights of the rewritten fifth-order adaptive-order (AO) WENO scheme with those of the existing WENO-Z+ scheme. The fifth-order WENO-AO scheme using sub-stencils of unequal sizes is reformulated into the standard WENO combination form with sub-stencils of equal size, and it is found that its unnormalized weights can be decomposed into three components: a constant term, a local smoothness measurement term for each sub-stencil, and a global smoothness measurement term for the global stencil. To fully utilize the latter two terms to construct an improved WENO scheme, an adaptive scaling factor is introduced to balance the contributions of the second term and the modified third term. Numerical experiments demonstrate that the improved fifth-order WENO-Z+ scheme can achieve high resolution in smooth regions while capturing shock discontinuities sharply and robustly.

MS05

Recent Advances in AI for Scientific Computing

Main organizer	Jinsil Lee (Seoul National University)
Co-organizers	Youngjoon Hong (Seoul National University); Myeongsu Lee (Seoul National University)

DESCRIPTION

This session delves into the intersection of Artificial Intelligence (AI) and scientific computing. Moving beyond conventional data analysis, AI is driving a new paradigm in computational science through innovative methodologies that encode physical laws and governing equations into neural architectures. This session addresses a broad range of topics in scientific computing using AI, spanning from the theoretical analysis of these AI models to their practical applications. By considering recent advancements in both application and theory, this session aims to discuss the current capabilities, limitations, and future directions of AI in scientific computing.

MS05A | 10:20-11:40 | Room H1

10:20-10:40 | Seungchan Ko

Inha University

Finite Element Operator Networks: Mathematical Theory and Numerical Computation

ABSTRACT

In recent years, modern machine learning techniques using deep neural networks have achieved tremendous success across a wide range of fields. Operator learning has emerged as a powerful framework for parametric PDE problems: by learning the underlying solution operator, it enables rapid solution predictions as the input data varies. In this talk, I will propose a new operator-learning method based on the finite element method, which is highly flexible across diverse settings without relying on any precomputed training data. Grounded in my recent results, the goal of this talk is to provide a broad mathematical investigation of the proposed method. First, through numerical experiments across a variety of scenarios, I will demonstrate practical effectiveness and versatility of the method. Second, leveraging mathematical theory for neural networks, I will develop a theoretical analysis of the approach and design theory-guided strategies that can substantially improve performance.

10:40-11:00 | Wei-Fan Hu

National Central University

Scientific Machine Learning: Methods and Applications

ABSTRACT

In recent years, the advancement of machine learning techniques has achieved remarkable success and significantly influenced various scientific fields. It also provides a novel avenue for creating a new category of numerical methods to address solutions for partial differential equations that are either intractable or impractical using traditional numerical approaches. Despite these advancements, numerous computationally challenging problems remain unsolved within the scientific computing community. These challenges can potentially be addressed through the application of machine learning techniques. In this talk, we focus on developing numerical methods that integrate the strengths of classical numerical methods with modern deep learning approaches to tackle some of these problems of our primary interests.

11:00-11:20 | Changhoon Song

Seoul National University

Transformers Subsume MLPs: Direct Transfer of Approximation Rates

ABSTRACT

Transformers have become a central architecture in modern machine learning, but their approximation theory has often been developed separately from the classical theory of multi-layer perceptrons. In this talk, I will present a simple emulation principle showing that Transformers can reproduce MLPs with only a constant-factor overhead in the number of parameters. As a consequence, any error rate established for MLPs transfers directly to Transformers without degradation in the rate. This provides a unified way to reinterpret several existing approximation results for Transformers and immediately yields new guarantees, including rates over Sobolev and Barron-type function classes. I will focus on the main idea of the construction—how attention can be used to aggregate token-wise information so as to emulate fully connected layers.

11:20-11:40 | ANNING LAI

The University of Osaka

Co-authors: Daisuke Furihata (The University of Osaka); Yuto Miyatake (The University of Osaka)

Reduced-Order Modelling of Global Discretization Error Dynamics for High-Dimensional Linear ODEs via the Iterative Rational Krylov Method**ABSTRACT**

Local discretization errors of time-stepping schemes can often be estimated, whereas the corresponding global error is harder to obtain, especially for high-dimensional ODE systems and semi-discretized PDEs. We study reduced-order modelling of global discretization error dynamics under the assumption that local error information is available. The global error is formulated as a forced discrete-time dynamical system driven by the local error sequence. After POD compression of local errors and suitable reformulation, this model is rewritten as a discrete-time MIMO linear time-invariant (LTI) system. This allows the use of projection-based model reduction techniques developed for control systems. In particular, we adopt the Iterative Rational Krylov Algorithm to construct a low-dimensional approximation of the global error model. The talk focuses on linear ODE problems with stable error propagation, and briefly discusses an extension to nonlinear problems via parameter-dependent LTI systems.

MS05B | 11:50-13:10 | Room H1**11:50-12:10 | Daniel Huang**

Peking University

Point Cloud Neural Operator for Parametric PDEs on Complex and Variable Geometries**ABSTRACT**

Surrogate models are critical for accelerating computationally expensive simulations in science and engineering, particularly for solving parametric partial differential equations (PDEs). Developing practical surrogate models poses significant challenges, particularly in handling geometrically complex and variable domains, which are often discretized as point clouds. In this work, we systematically investigate the formulation of neural operators---maps between infinite-dimensional function spaces---on point clouds to better handle complex and variable geometries while mitigating discretization effects. We introduce the Point Cloud Neural Operator (PCNO), designed to efficiently approximate solution maps of parametric PDEs on such domains. We evaluate the performance of PCNO on a range of pedagogical PDE problems, focusing on aspects such as boundary layers, adaptively meshed point clouds, and variable domains with topological variations.

UPDATED - CANCELLED - no replacement talk**12:10-12:30 | Zhiping Mao**

Eastern Institute of Technology, Ningbo

Galerkin Neural Networks-based Reduced Basis Method for Parametric Differential Equations**ABSTRACT**

Reduced basis methods (RBM) are powerful tools for parametric PDEs, but their offline stage typically relies on high-fidelity solutions from mesh-dependent solvers, which can be expensive and non-flexible for sharp boundary problems. Recently, neural networks have emerged as an effective tool for approximating partial differential equations (PDEs). In particular, the residual-based Galerkin Neural Network (GNN) method adaptively generates basis functions to approximate variational equations, progressively improving accuracy. However, this adaptive approach requires retraining for each new parameter of the parametric PDEs. In this work, we propose a novel GNN-RBM method for parametric PDEs' approximation by establishing a theoretically rigorous connection between greedy parameter sampling and neural network-based adaptive basis generation. The resulting basis functions are valid across the entire parameter domain, including parameters not used during training.

12:30-12:50 | Xuhui Meng

Huazhong University of Science and Technology

Physics-informed sampler for solver-free data generation in operator learning**ABSTRACT**

Neural operator training requires large datasets from expensive numerical solvers, especially for nonlinear, high-dimensional, time-dependent, and geometrically varying PDEs. We propose a physics-informed sampler that bypasses solvers entirely: it defines a generative model over solution space using Bayesian neural network priors, samples candidate solutions, and derives source terms/BCs/ICs via automatic differentiation of governing operators. Evaluated on reaction-diffusion, Poisson (parameterized geometries), 2D/5D time-dependent PDEs, and vortex-induced vibration, the sampler generates diverse PDE-consistent training pairs at hundreds of times lower cost than conventional methods, supporting accurate neural operator predictions across broad test conditions.

MS35

Fast Solvers for Multiphysics Problems

Main organizer	Shihua Gong (The Chinese University of Hong Kong, Shenzhen)
Co-organizers	Wei Wang (Academy of Mathematics and Systems Science, CAS); Chupeng Ma (Great Bay University)

DESCRIPTION

Fast solvers are critical for simulating complex multiphysics systems. This minisymposium will present recent advances in efficient and reliable solvers designed to tackle a wide range of challenges-including wave propagation, electromagnetic simulations, and other applications-highlighting both their versatility and practical impact. Topics will include robust preconditioners, iterative solvers, domain decomposition strategies, and frameworks for integrating multiple physical models, with a focus on convergence, scalability, and adaptability to modern high-performance computing environments.

This minisymposium will provide participants with a platform to gain insights into these real-world applications, exchange strategies, share experiences, and collaborate on advancing high-performance solvers for computational science and engineering.

MS35A | 10:20-11:40 | Room I1

10:20-10:40 | Beiping Duan

Shenzhen MSU-BIT University

A Second-order Structure-preserving Parametric FEM for surface evolution

ABSTRACT

We present a second-order-in-time, structure-preserving, and mesh-robust parametric finite element method for surface diffusion and the volume-preserving mean curvature flow. We first reformulate the original evolution equations into new systems in which the tangential motion is governed by a harmonic map heat flow. This heat flow maps a fixed reference surface onto the unknown evolving surface and drives points on the evolving surface to move in their tangent spaces so as to reduce the associated harmonic energy. As a result, in the discrete setting, the mesh quality can be maintained at a level comparable to that of the reference surface, unless singularities occur. The volume-preserving property is theoretically guaranteed by the delicate design of the scheme, while energy dissipation is enforced through a Lagrange multiplier. The proposed framework can be readily extended to other geometric flows.

10:40-11:00 | FENG WANG

Nanjing Normal University

A Pressure-Robust Nonconforming Immersed Finite Element Method for Stokes Interface Problems

ABSTRACT

It is well-established that an appropriate modification of test functions may lead to pressure-robust mixed methods for the Stokes problems. However, for immersed finite element approximations of the Stokes interface problems on unfitted meshes, it remains unclear whether the error of the velocity is independent of the pressure, since the velocity and the pressure are coupled in one of the interface conditions. In this talk, we provide a positive answer by a novel decomposition of the discontinuous pressure to a continuous function and a velocity related discontinuous part. We demonstrate that the immersed Crouzeix-Raviart/P0 element method achieves pressure robustness via an $H(\text{div})$ -conforming reconstruction of the test functions on the right-hand side. The stability and optimal error estimates of the proposed method are established with constants independent of the interface position relative to the mesh. Numerical experiments are presented to validate the theoretical findings.

11:00-11:20 | Shuo Zhang

Academy of Mathematics and Systems Science, Chinese Academy of Sciences

Strict Constraint Satisfaction in Multiphysics Solvers via Convexity-Driven Training

ABSTRACT

In the development of machine learning-based solvers for multiphysics problems, constraints are typically incorporated into the optimization objective as penalty terms. However, this approach often yields solutions that cannot strictly satisfy the underlying physical constraints, leading to non-physical results. In this work, we propose a training method that ensures strict constraint adherence and provide a theoretical analysis of its applicability. Distinct from general constrained optimization, the proposed objective function exhibits a specific form of convexity, which mitigates training difficulties and accelerates convergence. Numerical experiments on several computational instances demonstrate the effectiveness of this strategy. This is a joint work with Wenyu Dong.

11:20-11:40 | Zhiyu Tan

Xiamen University

Unified convergence analysis of non-variational finite element methods for a Pucci equation in two dimensions
ABSTRACT

In this paper, a unified framework based on discrete Miranda-Talenti type inequalities is developed for the design and analysis of non-variational finite element methods for a Pucci equation in two dimensions. The proposed framework is applicable to a wide range of discretizations, including conforming finite element methods, C^0 interior penalty methods, non-conforming finite element methods, and discontinuous finite element methods. A unified error analysis is carried out, from which quasi-optimal convergence results are obtained. To solve the resulting non-smooth discrete problem, a fixed-point method is proposed. The convergence of this method is rigorously established, and an explicit convergence rate is provided. Numerical experiments are presented and confirm the theoretical findings.

MS35B | 11:50-13:10 | Room I1
11:50-12:10 | Shihua Gong

The Chinese University of Hong Kong, Shenzhen

Sharp Inf-Sup Estimate and Fast Solvers for the Stokes Equation in Tight Domains with Periodic Pillars
ABSTRACT

Microfluidic chips are widely used to separate blood cells and other particles by arranging periodic pillar arrays inside flow channels. However, as the pillar density increases, standard numerical solvers for the Stokes equations often suffer from severe convergence stagnation. In this work, we show that this difficulty is not merely algorithmic, but is rooted in the geometry-induced degradation of the pressure-velocity coupling stability.

For tight domains with periodic pillars, we prove that the continuous Ladyzhenskaya-Babuška-Brezzi (inf-sup) constant decays sharply as $\mathcal{O}(m^{-1})$, where m denotes the number of pillars per unit length. This estimate implies an $\mathcal{O}(m)$ amplification in finite element a priori error bounds and an $\mathcal{O}(m^2)$ growth in the condition number of the pressure Schur complement. In this talk, I will also discuss several preconditioning techniques for efficiently solving the resulting Schur complement system.

12:10-12:30 | Huangxin Chen

Xiamen University

Robust Numerical Methods for Some Topology Optimization Problems
ABSTRACT

In this talk, we will introduce a prediction-correction iterative convolution thresholding method for the topology optimization for heat transfer problem. The prediction step is based on the variation of the objective functional by imposing the constraints, while the correction step ensures the monotonically decreasing behavior of the objective functional. The application of the new method for the coupled thermal-fluid topology optimization will be discussed. We will also introduce a robust phase field method for structural topology optimization.

12:30-12:50 | Qigang Liang

Tongji University

Adaptive Local Multilevel Methods for Elliptic and Maxwell Eigenvalue Problems
ABSTRACT

In this talk, we propose an efficient adaptive local multilevel preconditioned Jacobi-Davidson method for eigenvalue problems with singularity. Our multilevel method utilizes a local smoothing strategy to solve the preconditioned Jacobi-Davidson correction equation arising from adaptive finite element methods. As a result, the algorithm holds optimal computational complexity $\mathcal{O}(N)$. The theoretical analysis reveals that our method has a uniform convergence rate with respect to mesh levels and degrees of freedom. Further, we also extend this method with Helmholtz projection to solve Maxwell eigenvalue problems. Numerical experiments on complex domains are carried out to confirm the theoretical results and demonstrate the efficiency of the proposed method. This is a joint work with Prof. Xuejun Xu and Ph.D. students (Jianing Guo and Qingquan Zhang).

12:50-13:10 | BO WANG

Hunan Normal University

An isogeometric fast multipole boundary integral method for solving multiple scattering problems**ABSTRACT**

This talk presents a multi-patch isogeometric fast multipole boundary element method for simulating multiple scattering problems. The method preserves exact geometry of complex scatterers using NURBS patches, which also serve as the basis for discretizing the boundary integral equation. Exploiting the local support of NURBS, we recast the dense matrix-vector product as a quadrature-source potential evaluation and accelerate it via the fast multipole method. To enhance iterative solver convergence, we design a scatterer-aware ACA-SMW preconditioner that retains complete coarse-level scatterer blocks and performs DOF bisection only within individual scatterers. Numerical results confirm high-order accuracy for smooth geometries, improved GMRES convergence, and near-linear scaling for large-scale problems with complex non-convex scatterers.

MS16

Recent Advances in Numerical Shape and Topology Optimization Methods: From Theory to Practice

Main organizer	Wei Gong (Academy of Mathematics and Systems Science, Chinese Academy of Sciences)
Co-organizers	Julius Fergy Rabago (Kanazawa University, Japan); Shengfeng Zhu (East China Normal University, China)

DESCRIPTION

Shape and topology optimization has emerged as a transformative paradigm across engineering disciplines, from aerospace structural design to biomedical applications. This minisymposium brings together leading researchers to present cutting-edge developments bridging theoretical foundations and computational practice. The session will explore advances in high-fidelity numerical methods, including level-set approaches, phase-field models, and machine learning-enhanced algorithms. Particular emphasis will be placed on rigorous mathematical analysis-convergence theory, error estimates for shape derivatives, and well-posedness of optimization problems-alongside efficient implementation strategies addressing large-scale applications. Topics encompass PDE-constrained optimization on evolving domains, multi-physics coupling, uncertainty quantification, and industrial-scale computations. The minisymposium aims to foster dialogue between theoretical and applied perspectives, highlighting methodologies that achieve both computational efficiency and mathematical reliability in complex design scenarios.

MS16A | 10:20-11:40 | Room S2

10:20-10:40 | Yifeng Xu

Shanghai Normal University

Adaptive FEM for the Borrvall-Petersson model in topology optimization of Stokes flow

ABSTRACT

This presentation examines an adaptive finite element method for the Borrvall-Petersson problem in topology optimization of fluids. In addition to a box constraint and a volume restriction, the model features regularization of the material distribution field by an inverse permeability term so that the optimality system consists of generalized Stokes equations and a variational inequality. The velocity field is approximated by the nonconforming linear element (Crouzeix-Raviart element) while the piecewise constant is applied to the pressure field and the material distribution, respectively. A standard adaptive algorithm is devised for efficient numerical simulation of the model and is proved to generate a null sequence of estimators and a subsequence of discrete solutions converging to some solution of the optimality system. Numerical results illustrate the effectiveness of the proposed algorithm.

10:40-11:00 | Xiaoping Wang

Chinese University of Hong Kong (Shenzhen)

Advances in Numerical Methods for Topology Optimization: Applications Across Disciplines

ABSTRACT

This talk explores the cutting-edge numerical methods and their diverse applications in the field of topology optimization. We will highlight the development of robust numerical strategies designed to tackle the challenges that arise from the high dimensionality and non-linearity inherent in topology optimization problems. The iterative thresholding method will be discussed for its significant improvements over conventional techniques, enhancing both the efficiency and stability of solutions. Additionally, the presentation will highlight innovative research integrating machine learning with numerical methods to accelerate the process of topology optimization.

11:00-11:20 | Jizu Huang

Academy of Mathematics and Systems Science, Chinese Academy of Sciences

PRNN-STO: A parametric representation-oriented neural network method for Shape and topology optimization

ABSTRACT

In this talk, we propose a parametric representation-oriented neural network method for shape and topology optimization problems (PRNN-STO), which consists of the following key components. First, this method uses parametric representations combined with logical operations to effectively capture topological changes within the design domains, thereby reducing the dimensionality of the optimization space and enhancing its ability to represent complex topologies. Second, the Karush-Kuhn-Tucker (KKT) system arising from the optimization problem is solved by integrating the Alternating Direction Method of Multipliers (ADMM) and the Physics-Informed Neural Network (PINN). Due to its mesh-free nature, the proposed method avoids mesh-related issues inherent to traditional FEM-based approaches. Numerical examples demonstrate the accuracy, robustness, and effectiveness of PRNN-STO across a range of shape and topology optimization problems.

MS16B | 11:50-13:10 | Room S2

11:50-12:10 | Wei Gong

Chinese Academy of Sciences

A penalty method for topology optimization problems

ABSTRACT

We propose a novel penalty framework for compliant mechanism problems, incorporating a convex nonlocal perimeter approximation. We rigorously analyze the existence of solutions to the optimization problem derived from the penalty method. Furthermore, we establish that the discrete problem Gamma-converges to the continuous problem. To solve the discrete problem, we develop a projected gradient method that guarantees strict monotonic descent of the objective function. Numerical experiments on the compliant mechanism and heat dissipation problems validate the effectiveness of the proposed method. We also generalize this approach to minimum compliance problems with pointwise stress constraints. This is a joint work with Yuanda Ye.

12:10-12:30 | Shengfeng Zhu

East China Normal University

Co-authors: Jiajie Li (Shanghai Jiao Tong University); Hui Yang (East China Normal University)

Phase-Field Topology Optimization for Thermo-Fluid Coupled Systems

ABSTRACT

We present a phase-field based framework for topology optimization in thermo-fluid coupling systems. The existence of optimal solutions is established, and the Fréchet differentiability of the state variables with respect to the design field is proven. Based on this, we derive gradient flow formulations for both smooth and obstacle-type potentials. A stabilized semi-implicit scheme is introduced, while a primal-dual active set strategy is employed to handle variational inequalities. Numerical results demonstrate the efficiency and robustness of the proposed approach.

12:30-12:50 | Julius Fergy Rabago

Kanazawa University

Topological and Shape Optimization Methods for Inverse Shape Reconstruction

ABSTRACT

This talk focuses on inverse reconstruction problems governed by elliptic partial differential equations, where the objective is to identify unknown subregions associated with discontinuous coefficients from boundary measurements. We discuss numerical methods based on topological sensitivity analysis and shape optimization for recovering the location and geometry of hidden structures. Particular emphasis is placed on the development of efficient reconstruction algorithms, robustness with respect to noisy measurements, and applications to interface detection problems arising in applied sciences and engineering. This is based on joint work with L.~Afraites (Université Sultan Moulay Slimane, Morocco), A.~Hadri (Université Ibn Zohr, Morocco), and M.~Hrizi (Université de Monastir, Tunisia).

MS33

Geometric Shape Generation (II)

Main organizer	Joseph Cho (Handong Global University)
Co-organizers	Seong-Deog Yang (Korea University); Masashi Yasumoto (Tokushima University)

DESCRIPTION

Differential geometry provides the continuous language for understanding shapes and symmetries, giving rise to applications in various fields including computer graphics, digital fabrication, and architectural design. In applications, modern computational power allows engineers to simulate, analyze, and optimize complex geometric structures using finite element method, and therefore, it becomes necessary to translate smooth, continuous concepts into discrete objects. Consequently, the discretization of curves and surfaces serves as the essential first step in any robust shape generation pipeline.

Discrete differential geometry offers a comprehensive theoretical framework to address this challenge. Rather than relying on arbitrary or purely numerical approximations, this field provides elegant solutions to the discretization problem that deeply respect and preserve the inherent mathematical structures, invariants, and symmetries that characterize the shape under consideration. This second part of the "Geometric Shape Generation" minisymposium will be a single session minisymposium, focusing on the foundational mathematical frameworks that enable the principled discretization of geometric objects. While maintaining an eye toward real-world applications, the session approaches discrete shape generation from a mathematical perspective. Featuring four speakers rooted in pure mathematics, the presentations will emphasize the theoretical underpinnings of how continuous geometric properties can be faithfully and rigorously translated into discrete objects.

MS33 | 11:50-13:10 | Room S1

11:50-12:10 | Shogo Shimada

Tokushima University

Backlund transformations for curves and their applications to semi-discrete K-surfaces

ABSTRACT

Transformation theory of surfaces plays an important role in the study of integrable systems. We first focus on Backlund transformations for surfaces with constant negative Gaussian curvature (K-surfaces). Backlund transformations provide new K-surfaces from a given one and, at the same time, generate new solutions to the sine-Gordon equation - the structure equation of K-surfaces - from known ones.

We then introduce Backlund transformations for curves with constant nonzero torsion. We show that these transformations give rise to two types of semi-discrete integrable equations, generalizing results obtained by Calini and Ivey. Furthermore, we derive superposition principles for solutions of these equations through the geometry of semi-discrete K-surfaces. Finally, we present examples of semi-discrete K-surfaces constructed via these superposition principles. This is joint work with Masashi Yasumoto.

12:10-12:30 | Takeshita Sakuma

Tokushima University

Iterated minimal Darboux transformations

ABSTRACT

Transformations for surfaces are crucially important in constructing new surfaces. Here we focus on isothermic surfaces. They admit conformal curvature line coordinates, and it is known that they admit various transformations.

In this presentation, we introduce the permutability of transformations for isothermic surfaces in the Euclidean space. We show that a superposition principle of Darboux transformations for minimal surfaces can be viewed as an application of the permutability of transformations for isothermic surfaces. Furthermore, we illustrate concrete examples of minimal surfaces obtained by our result, and explore their asymptotic behaviors. This is joint work with Masashi Yasumoto.

12:30-12:50 | Denis Polly

TU Wien

Discrete maximal surfaces from incircular nets**ABSTRACT**

Incircular nets have been used in the statistical mechanics community to study the Ising model. Surprisingly, it turned out that a certain lift of an incircular net in Lorentz space converges to a maximal surface as the model approaches its thermodynamic limit. This motivates the question, which of these lifts, interpreted as discrete surfaces, can already be considered maximal in the discrete category. In this talk, we will describe a subclass of isothermic incircular nets that lift to (discrete) S-isothermic surfaces. Translating an approach introduced by Bobenko, Hoffmann and Springborn (for minimal surfaces in Euclidean space), we will then identify a subclass of isothermic incircular nets that correspond to discrete maximal surfaces and their associated families. This talk is based on joint work with Niklas Affolter, Felix Dellinger, Christian Müller and Nina Smeenk

12:50-13:10 | Gudrun Szewieczek

University of Innsbruck

Bistable kinematic structures from integrable discrete surfaces**ABSTRACT**

Bistable, or “snapping,” structures have the ability to hold two stable states without continuous energy input. This talk introduces a novel class of such systems: snapping four-bar nets. These are multi-looped kinematic chains that possess exactly two distinct assembly configurations and zero degrees of freedom. A transition between these states is not a rigid-body motion but a “snap-through” enabled by material flexibility.

Central to this talk is an unexpected bridge between kinematics and discrete differential geometry. We demonstrate how these bistable structures can be systematically designed using discrete Koenigs nets—a broad class of integrable discrete surfaces that includes, among others, discrete minimal surfaces.

This is joint work with Daniel Huczala, Martin Pfurner and Hans-Peter Schröcker.

CONTRIBUTED TALKS

Monday, August 24 2026

CT01

High-Order and Structure-Preserving Numerical PDE Methods

Date & time	Monday, August 24 2026, 09:50-11:10
Room	I1
Chair	Jaemin Shin

09:50-10:06 | KA LUN LEUNG

HKUST

A Structure-Preserving Scheme for Computing the Gradient of the Eikonal Equation

ABSTRACT

In this presentation, we introduce a structure-preserving method for computing the normalized traveltimes gradient, or orientation field, governed by the eikonal equation. Instead of solving the scalar eikonal equation first and then approximating its gradient, we directly evolve the orientation field as a spherical-valued solution. The talk will focus on the derivation of the governing equation for the first-arrival orientation field and the construction of a geometry-preserving numerical update scheme. The discretization combines a Godunov-type upwind approximation, the analytical derivative of spherical linear interpolation (SLERP), and a spherical forward Euler (SFE) pseudo-time evolution. This design keeps all iterates on S^2 without projection or normalization. Numerical examples in two and three dimensions demonstrate the accuracy and geometric consistency of the method. This is joint work with Prof. Shingyu Leung (HKUST, Hong Kong SAR).

10:06-10:22 | Zelin Xin

Nanjing University of Aeronautics and Astronautics

Co-authors: Chunwu Wang (Nanjing University of Aeronautics and Astronautics); Pei Fu (Nanjing University of Aeronautics and Astronautics)

A Hybrid WENO Method for Hyperbolic Conservation Laws on the Polygonal Mesh With Mixed Elements

ABSTRACT

In this talk, we present one class of high-order hybrid weighted essentially non-oscillatory (WENO) schemes for solving the hyperbolic conservation laws based on the finite volume framework. The method is designed for unstructured polygon meshes consisting of both triangular and quadrilateral elements. We first use a distance-dependent weighted least squares reconstruction method, where the distances between stencil cells and the target cell are incorporated into the polynomial reconstruction to determine the reconstruction coefficients. Then, a hybrid strategy is introduced that uses an efficient troubled cell indicator to selectively apply characteristic decomposition and nonlinear weights, thereby reducing computational cost. The proposed scheme effectively suppresses spurious oscillations and improves computational efficiency. Numerical experiments demonstrate that the hybrid method accurately captures discontinuities and achieves a notable reduction in computational expense.

10:22-10:38 | Wensheng Zhang

Chinese Academy of Sciences

High-order difference schemes for poroelastic wave simulation

ABSTRACT

In this talk, I will introduce the high-order finite-difference schemes on a staggered-grid for the 2D poroelastic wave equations with spatially varying material parameters. Based on the energy method, we get the sufficient stability condition for numerical computations. This allows to find suitable time and spatial steps according to material parameters and the difference scheme coefficients. Numerical examples verify the theoretical analysis of our method. The perfectly matched layer is adopted in order to eliminate boundary reflections.

10:38-10:54 | Haruki Takemura

The University of Tokyo

Fully semi-Lagrangian schemes using spline and Hermite interpolation for nonlinear advection--diffusion equations
ABSTRACT

The standard semi-Lagrangian technique handles the advection term by tracing characteristic curves backward over each time step. In contrast, a fully semi-Lagrangian scheme applies semi-Lagrangian techniques to both the advection and diffusion terms, where the treatment of the diffusion term is based on a probabilistic representation of the solution. We study the convergence of fully semi-Lagrangian schemes applied to one-dimensional nonlinear advection--diffusion equations, including the Burgers equation, on a periodic domain. Higher-order interpolation operators, such as spline and Hermite interpolations, are used for discretization in space. For interpolation of degree $(2s-1)$, we establish error estimates of order $O(\Delta t + h^{2s} \Delta t)$ in the L^2 -norm and $O(\Delta t + h^s \Delta t^{1/2})$ in the H^s -norm, where h is the spatial mesh size and Δt is the time step size.

10:54-11:10 | Zhe Li

Shanghai Normal University

Unconditional stability and hp-convergence of multi-interval spectral collocation time-stepping for parabolic equations
ABSTRACT

We propose a high-order fully discrete scheme for second-order parabolic equations, combining an hp finite element method in space with spectral collocation in time using Legendre-Gauss-Lobatto points. A multi-interval time-stepping strategy is introduced to handle long-time evolution and local singularities. The scheme is unconditionally stable, with rigorous error estimates showing spectral accuracy in time and optimal hp convergence in space for smooth solutions. To resolve initial singularities, we employ geometrically refined time grids and linearly increasing polynomial degrees, which restore exponential convergence. Numerical experiments on linear problems, Allen-Cahn and Gray-Scott equations, and comparisons with other methods confirm the theoretical results and demonstrate robustness.

Tuesday, August 25 2026

CT04

Mathematical Biology, Reaction Networks, and Collective Dynamics

Date & time	Tuesday, August 25 2026, 11:20-12:40
Room	M
Chair	Hyeongki Park

11:20-11:36 | ShyanShiou Chen

Department of Mathematics, National Taiwan Normal University

An Introduction to Fractional-Order HIV Dynamics: Memory Effects, Transmission Mechanisms, and Immune Response

ABSTRACT

Fractional-order differential equations provide a useful framework for modeling biological systems with memory effects. In HIV dynamics, such memory may arise from intracellular processes, immune activation, treatment response, and long-term virus-host interactions. This work introduces a fractional-order HIV infection model that incorporates virus-to-cell transmission and cell-to-cell transmission. The main variables include uninfected target cells, infected cells, free virus particles, and immune effector cells. The basic reproduction number (R_0) is derived and interpreted in terms of the two infection routes. Numerical simulations illustrate how the fractional order and immune response delay influence viral load and immune activity. The results suggest that memory effects may alter transient dynamics, while (R_0) remains central to determining viral persistence or clearance.

11:36-11:52 | Chang-Yuan Cheng

National Kaohsiung Normal University

Within-host virus infections through high-order interactions between lymphatic organs

ABSTRACT

When considering interconnected lymphatic organs as simplicial structures, the entire system becomes a complex network. To study how high-order infections impact viral dynamics, we first simplify the network system to a mean-field equation that describes coordinated viral dynamics across multiple infection sites. Even the simplified model may display a backward bifurcation, leading to bistable dynamics. This means that a mild initial infection may disappear, but a severe initial infection can cause the virus to persist. Moreover, we study the local and global stability of equilibria, Hopf bifurcation, and codim 2 bifurcations in the mean-field system. This work is a collaboration with Chun-Hsien Li and Shyan-Shiou Chen.

11:52-12:08 | Dylan Antonio Talabis

University of the Philippines-Diliman

Approximating Multistable Parameter Regions in Mass Action Systems

ABSTRACT

Identifying parameter regimes that support multistability is a central challenge in mass action systems. Structural theory can determine whether multistationarity is possible, but it often leaves open the more practical question of where stable multistability occurs and how its parameter regions can be described. We present a computational and machine-learning framework for discovering and characterizing rare multistable regimes in mass-action systems. The framework combines Latin hypercube sampling, adaptive sampling, and interpretable surrogate modeling. A surrogate is trained and used to guide later sampling rounds toward regions with high predicted probability of multistability. In benchmark networks, the method detects multistability as a rare but reproducible phenomenon and recovers qualitative agreement with known multistationarity conditions. The approach provides a practical bridge between reaction network theory, nonlinear dynamics, and interpretable data-driven exploration.

12:08-12:24 | Bo-Sheng Chen

National Yang Ming Chiao Tung University

Wave propagation in non-cooperative nonlocal diffusive systems with network structures**ABSTRACT**

This work investigates the existence and qualitative properties of traveling waves for a class of non-cooperative nonlocal diffusive systems on complex networks, motivated by multi-group disease-transmission models. In this model, movement is described by an integral kernel that permits long-distance jumps (e.g., animal migration, air travel, seed dispersal), thereby capturing dispersal effects absent in classical random diffusion.

Due to the lack of classical elliptic estimates for nonlocal diffusive operators, analyzing traveling wave solutions presents significant challenges. To overcome these difficulties, we establish a nonlocal diffusive Harnack-type inequality in coupled systems. This provides the essential estimates to establish the existence of a minimal wave speed for traveling waves.

This is a joint work with Prof. Chang-Hong Wu.

12:24-12:40 | Yu-Hao Liang

National University of Kaohsiung

Bipartite Flocking Dynamics in Time-Delayed Cucker-Smale Systems**ABSTRACT**

The emergence of collective behavior in multi-agent systems is strongly affected by interaction structures and communication delays. In this talk, we study a class of time-delayed Cucker-Smale models with both cooperative and competitive interactions, leading to bipartite flocking phenomena. Under a spanning-tree communication topology with one leader, we derive sufficient conditions ensuring unconditional bipartite flocking. The analysis reveals how delayed information exchange influences the asymptotic formation of two coherent groups moving with opposite velocities. Several numerical examples are presented to illustrate the theoretical findings.

CT02

Kinetic Equations, Complex Fluids, and Vortex Dynamics

Date & time	Tuesday, August 25 2026, 15:50-17:10
Room	S1
Chair	Jinwoo Jang

15:50-16:06 | Hung-Wen Kuo

National Cheng Kung University

Initial layer for the Boltzmann equation

ABSTRACT

Understanding the relation between the Boltzmann equation in kinetic theory and fluid dynamics requires a precise description of the singular layers that arise when the mean free path is small. This work focuses on the initial layer, where discontinuities in the initial data propagate through the Boltzmann dynamics. We describe these discontinuities in both the space-time variables (x, t) and the microscopic velocity $\boldsymbol{\xi}$.

Our approach is based on an explicit construction of the Green's function, which gives a quantitative representation of the solution. This structure allows us to analyze how nonlinear collisions interact with transport and how discontinuities evolve. The results identify the explicit kinetic form of the singularities and show that fluid-like waves already emerge within the initial layer. Thus, the construction provides a bridge between the Boltzmann equation and hydrodynamic behavior. This is joint work with Tai-Ping Liu and Shih-Hsien Yu.

16:06-16:22 | Dingqun Deng

Akita University

Uniqueness of Weak Solutions to the Non-cutoff Boltzmann equation

ABSTRACT

In this talk, we study the uniqueness of weak solutions to the non-cutoff Boltzmann equation with moderately soft potentials, a classical kinetic model. The uniqueness of large weak solutions is challenging due to the nonlinearity and limited regularity. To overcome these difficulties, we utilize dilated dyadic decompositions in spatial-velocity frequency phase space to capture hypoellipticity and reduce the fractional derivative structure of the Boltzmann collision operator to a zeroth-order form. Within this framework, we establish the uniqueness of large-data weak solutions under the assumption of finite L^2 - L^r energy. The main novelties are the zeroth-order reduction and the negative-order hypoelliptic estimate, which gains integrability in (t, x) , and together they overcome the difficulties posed by large solutions.

16:22-16:38 | Jiabao Yang

Musashino University

Stability-Function Design of a Dissipative Multistage Directional Discrete-Gradient Method for Nonsmooth Nonconvex Optimization

ABSTRACT

Eftekhari, Vandereycken, Vilmart, and Zygalakis (2021) proposed the Runge-Kutta-Chebyshev descent method (RKCD) for strongly convex optimization, viewing optimization algorithms as discretizations of gradient flows. Riis, Ehrhardt, Quispel, and Schonlieb (2022) proposed randomised Itoh-Abe methods for nonsmooth and nonconvex objectives and showed convergence to Clarke stationary points.

In our previous work, we combined RKCD's multistage structure with Riis-type directional discrete-gradient updates and proved convergence to Clarke stationary points. This study designs the multistage coefficients via stability functions. Near a smooth and locally convex minimizer, the behavior is described by a quadratic model, and Hessian eigenvalues represent local curvatures. Since the stability function is rational rather than Chebyshev-polynomial-type, we formulate coefficient design as a Zolotarev minimax problem and place its zeros accordingly to improve local error damping.

16:38-16:54 | Sri Pudjaprasetya

Institut Teknologi Bandung

Savage-Hutter Modeling of Avalanches in U-shaped Bays: Numerical Simulations and Validation with Analytical Solutions**ABSTRACT**

Gravity-driven shallow granular flows in inclined channels with parabolic-like cross-sections can be modeled using the Savage-Hutter equations. Such flows occur in avalanches descending mountain valleys or submarine landslides in underwater canyons. This study develops a momentum-conserving staggered-grid (MCS) numerical scheme for simulating Savage-Hutter flows in U-shaped bays. Zahibo's analytical dambreak solutions are employed to validate the scheme, with extensions provided to complete his explicit formulas. The simulations capture the evolution of dambreak granular flows in various U-shaped bays, matching analytical results and reproducing accelerating avalanche effects. Additional simulations address granular masses sliding down inclined U-shaped bays that smoothly transition into flat bays, demonstrating the model's capability to reproduce diverse flow scenarios and complex terrain effects.

16:54-17:10 | Takeshi Gotoda

Institute of Science Tokyo

Enstrophy variation induced by vortex collapse in inviscid flows**ABSTRACT**

Enstrophy dissipation in the zero-viscosity limit is a key feature of 2D turbulence. This property suggests that non-smooth solutions of the 2D Euler equations can dissipate enstrophy. We investigate this variation through vortex dynamics by focusing on point-vortex collisions in inviscid flows. These motions are governed by the point-vortex system formally derived from the 2D Euler equations, which can exhibit self-similar collapsing solutions. Previous studies showed that a triple collapse of point vortices leads to enstrophy dissipation under the filtered-Euler equations, which is a regularized Euler model. This work numerically demonstrates that specific four and five point-vortex solutions of the 2D filtered-Euler equations converge to self-similar collapsing orbits, resulting in enstrophy dissipation as the filter scale approaches zero.

Wednesday, August 26 2026

CT07

Data-Driven Geometry, Imaging, and Materials

Date & time	Wednesday, August 26 2026, 09:50-11:10
Room	I1
Chair	Seungchul Lee

09:50-10:06 | DMITRII CHAIKOVSKII

Shenzhen MSU-BIT University

Ultrametric-aware completion of mitochondrial DNA distance matrices for phylogenetic reconstruction

ABSTRACT

Mitochondrial DNA distance matrices are widely used for distance-based phylogenetic reconstruction, but all pairwise alignments become costly for many taxa, and incomplete matrices may distort tree topology and branch lengths. Generic completion methods often ignore the hierarchical, approximately ultrametric structure of evolutionary distances.

We propose Hyb-Adam-UM, a hybrid method that starts from a limited Needleman-Wunsch alignment backbone and estimates missing entries by minimizing a robust triplet-based ultrametric-violation functional. Observed distances are kept fixed, with symmetry, non-negativity, and zero diagonal enforced; the constrained non-smooth problem is solved by an Adam-style finite-difference scheme.

Tests on a 15x15 monkey mtDNA distance matrix with up to 85% missing data show that Hyb-Adam-UM reduces ultrametric violations, remains competitive in reconstruction and Neighbor-Joining fidelity, and performs best under extreme missingness.

10:06-10:22 | Suh-Yuh Yang

National Central University

A Variationally Regularized U-Net for Medical Image Segmentation

ABSTRACT

We propose a variationally regularized U-Net (VR-U-Net) for accurate and interpretable medical image segmentation. The method integrates deep neural networks with variational modeling through a two-stage loss that combines pixel-level fidelity and region-level regularity. A TV-regularized softmax is introduced at the network output to generate smooth quasi-characteristic probability maps, which are trained by a cross-entropy loss and used to initialize a variational refinement stage. This refinement minimizes a modified Chan-Vese energy via an unconditionally energy-stable iterative thresholding scheme, improving regional homogeneity and boundary alignment. The refined characteristic functions are further supervised by a Dice loss. The resulting objective enables end-to-end training with a clear variational interpretation. Experiments on several medical image datasets show that VR-U-Net outperforms the standard U-Net and related variants.

10:22-10:38 | Gary Choi

The Chinese University of Hong Kong

Density-Equalizing Map with Applications

ABSTRACT

We present surface and volumetric mapping methods based on a natural principle of density diffusion. Specifically, we start with a prescribed density distribution in a surface or volumetric domain and then create shape deformations with different regions enlarged or shrunk based on the density gradient. Using the proposed methods, we can easily achieve various mapping effects with controllable area changes. Applications to shape registration, morphing, remeshing, medical shape analysis, and data visualization will be presented.

10:38-10:54 | Hao Wang

Sichuan University

Accelerating the Computations of the Minimum Energy Paths in Solid-State Phase Transitions: Towards a Transfer Learning Framework**ABSTRACT**

Solid-state phase transitions typically follow a Minimum Energy Path (MEP). Classical methods such as G-SSNEB compute the MEP in the full high-dimensional configuration space, which becomes prohibitive when paths must be scanned over pressures, defect types, and system sizes. We propose the Preset Structure Strain Path (PSSP) method, which uses feature extraction and transfer learning to compute MEPs efficiently across these conditions. PSSP is based on the fact that in defective systems, lattice strain sets the direction of the MEP, while the local atomistic environment changes little but governs the energy. PSSP fully exploits this separation by presetting the displacement field as a transferable feature and optimizing only the lattice evolution in a low-dimensional space. By doing this, the strain paths learned in one setting can be reused under different pressures, defects and system sizes.

CT05

Discrete Dynamics, Combinatorics, and Optimization

Date & time	Wednesday, August 26 2026, 15:50-17:10
Room	I1
Chair	Youngjoon Hong

15:50-16:06 | Akane Kawaharada

National Defense Academy of Japan

Classification of orbits in linear cellular automata based on initial seeds

ABSTRACT

The orbits of cellular automata (CAs), which are discrete mathematical models, are known to generate fractals with many examples of self-similarity. When using a CA as a fractal generator, we usually consider orbits from the single-site seed, an initial configuration that gives only a single cell a positive state. In the case of a two-state CA, the seed is uniquely determined to be 1, because the possible states of each cell are 0 or 1. However, in CAs with three or more states, there are multiple candidates for the seed. For example, in three-state CA, the possible states are 0, 1, and 2, and the seed candidates are 1 and 2. In a four-state CA, the possible states are 0, 1, 2, and 3, and the seed candidates are 1, 2, and 3. As the number of possible states increases, the number of seed candidates also increases. In this talk, we will prove that it is sufficient to consider only the case where the seed of linear CAs is 1.

16:06-16:22 | Akiko Fukuda

Shibaura Institute of Technology

Co-authors: Sennosuke Watanabe (The University of Fukuchiyama); Yuki Nishida (Kyoto Prefectural University); Junta Matsukidaira (Ryukoku University)

Enumeration and characterization of number-conserving rules in second-order cellular automata

ABSTRACT

Number-conserving cellular automata are an important class of discrete dynamical systems that have been widely studied in connection with particle systems, traffic flow models and conservation laws. This study investigates number-conserving rules in second-order binary three-neighbor cellular automata. We present a polynomial representation of the local rules and their general expression. Using this representation, the number-conservation condition is transformed into a system of linear equations. Solving this system of equations under binary constraints reveals that 74 of the 2^{64} possible rules satisfy the number-conservation property. Furthermore, these rules are classified into 30 equivalence classes under standard equivalence relations. Additionally, a necessary and sufficient condition for a cellular automaton to be number-conserving is derived.

16:22-16:38 | Yuki Nishida

Kyoto Prefectural University

Co-authors: Sennosuke Watanabe (The University of Fukuchiyama); Yoshihide Watanabe (Doshisha University)

Tropical linearization and stability analysis of difference equations at the tropical origin

ABSTRACT

The tropical semiring is a semiring of real numbers together with an additional element “infinity”, where the operations of “min” and “+” are regarded as addition and multiplication, respectively. By taking the ultradiscrete limit of some discrete dynamical systems, we obtain dynamical systems described in terms of the tropical semiring. We propose a tropical linearization approach for the stability analysis of such dynamical systems. We show that the fixed point at the tropical origin is asymptotically stable if the minimum eigenvalue of the tropical Jacobian matrix is positive. On the other hand, the tropical origin is proved to be unstable if the minimum eigenvalue of the tropical Jacobian matrix is negative. Since infinity and 0 are the tropical additive and multiplicative identities, respectively, these results are analogous to those in the usual linearization process. We also exhibit an application of our result to multi-machine interactive production processes.

16:38-16:54 | Hui-Lan Chang

National University of Kaohsiung

Traceability Codes and an Upper Bound for 4-Traceability**ABSTRACT**

Traceability codes, introduced by Chor, Fiat, and Naor (1994), are combinatorial structures for traitor tracing schemes protecting digital content. A t -traceability code identifies the source of unauthorized content assuming at most t users colluded. Let $M_{TA}(n, q, t)$ be the maximal cardinality of q -ary t -traceability codes of length n . Blackburn, Etzion, and Ng (2010) asked whether $M_{TA}(n, q, t) \leq c \cdot q^{\lceil n/t^2 \rceil}$ for some constant c depending only on n and t . This has been validated for $t=2$ (Blackburn et al., 2010) and $t=3$ (Shangguan, Ma, and Ge, 2018). We present key lemmas for traceability codes of any strength, yielding upper bounds when the minimum distance is sufficiently large. These lemmas establish upper bounds for $t=3$ and $t=4$, further answering the question affirmatively. Recent developments are also discussed. Joint work with Ching-Chih Hsu.

Thursday, August 27 2026

CT06

Special Functions, Nonlocal Problems, and Wave Equations

Date & time	Thursday, August 27 2026, 08:30-09:50
Room	H1
Chair	Dongwook Shin

08:30-08:46 | Tzon-Tzer Lu

Department of Applied Mathematics, National Sun Yat-sen University

Picard and Adomian Decomposition Methods Solving Fractional ODEs

ABSTRACT

Fractional calculus is the hottest research topic recently. Fractional differential equations can model many practical problems. So it has many applications in fluid dynamics, geology, material science, electromagnetism, astrophysics, optics, bio-sciences, and economics, to name a few. Nowadays, fractional calculus plays a crucial role in all disciplines.

Picard's iteration and Adomian decomposition methods are efficient, reliable, and powerful techniques for solving differential equations. In this talk, we employ them to compute fractional ordinary differential equations with various types of fractional derivatives, e.g., Riemann-Liouville, Caputo, Caputo-Fabrizio, Atangana-Baleanu. Both methods can solve parameter problems that general numerical methods fail to do. Finally, we compare these two methods to identify their advantages and disadvantages, and remark on their possible extension to fractional partial differential equations.

08:46-09:02 | Shinya Miyajima

Tohoku University

Co-authors: Amir Sadeghi (Islamic Azad University)

Numerical algorithms for complementary error matrix function

ABSTRACT

A solution to systems of partial differential equations can be written by using the complementary error matrix function. In this talk, we propose three numerical algorithms for computing the matrix function. The first, second, and third algorithms are based on the truncation of the Taylor expansion, Gauss-Legendre quadrature, and quadrature based on the double exponential formula, respectively. The first algorithm is designed such that the truncation error is equal or smaller than a given tolerance. The second and third algorithms are constructed so that the sum of truncation and discretization errors is equal or smaller than the tolerance. We see from the results of the numerical experiments that the proposed algorithms improve upon the use of general purpose alternatives when the input matrix is unsymmetric or the norm of the matrix is not large.

09:02-09:18 | Tomoki Okamoto

Musashino University

Co-authors: Tatsuki Mori (Musashino University)

Spectral structure of a nonlocal linearized eigenvalue problem for a 1D phase-field model

ABSTRACT

We investigate the spectral structure of a nonlocal linearized eigenvalue problem arising from a one-dimensional phase-field model. Because of the nonlocal term, Sturm-Liouville theory cannot be applied directly, and additional ideas are required to understand the spectral structure. Miyamoto-Mori-Tasaki-Tsujikawa-Yotsutani (JDE, 2025) considered the case in which the coefficient multiplying the nonlocal term is small. By comparing the problem with the corresponding problem obtained by removing the nonlocal term, they determined the spectral structure associated with symmetric solutions and described the behavior of the eigenvalues. In this talk, we consider the case in which this coefficient is large. We prove that the monotonicity of the two eigenvalues arising from the nonlocal term changes as the diffusion coefficient varies, and that both eigenvalues are monotone functions of the diffusion coefficient when the parameter multiplying the nonlocal term exceeds 4.

09:18-09:34 | Hao Hu

Academy of Mathematics and Systems Science, Chinese Academy of Sciences

Scaling Optimized Hermite Approximation Methods**ABSTRACT**

Classical spectral approximation theories, which are established for spaces with finite smoothness, are incapable of describing the sophisticated convergence characteristics of scaled Hermite and Laguerre approximation methods. This paper constructs a novel unified error estimation framework for scaled spectral approximations on unbounded domains based on generalized Hermite and Laguerre functions. By rigorously quantifying the trade-off between spatial truncation and frequency truncation errors, the proposed framework enables the systematic and rational selection of optimal scaling factors. We theoretically prove that the optimal scaling factor balances different types of truncation errors, leading to rigorous characterizations of general exponential convergence rates - a key result that is unattainable via classical spectral approximation theories. Moreover, this framework elucidates the counterintuitive pre-asymptotic convergence behaviors of unscaled Hermite and Laguerre approximations for functions with algebraic decay. We further verify the optimality of scaled quadrature rules and reveal a non-trivial phenomenon: concatenated Laguerre approximations deliver faster convergence rates than standalone Hermite expansions, even for highly smooth functions with Gaussian decay, which contradicts conventional empirical intuition. This study resolves several long-standing open problems concerning the theoretical properties of Hermite and Laguerre spectral approximations.

09:34-09:50 | Angelyn Lao

De La Salle University

Graph-Theoretical Approaches in Epidemiology**ABSTRACT**

Graph-theoretical methods have emerged as powerful mathematical tools for modeling and analyzing the complex interactions that drive disease transmission and population health. By representing individuals, communities, or biological entities as interconnected networks, graph theory provides valuable insights into transmission pathways, disease spread, and the effectiveness of intervention strategies. This presentation will demonstrate how graph-theoretical approaches can be applied to epidemiological data to identify transmission hotspots, detect influential nodes, evaluate contact patterns, and predict disease dynamics. Drawing from applications in infectious disease modeling and public health, the talk will illustrate how network analysis enhances our understanding of epidemic processes and supports evidence-based decision-making for disease prevention, outbreak response, and global health security.

CT03

Scientific Machine Learning for Differential Equations and Multiscale Computing

Date & time	Thursday, August 27 2026, 11:50-13:10
Room	H3
Chair	Jae-Hyuk Lim

11:50-12:06 | Dongwook Shin

Ajou University

Co-authors: Jiyeon Kim (Ajou University); Kyoungjin Jung (Ajou University)

Deep operator networks based on the finite element method

ABSTRACT

Partial differential equations play a central role in the mathematical description of natural and social phenomena. Although classical numerical methods provide reliable solutions, their computational cost can be high in real-time analysis and large-scale simulations. In this talk, we present numerically informed operator networks whose architectures and loss functions are motivated by the finite element method. The proposed framework incorporates finite element discretizations into neural operator learning. In particular, we discuss a convolutional operator network and a sparse neural operator network. These approaches significantly reduce the number of trainable parameters and preserve predictive accuracy. We also analyze convergence, stability, and approximation error. Based on this analysis, we propose training strategies that achieve optimal convergence rates. Numerical experiments support the theoretical findings and show the performance of the proposed methods.

12:06-12:22 | Chang Ma

HKUST

StablePDNet: Enhancing Stability of Operator Learning for Solving Differential Equations

ABSTRACT

Learning solution operators for differential equations with neural networks has shown great potential in scientific computing, but ensuring their stability under input perturbations remains a critical challenge. This paper presents a robust self-supervised neural operator framework that enhances stability through adversarial training while preserving accuracy. We formulate operator learning as a min-max optimization problem, where the model is trained against worst-case input perturbations to achieve consistent performance under both normal and adversarial conditions. We demonstrate that our method not only achieves good performance on standard inputs, but also maintains high fidelity under adversarially perturbed inputs. The results highlight the importance of stability-aware training in operator learning and provide a foundation for developing reliable neural PDE solvers in real-world applications, where input noise and uncertainties are inevitable.

12:22-12:38 | Kazuaki Tanaka

Waseda University

Co-authors: Kohei Yatabe (Tokyo University of Agriculture and Technology)

Rigorous Solution Enclosures for Differential Equations via Neural-Network-Generated Sub- and Super-Solutions

ABSTRACT

Neural networks can approximate solutions of differential equations, but their predictions usually lack rigorous guarantees. We present a Learn and Verify framework for constructing certified solution enclosures. In the learning phase, physics-informed neural networks generate candidate lower and upper bounding functions using a Doubly Smoothed Maximum loss. In the verification phase, interval arithmetic and adaptive subdivision certify the required differential inequalities over the continuous domain, including rounding and discretization effects. The resulting bounds are independent of the training process and provide machine-verifiable certificates for the existence and accuracy of the enclosed solution. Numerical examples for nonlinear ordinary differential equations demonstrate that the framework can provide rigorous solution enclosures.

12:38-12:54 | JIARONG CHEN

Beijing Institute of Technology

Penalty-Free Natural Deep Ritz Method Based on de Rham Complex for High-Dimensional Dirichlet Boundary Value Problems

ABSTRACT

Deep neural networks show great promise for high-dimensional partial differential equations. To address the intractable tuning of penalty parameters for essential boundary conditions, this work extends the Natural Deep Ritz Method (NatDRM) [H. Yu and S. Zhang, J. Comput. Phys., 537 (2025)] to a unified framework for all $d \geq 2$ based on the de Rham complex and penalty-free boundary decomposition: curl-type operators act on dimension-adaptive potentials, Dirichlet constraints are transformed into three coupled Neumann-type subproblems with Ritz-type losses to eliminate the boundary penalty parameter β , and dimension-unified discrete losses, lightweight boundary gauge-fixing regularizations, joint training procedures, and extensions to variable-coefficient elliptic and semilinear Poisson problems are derived. Numerical experiments up to 6D demonstrate that penalty-free NatDRM matches or outperforms optimally tuned DRM and PINN in most cases.

12:54-13:10 | Zhang Huaijia

Beijing Institute of Technology

A Tensor Neural Network Method for High-Order Homogenization of Locally Periodic Elliptic Problems

ABSTRACT

We develop a high-order tensor-neural-network method for locally periodic elliptic multiscale problems $-\nabla \cdot (A(x, x/\varepsilon) \nabla u^\varepsilon) = f$. Unlike the classical periodic case, the locally periodic setting yields a more involved hierarchy of cell problems and corrector equations depending on the slow variable. We derive a computable high-order two-scale expansion and prove an H^1 convergence estimate in boundary-layer-free settings. The tensor neural network (TNN) framework uses tensor-product structure to evaluate high-dimensional integrals by deterministic one-dimensional quadrature, avoiding Monte Carlo errors. This is crucial for high-order homogenization where numerical errors may propagate through successive correctors and destroy the expected convergence rate. Numerical experiments verify the method accurately computes high-order correctors and recovers predicted convergence behavior.

STUDENT CHAPTER TALKS (CT-SC)

Tuesday, August 25 2026

CT-SC A

Optimization, Optimal Transport, and Learning Dynamics

Date & time	Tuesday, August 25 2026, 15:50-17:10
Room	M
Chair	Yihao Xu

Individual talk times follow the published source order and remain to be confirmed.

Feng Yaxin

The Hong Kong University of Science and Technology

Discrete Mean-Field Games on Graphs as Finite-Dimensional Initial-Value Optimization

ABSTRACT

In this work, we propose an initial-value formulation of discrete mean-field games on finite graphs (Graph MFG) and design a neural-network-based solver. Graph MFG describes an infinite number of non-cooperative, interacting homogeneous agents moving between node states along edges to optimize their respective objectives. The Nash equilibrium of a Graph MFG is characterized by a coupled system of ordinary differential equations (ODEs), comprising a forward continuity equation and a backward Hamilton-Jacobi equation at each node of the graph. We focus primarily on potential mean-field games (Potential MFG) on finite graphs, which possess an infinite-dimensional constrained optimization structure. We reformulate Potential MFG as an initial-value, finite-dimensional optimization problem with dynamic constraints, termed Graph MFG-IV. Specifically, the initial condition of the Hamilton-Jacobi equation is treated as the sole optimization variable, constrained by a system of coupled Hamilton-Jacobi and continuity equations that serves as an ODE integrator. This finite-dimensional reformulation avoids time discretization of infinite-dimensional paths and has a substantially smaller search space than the general pathwise problem setting.

Yiyang Li

The Hong Kong Polytechnic University

First-Order Algorithms for Stochastic Multi-Objective Optimization Problems

ABSTRACT

Stochastic multi-objective optimization (SMOO) problems arise in many applications in which multiple conflicting performance criteria are evaluated under uncertainty through their expectations, such as return and risk. In this paper, we develop a projected-gradient algorithm that combines sample average approximation with a scalarization-free approach for SMOO. We introduce a Tikhonov-regularized simplex quadratic program to define a single-valued multi-gradient direction and a regularized Pareto-stationarity measure. We establish the Lipschitz continuity of the induced multiplier and direction mappings on the convex feasible set. We also show that the regularized stationarity measure converges to the Pareto-stationarity measure as the regularization parameter tends to zero. We establish stationarity-complexity results for the proposed algorithm and quantify the sample size required to guarantee approximation accuracy. Numerical results demonstrate the effectiveness of the proposed algorithm.

Seunghoon Jeong

Pohang University of Science and Technology

Transformer Attention Dynamics Through the Lens of Nonconvex Wasserstein Gradient Flows

ABSTRACT

Since the seminal Transformer architecture introduced by Vaswani et al., attention mechanisms have become a central organizing principle in modern machine learning, including large language models and many other learning systems. In the mean-field regime, simplified attention layers can be viewed as interacting particle systems whose continuum limit is governed by a McKean-Vlasov equation. Such equations can often be formulated as Wasserstein gradient flows over the space of probability measures with finite second moments.

In this talk, I will discuss recent results on the analytic properties of stationary McKean-Vlasov solutions and their role in the long-time behavior of simplified attention dynamics. In particular, although the underlying energy landscape is generally nonconvex, we show that the associated McKean-Vlasov dynamics can still converge asymptotically to a stationary solution. This suggests that simplified Transformer attention dynamics possess an intrinsic long-time selection mechanism governed by the stationary structure of nonconvex Wasserstein gradient flows. This is joint work with Beomjun Choi (KAIST) and Geuntaek Seo (POSTECH).

XU Yihao

The Chinese University of Hong Kong

Entropy-Regularized Causal Optimal Transport: Improved Bregman Projections and Stopping Duality

ABSTRACT

Optimal transport (OT) provides a general framework for comparing probability distributions and solving matching problems, but direct discretizations often require large linear programs. Entropy-regularized optimal transport (EOT) replaces this hard problem with a structured convex formulation using Kullback-Leibler geometry, enabling scalable Bregman-projection updates. We study causal EOT, in which an information constraint enforces non-anticipativity. For Brownian randomized stopping with a prescribed time law, the coupling must satisfy both marginal and causal constraints, so standard EOT algorithms cannot be applied directly.

To address this issue, we develop an improved Bregman-projection scheme designed to handle the marginal and non-anticipativity constraints. It decomposes the discretized causal problem into tractable projection steps, replacing a global linear-program solve with scalable iterative updates. A delayed causal construction supplies finite-entropy feasible couplings and, for atomless time marginals and bounded continuous costs, connects the regularized values to causal OT as the entropy parameter vanishes. From a complementary optimal-stopping viewpoint, a time-law Lagrange multiplier yields a finite-horizon dual. This dual both clarifies the constraints and provides a complementary computational formulation.

Wang Aokun

Nanyang Technological University, Singapore

DPOT: A DeepParticle Method for Computation of Optimal Transport with Convergence Guarantee

ABSTRACT

We propose a novel machine-learning approach for computing the optimal transport map between two continuous distributions from their unpaired samples, based on the DeepParticle method. The proposed method leads to a min-min optimization problem during training and imposes no restrictions on the network architecture. Theoretically, we establish a weak convergence guarantee and a quantitative error bound between the learned map and the optimal transport map. Our numerical experiments validate the theoretical results and the effectiveness of the new approach, particularly on real-world tasks.

Di Hou

Department of Mathematics, National University of Singapore, Singapore

A Low-Rank Augmented Lagrangian Method for Polyhedral-SDP and Moment-SOS Relaxations of Polynomial Optimization

ABSTRACT

Polynomial optimization problems can be reformulated as convex conic programs, but the resulting relaxations are often computationally demanding at large scale. In this work, we propose RiNNAL-POP, a low-rank augmented Lagrangian method for solving large-scale polyhedral-SDP relaxations of polynomial optimization problems. The method combines a tailored projection scheme for the numerous nonnegativity and consistency constraints with an exploitation of hidden facial structure to eliminate many linear constraints. A projected-gradient step adaptively adjusts the factorization rank and helps escape spurious local minima. We also extend the framework to moment-SOS relaxations. Numerical experiments on benchmark problems demonstrate the robustness and efficiency of RiNNAL-POP.

Wednesday, August 26 2026

CT-SC B

Scientific Machine Learning and Data-Driven Inference

Date & time	Wednesday, August 26 2026, 09:50-11:10
Room	M
Chair	Jungmin LEE

Individual talk times follow the published source order and remain to be confirmed.

Chenlong Pei

The Academy of Mathematics and Systems Science, Chinese Academy of Sciences

FLUID: Flow-Based Unified Inference for Dynamics

ABSTRACT

Bayesian filtering and smoothing for high-dimensional nonlinear dynamical systems are fundamental yet challenging problems in many areas of science and engineering. Gaussian-based approximations often break down when posterior distributions are highly nonlinear or non-Gaussian, while sequential Monte Carlo methods can be computationally demanding and often suffer from particle degeneracy, especially over long time horizons or when smoothing distributions are required. Recent deep generative models are capable of representing complex high-dimensional posteriors, but they typically treat filtering and smoothing separately and often rely on costly per-instance optimization, which limits their applicability in online and large-scale settings.

To address these challenges, we propose FLUID, a flow-based unified amortized inference framework for filtering and smoothing dynamics. The core idea is to encode each observation history into a fixed-dimensional summary statistic and use this shared representation to learn both a forward flow for the filtering distribution and a backward flow for the backward transition kernel. Specifically, a recurrent encoder maps each observation history to a fixed-dimensional summary statistic whose dimension does not depend on the length of the time series. Conditioned on this shared summary statistic, the forward flow approximates the filtering distribution, while the backward flow approximates the backward transition kernel. The smoothing distribution over an entire trajectory is then recovered by combining the terminal filtering distribution with the learned backward flow through the standard backward recursion. By learning the underlying temporal evolution structure, FLUID also supports extrapolation beyond the training horizon. Moreover, by coupling the two flows through shared summary statistics, FLUID induces implicit regularization across latent-state trajectories and improves trajectory-level smoothing. In addition, we develop a flow-based particle-filtering variant that provides an alternative filtering procedure and enables effective-sample-size (ESS) diagnostics when explicit model factors are available. Numerical experiments on a high-dimensional advection-diffusion system, a strongly nonlinear stochastic-volatility model, a high-dimensional PDE system, and Lorenz systems in both single-scale and two-scale settings demonstrate that FLUID provides accurate approximations of both filtering distributions and smoothing paths.

CHENG Zilan

Nanyang Technological University, Singapore

Preconditioned One-Step Generative Modeling for Bayesian Inverse Problems in Function Spaces

ABSTRACT

We propose a machine-learning algorithm for Bayesian inverse problems in the function-space regime. Based on one-step generative transport, the method learns an amortized neural operator whose pushforward of a Gaussian source approximates the posterior distribution conditioned on each new observation. We show that white-noise sources are incompatible with the function-space limit and therefore adopt a prior-aligned Gaussian random field (GRF) as the source. We justify this choice through the Lipschitz regularity of the resulting one-step conditional posterior transport and numerical experiments on linear inverse and PDE-based inverse problems. The method is not distilled from Markov chain Monte Carlo (MCMC): it is trained only with prior samples and simulated partial noisy observations. Once trained, it generates a 64×64 posterior sample in approximately 10-3 s, avoiding repeated forward-model evaluations in MCMC and repeated network evaluations in multistep generative samplers while matching key posterior summaries.

Seungwan Han

Pohang University of Science and Technology

A Scaled TW-PINN for Traveling-Wave Solutions of Reaction-Diffusion Equations with General Coefficients

ABSTRACT

We propose a physics-informed neural network framework, termed scaled TW-PINN, for computing traveling-wave solutions of reaction-diffusion equations with general reaction and diffusion coefficients in arbitrary spatial dimensions. By introducing a scaling transformation based on the traveling-wave formulation, we reduce the original problem to a one-dimensional equation with unit reaction and diffusion coefficients. This reduction enables the construction of a single PINN solver that can be reused across different coefficient regimes and spatial dimensions. Numerical experiments in one and two spatial dimensions, together with comparisons with the wave-PINN method, demonstrate the accuracy and computational advantages of the proposed approach. We further extend the proposed framework to more general initial conditions and present corresponding numerical results. In addition, we present preliminary numerical results on applying the proposed framework to soliton solutions of the Korteweg-de Vries (KdV) equation, demonstrating its potential applicability to a broader class of nonlinear partial differential equations.

SeongHeon Lee

Pohang University of Science and Technology

Uniform Ergodicity of Continuous-Space Pseudo-Gibbs Samplers in Coupled Generative Models for Inverse Problems

ABSTRACT

While pseudo-Gibbs sampling is widely used to circumvent intractable joint distributions by alternating between conditional sampling steps, its strict convergence guarantees have largely been restricted to discrete spaces or otherwise tractable models. Applying this alternating inference to continuous state spaces with deep generative models frequently degenerates into deterministic mode collapse, in which the sampler contracts to a point mass rather than the target distribution and total-variation uniform ergodicity fails.

In this talk, we establish the uniform ergodicity of a continuous-space pseudo-Gibbs sampler (CPGS) constructed from coupled deep generative models. We show that strictly positive Gaussian noise injection, together with the compactness induced by a boundary projection, is a sufficient-and, by construction, always satisfiable-condition for Doeblin's minorization on the state space, thereby guaranteeing convergence in total variation. By shifting the analysis to the quadratic Wasserstein metric (W_2), we further prove that the contraction rate is governed solely by the conditional Lipschitz constants of the generative models, as the injection noise cancels exactly in the Wasserstein coupling. This decoupling shows that the noise required to prevent deterministic collapse does not compromise the chain's contraction rate.

LEI Han

The Chinese University of Hong Kong

Geometry-Aware Image Generation Framework for Medical Imaging

ABSTRACT

Deep learning in medical imaging is constrained by data scarcity arising from rare pathological cases and stringent privacy regulations. Although data augmentation is crucial for mitigating this issue, conventional techniques rely heavily on standard affine transformations, such as rotation, translation, and scaling. These operations are not geometry-aware: they fail to accommodate anatomical variations in bones or organs across individuals and often yield artifacts that deviate from clinical reality. Deep generative models such as generative adversarial networks (GANs) and variational autoencoders (VAEs) have also been introduced, but they still struggle to capture and preserve complex geometric structures explicitly.

To bridge this gap, we propose a novel geometry-aware image-generation framework underpinned by the Harmonic Beltrami Signature. By leveraging this quasi-conformal geometry-based descriptor, our method encodes intrinsic geometric features, enabling the network to generate highly realistic, anatomically consistent, and medically meaningful images. Numerical experiments demonstrate the effectiveness of the framework in synthesizing high-quality medical data. This geometry-aware generation approach is also highly generalizable and holds substantial potential for synthesizing diverse medical images.

CT-SC C

Mathematical Modeling and Numerical Methods for Dynamical Systems

Date & time	Wednesday, August 26 2026, 11:20-12:40
Room	M
Chair	Yuntong Huang

Individual talk times follow the published source order and remain to be confirmed.

Junchao Duan

The Hong Kong Polytechnic University

An Ultraspherical Spectral Method for Differential Stochastic Linear Complementarity Problems

ABSTRACT

We develop an ultraspherical spectral method for solving differential stochastic linear complementarity problems (DSLCPs), in which a deterministic ordinary differential equation (ODE) is coupled with time-dependent random linear complementarity constraints, leading to nonsmooth closed-loop dynamics. The samplewise complementarity conditions are regularized by Fischer-Burmeister smoothing, and the stochastic feedback is approximated using sample average approximation (SAA). The resulting finite-sample ODE is discretized in time by the ultraspherical spectral method, and the associated finite-dimensional algebraic system is solved by a block Gauss-Seidel iteration. Under a uniform P-matrix condition and appropriate measurability and regularity assumptions, we establish the existence and uniqueness of solutions to the original DSLCP and its successive approximations: the smoothed reformulation, the corresponding finite-sample SAA problem, and the final finite-dimensional algebraic system obtained through spectral time discretization. A numerical experiment illustrates the accuracy and computational efficiency of the proposed method.

Caoyi Liu

Department of Mathematics, National University of Singapore, Singapore

A Uniformly Accurate Multiscale Time Integrator for the Nonlinear Klein-Gordon Equation via Simplified Transmission Conditions

ABSTRACT

We study the numerical approximation of the nonlinear Klein-Gordon equation in the nonrelativistic regime, where the solution is highly oscillatory in time with wavelength $O(\epsilon^2)$. This requires restrictive meshing strategies for standard methods and creates significant difficulties in designing uniformly accurate numerical methods. We present a new and simplified multiscale time integrator based on a frequency-based multiscale decomposition on each time interval with simplified transmission conditions. The numerical scheme applies an exponential wave integrator and a Fourier pseudospectral method for temporal and spatial discretization, respectively, and achieves optimal spatial accuracy and a uniformly first-order convergence rate in time. We also introduce a multiscale interpolation technique that provides uniformly accurate approximations at any time $t > 0$ by linearly interpolating the micro-variables within each time interval. Numerical experiments demonstrate the efficiency and robustness of the method compared with classical approaches. The work provides a practical framework for constructing uniformly accurate schemes for highly oscillatory partial differential equations.

Takatoshi Yoshii

School of Fundamental Science and Engineering, Waseda University, Japan

Optimal Strategies for Headway Adjustment in Response to Train Delays

ABSTRACT

Train delays in densely operated railway systems propagate through increased dwell times caused by passenger accumulation at stations. We formulate and analytically solve an optimal-control problem for headway regulation, in which the train immediately preceding a delayed train is intentionally held to redistribute waiting passengers. Passenger arrivals and boarding are modeled using constant rates, yielding an explicit expression for the additional dwell time. The cost functional is defined by the product of the delay duration and the number of affected passengers. Analytical optimization yields a closed-form expression for the optimal holding time, which is approximately one-half of the delayed train's delay when the initial delay is sufficiently large. The resulting control equalizes headways, redistributes passenger demand, and suppresses delay propagation. These results provide a mathematical characterization of optimal headway regulation based on passenger-delay cost.

Tianyuan Zhao

Graduate School of Engineering, Nagoya University, Japan

Adaptive Observations for Data Assimilation: Observation Requirements for Accurate State Estimation in a Chaotic Dynamical System

ABSTRACT

Data assimilation is a method for improving the accuracy of state estimation by combining model predictions with observational data. For high-dimensional systems, observing all state variables is often impractical. Consequently, the performance of data-assimilation methods is strongly influenced by the choice of observation operator, motivating adaptive observation operators that focus on the most unstable directions of the dynamics.

Our study examines adaptive-in-time observation operators in data assimilation for a chaotic dynamical system under different physical parameters that affect the instability of the dynamics. Numerical experiments examine how the minimum number of observations required for accurate state estimation depends on dynamical instability and observational error. The results suggest that adaptive observations are applicable across a broad range of dynamical conditions and that more unstable dynamics generally require more observations for accurate state estimation.

HUANG Yuntong

The Hong Kong University of Science and Technology

Phase-Field Modeling of Grain-Boundary Grooving with Tunable Misorientation-Dependent Energy

ABSTRACT

Grain-boundary grooving, in which grain boundaries meet a free surface, provides a useful setting for studying how interfacial energy, surface diffusion, and microstructural geometry interact during microstructural evolution. In this work, we develop a phase-field model based on the Kobayashi-Warren-Carter framework to investigate the effect of grain-boundary energy on grooving in bicrystal systems. We first validate the model against the classical Mullins theory of thermal grooving. After normalization, the simulated groove profiles collapse onto the expected universal profile, and the groove depth follows the characteristic surface-diffusion-controlled growth behavior. This establishes a reliable baseline for studying how grain-boundary energy affects groove morphology. We then examine misorientation-dependent grain-boundary energy. For a Read-Shockley-like energy response, the stable groove angle increases systematically with misorientation and is broadly consistent with the expected interfacial force balance. This shows that the orientation field transfers changes in grain-boundary energy into measurable changes in groove geometry. Finally, we study the effect of grain rotation on grain-boundary grooving. Grain rotation introduces asymmetry into the groove, with one side becoming deeper and the other shallower in the setting considered. These results show that KWC-type phase-field models can connect interfacial thermodynamics with mesoscale groove evolution, providing a useful route for multiscale studies of anisotropic and prescribed grain-boundary energetics in evolving microstructures.

CT-SC D

Phylogenetic Networks and Topological Data Analysis

Date & time	Wednesday, August 26 2026, 15:50-17:10
Room	M
Chair	Shunsuke Maeda

Individual talk times follow the published source order and remain to be confirmed.

Sijin Yeom

Pohang University of Science and Technology

Induced Probability Measures on Persistence Diagrams: Persistent Cross-Entropy

ABSTRACT

Persistent entropy summarizes values within a single persistence diagram. However, two diagrams generally lie on different event spaces, making persistent cross-entropy nontrivial. We introduce an induced probability measure on a reference diagram using persistence-weighted kernel similarities to an explaining diagram. This encodes information from the explaining diagram on the reference diagram, enabling us to define persistent cross-entropy. We illustrate how it captures relationships between persistence diagrams through numerical examples, including causality analysis in dynamical systems.

Kanta Kotsuzumi

¹ Department of Pure and Applied Mathematics, Graduate School of Fundamental Science and Engineering, Waseda University, Japan

Reconstructing Level-3 Phylogenetic Networks from Shortest/Longest Distances and Shortest-Path Counts

ABSTRACT

The distance-based phylogenetic reconstruction problem asks how much of an evolutionary history can be reconstructed from information measured only between pairs of observed taxa, such as species or molecular sequences. Mathematically, this is an inverse problem in which local measurements are used to determine a complex global combinatorial structure. Phylogenetic trees are a standard model for histories governed solely by branching, and this reconstruction problem has been studied extensively for trees, yielding several criteria and algorithms. Yet many evolutionary histories are not adequately tree-like. Events such as hybridization and gene flow can bring previously separated lineages together, which a tree cannot represent. Phylogenetic networks provide a more flexible model for such histories. In this setting, the taxa label the leaves, whereas the internal vertices, edges, and non-tree-like connections are unknown and must be inferred. The input therefore contains no direct description of the full network topology. The corresponding question is: how much of a network can be reconstructed from pairwise data at its leaves?

We study this problem for proper, unweighted, unrooted, binary phylogenetic networks of level 3. Here, level is a standard measure of network complexity; informally, it measures how far the nontrivial biconnected components of the network are from being trees. Huber et al. (2022) showed that level-2 networks can be reconstructed from the shortest and longest distances between each pair of leaves. For level-3 networks, however, examples show that a direct extension of this length-based method does not always reconstruct the network correctly. This failure is the obstruction addressed in our work.

To overcome this obstruction, we enrich the pairwise data by adding one further invariant: the number of shortest simple paths between each pair of leaves. Some level-3 structures cannot be distinguished using shortest and longest path lengths alone but become reconstructable once shortest-path counts are included. Thus, the count is not introduced merely as an additional descriptor; it addresses a specific failure of the length-based reconstruction strategy. We refer to the combined information-shortest-path length, longest simple-path length, and shortest-path count-as shortest-longest-count data.

Under the necessary identifiability condition that no non-isomorphic network on the same leaf set has the same shortest-longest-count data, we solve the distance-based phylogenetic reconstruction problem for this class. We give a constructive algorithm that reconstructs the network up to leaf-labeled isomorphism by combining local reductions with a finite catalog of level-3 building blocks. The result extends distance-based reconstruction beyond the level-2 setting and shows how shortest-path counts overcome the level-3 obstruction.

Yukino Kawai

Graduate School of Fundamental Science and Engineering, Waseda University, Japan

Separation Index for Cluster-Label Convexity on Weighted Phylogenetic Trees**ABSTRACT**

A phylogenetic tree has cluster labels on its leaves, and measuring how well these labels reflect the tree structure is a fundamental problem in phylogenetics and hierarchical clustering. A labeling is called convex when the minimal subtrees spanned by the individual color classes are pairwise disjoint. Known measures such as the consistency index (CI) and the convex recoloring distance (CRD) describe this fit. However, they depend only on the tree topology and ignore branch lengths.

We study k -colorings of the leaves of a weighted, unrooted, binary phylogenetic tree. For each edge, we count the colors appearing on both sides and use this to define a branch-length-based separation index. The index is maximal if and only if the labeling is convex. When the labeling is not convex, the index detects color mixing that CI and CRD cannot identify. Finally, we give an $O(nk)$ -time algorithm for computing the index and report numerical experiments, including experiments with real data.

Shunsuke Maeda

Graduate School of Fundamental Science and Engineering, Waseda University, Japan

A Mixed-Integer Programming Approach to the Tree-Based Orientation Problem**ABSTRACT**

Distance-based methods are widely used in phylogenetics to infer phylogenetic networks from dissimilarity matrices. However, most inferred networks are undirected, preventing the interpretation of evolutionary directions. To address this issue, the orientation problem—which seeks to assign directions to the edges of an undirected network so as to obtain a directed phylogenetic network—has recently gained increasing attention. In this talk, we study the Tree-Based Orientation problem, which asks whether an undirected network can be oriented as a tree-based phylogenetic network. We present a practical mixed-integer programming formulation for solving this problem.

CT-SC E

Numerical Analysis, Linear Algebra, and Inverse Problems

Date & time	Wednesday, August 26 2026, 17:20-18:40
Room	M
Chair	CHENG Zilan

Individual talk times follow the published source order and remain to be confirmed.

XIONG Yu

Nanyang Technological University, Singapore

A Priori and A Posteriori Error Analyses of a Pressure-Robust Virtual Element Method for the Two-Dimensional Brinkman Problem

ABSTRACT

This talk investigates both a priori and a posteriori error estimates for a pressure-robust and divergence-free virtual element method to approximate the incompressible Brinkman problem on polygonal meshes. The exactly divergence-free property of the virtual space preserves the mass conservation of the system. By extending the lowest-order Raviart-Thomas element to polygonal meshes, we construct a divergence-preserving reconstructor for the discretization of the right-hand side. A rigorous a priori error analysis is developed, showing that the velocity error is independent of both the continuous pressure and the viscosity. Taking advantage of the virtual element method's ability to handle more general polygonal meshes, we design an adaptive mesh-refinement approach and construct a residual-type a posteriori error indicator. This indicator is proven to provide global upper and local lower bounds for the discretization error. Finally, numerical experiments demonstrate the robustness, accuracy, reliability, and efficiency of the method.

YANG Qizheng

The Chinese University of Hong Kong

A Deep Learning-Enhanced Dual-Index Direct Sampling Method for PDE Inverse Problems

ABSTRACT

Inverse problems in partial differential equations (PDEs) are notoriously challenging because of their inherent ill-posedness. Traditional optimization-based methods reconstruct internal structures by matching boundary measurements and minimizing objective functions equipped with data-fidelity and regularization terms. Although these methods yield high reconstruction accuracy, they incur prohibitive computational costs because forward PDEs must be solved iteratively. To alleviate this computational burden, the Direct Sampling Method (DSM) was proposed as a computationally efficient alternative. By calculating a positive index value for each point in the domain, DSM constructs an index function to locate internal inhomogeneities without requiring iterative PDE solvers. It demands less measurement data and exhibits strong robustness to measurement noise. Recently, a dual-index DSM was developed to reconstruct two different types of inhomogeneities simultaneously from limited data by constructing two distinct index functions. However, its performance depends heavily on the design of specialized probing functions, whose accuracy leaves room for improvement. In this work, we propose a novel approach that integrates deep learning to enhance the design and accuracy of these probing functions for the dual-index DSM. Numerical experiments demonstrate that the probing functions generated by our AI-driven framework better satisfy the accuracy requirements of the dual-index DSM, thereby significantly improving overall reconstruction quality.

Motohiro Otsuka

Graduate School of Engineering, Nagoya University, Japan

Error Control for Double-Exponential-Based Algorithms for Computing Quadratic Forms Associated with $A \log(A)$

ABSTRACT

This study focuses on the computation of quadratic forms associated with $A \log(A)$, where A is a positive semidefinite Hermitian matrix and $\log(A)$ denotes the matrix logarithm.

Using an integral representation of the matrix function, a double-exponential (DE) quadrature formula approximates such quadratic forms through the solution of several shifted linear systems. While previous studies have mainly focused on the quadrature error arising from the DE approximation, less attention has been paid to the algebraic error caused by solving these shifted linear systems approximately.

In this study, we derive an upper bound for this algebraic error using the residuals of the approximate solutions. This yields a stopping criterion for iterative solvers that keeps the total error in the target quadratic form below a prescribed tolerance. Numerical results demonstrate that the proposed criterion enables the computation of the target quadratic form within the prescribed tolerance.

Zhixuan Xu

1 Department of Applied Physics, Nagoya University, Japan; 2 Department of Mathematics, Meijo University, Japan

On Two Numerical Approaches for Linear Systems $ABx = b$

ABSTRACT

We consider the linear system $ABx = b$, which can be rewritten as the two-stage system $Ay = b$ and $Bx = y$. Here A and B are nonsingular square matrices of dimension N , and x , y , and b are vectors of dimension N . When solving such systems numerically, the two formulations exploit the matrices A and B in different ways and may therefore yield different results under finite-precision arithmetic.

We propose two numerical approaches for solving linear systems of the form $ABx = b$. These approaches can be readily incorporated into linear solvers for $Ax = b$, including direct methods, stationary iterative methods, and Krylov subspace methods. In the first approach, the matrix-vector product ABp is computed implicitly as $A(Bp)$. In the second approach, one first solves $Ay = b$ and then solves $Bx = y$ using the computed approximation of y .

We focus on Krylov subspace methods for the following reason. In the first approach, the implicit construction can reduce the computational cost from $O(Nnz^3)$ to $O(Nnz)$ when A and B are sparse and Nnz is the number of nonzeros. However, this construction is applicable only to Krylov subspace methods, so we restrict our discussion to this setting. Although the second approach can be used with other linear solvers, we do not consider those settings here.

Numerical experiments in double-precision arithmetic will compare the two approaches in terms of iteration count, CPU time, and true relative residual under several choices of A and B .

Qiu-Yi Chen

1 Department of Applied Physics, Nagoya University, Japan; 2 School of Mathematics and Statistics, Hainan University, China

Tensor Form of the LSMR Method for a Generalized Sylvester Quaternion Tensor Equation with an Application

ABSTRACT

This paper concerns the least-squares solutions of a generalized Sylvester quaternion tensor equation arising from color-video restoration. Using properties of quaternions, the vectorization operator, and the Kronecker product, we propose a tensor form of the least-squares minimum residual (LSMR) method for finding a least-squares solution. Numerical examples from practical applications demonstrate the effectiveness of the proposed method. A comparison with an existing method is also provided.



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