

International Workshop on Numerical Methods and Scientific Computing

May. 6, 2026 – May. 9, 2026
The Hong Kong Polytechnic University

Preface

Welcome to International Workshop on Numerical Methods and Scientific Computing, as organized by the Department of Applied Mathematics of The Hong Kong Polytechnic University in 2026.

The workshop aims to bring together leading researchers, academics, and practitioners in numerical methods and scientific computing to present recent advances, exchange ideas, and foster new collaborations. The program will feature discussions on current topics in numerical analysis, computational techniques, and their applications across a broad range of scientific and engineering disciplines.

We are grateful to the members of Organizing Committee and Local Organizing Committee for their hard work. We are also grateful to the staff members of the Department of Applied Mathematics for their time and effort making this conference possible.

The workshop gratefully acknowledges the patronage of The Hong Kong Polytechnic University, and the financial support of CAS AMSS-PolyU Joint Laboratory of Applied Mathematics (JLab).

We sincerely hope that this workshop will enhance international collaboration between applied mathematicians and provide an opportunity for young researchers to learn the current state of the art in scientific computing and PDEs.

Finally, we hope all participants have a fruitful workshop in The Hong Kong Polytechnic University and wish all overseas participants an enjoyable stay in Hong Kong.

Acknowledgements

We are very grateful for the support and contributions to International Workshop on Numerical Methods and Scientific Computing as given by

The Hong Kong Polytechnic University (PolyU)

Department of Applied Mathematics, PolyU

CAS AMSS-PolyU Joint Laboratory of Applied Mathematics (JLab)

We would also like to thank the staff members in the Department of Applied Mathematics who have worked together in handling the various arrangements related to the conference. Their assistance has been indispensable.

Organizing Committees

Local Organizing Committee

Jianbo Cui

Zhonghua Qiao

Buyang Li

Zhi Zhou

Yanping Lin (Chair)

Shijun Zhang

Organizing Committee

Buyang Li

Zhonghua Qiao

Yanping Lin

Zhimin Zhang (Chair)

Xin Liu

Scientific Committee

Zhaojun Bai

Zuowei Shen

Ya-xiang Yuan

Xiaojun Chen

Chi-Wang Shu

Zhimin Zhang (Chair)

Jie Shen

Yuesheng Xu

Conference Highlights

Conference Venue

The workshop will be held on the PolyU campus TU 107. Please refer to the campus map. Please note that smoking is not allowed on the PolyU campus.



Opening Ceremony & Group Photo

The opening ceremony and group photo will be held in TU107 at 9: 00 on 7 May 2026 (Thursday).

Registration & Information Desk

Registration desk will be set up at outside TU107 from 8:30-11:45 on 7 May 2026.

On-campus Internet Access

NetID: gstama

Password: Polyu4ever

SSID: PolyUWLAN

Ref: <https://www.polyu.edu.hk/its/it-services/wi-fi-services/>

Invited participants are entitled to:

- Attendance to all conference sessions
- Invitation to the opening ceremony
- Invitation to the lunch and banquet
- Coffee breaks

Lunch

Ju Yin House Restaurant, 4/F, Communal Building on 7-9 May, 2026.

Banquet

Ju Yin House Restaurant, 4/F, Communal Building on 7 May, 2026.

Conference Venue

7th May 2026

Opening Ceremony & Group Photo: **TU107 at 9: 00**

Registration & Information Desk: **outside TU107 (8:30–11:45)**

Invited Talks: **TU107 (9:15–11:45 & 14:00–17:30)**

Lunch: **11:45–14:00**

Ju Yin House Restaurant, 4/F, Communal Building

Banquet: **18:00–20:00**

Ju Yin House Restaurant, 4/F, Communal Building

8th May 2026

Invited Talks: **TU107 (9:15–11:45 & 14:00–17:30)**

Lunch: **11:45–14:00**

Ju Yin House Restaurant, 4/F, Communal Building

9th May 2026

Invited Talks: **TU107 (9:15–11:45)**

Lunch: **12:00–14:00**

Ju Yin House Restaurant, 4/F, Communal Building

7 of May, 2026 - Thursday, TU107

8:30–9:00	Registration	
9:00–9:15	Welcome remarks (Defeng Sun, Zhimin Zhang, Yanping Lin)	
Chair	Xin Liu Chinese Academy of Sciences	
9:15–9:45	Ya-xiang Yuan Chinese Academy of Sciences	Optimization on the intersection of manifolds: orthogonal tangent directions and geometric methods
9:45–10:15	Hai-Qing Lin Zhejiang University	Collapse of the Fermion Sign Problem and the Superconducting Phase
10:15–10:45	Coffee Break	
Chair	Zhonghua Qiao The Hong Kong Polytechnic University	
10:45–11:15	Tao Tang Guangzhou Nanfang College	High-Order Product-type Runge-Kutta Methods for Gradient Flows with Degenerate Mobility
11:15–11:45	Raymond Hon-fu Chan Lingnan University	Solving Convolution-type Integral Equations with High-frequency Using Neural Operators
11:45–14:00	Lunch	
Chair	Xiaofeng Yang University of South Carolina	
14:00–14:30	Jie Shen Eastern Institute of Technology , Ningbo	Efficient and accurate spectral methods for PDEs in complex domains
14:30–15:00	Dongwoo Sheen Xinjiang University	Stabilized surface finite element method for the optimal control problem of stationary convection-dominated diffusion equations
15:00–15:30	Shangyou Zhang University of Delaware	Conforming Divergence-Free Rectangular Finite Elements for Axisymmetric Stokes Equations
15:30–16:00	Coffee Break	
Chair	Yanping Lin The Hong Kong Polytechnic University	
16:00–16:30	Xiaojun Chen The Hong Kong Polytechnic University	Differential Stochastic Variational Inequalities with Parametric Optimization
16:30–17:00	Chao Li The Hong Kong Polytechnic University	Spherical Zone t -Designs and Approximation
17:00–17:30	Dongming Wei Nazarbayev University	Numerical Study of Nonlinear Options Pricing PDE/PIDE Models
18:00–20:00	Banquet	

8 of May, 2026 - Friday, TU107

Chair	Zhimin Zhang Wayne State University	
9:15–9:45	Chi-Wang Shu Brown University	High order numerical methods for hyperbolic equations
9:45–10:15	Yan Xu University of Science and Technology of China	A Unified Framework of Analysis for Structure-Preserving Mimetic Difference Method
10:15–10:45	Coffee Break	
Chair	Zhimin Zhang Wayne State University	
10:45–11:15	Zhaojun Bai University of California, Davis	Advances and Challenges in Algebraic Eigenvalue Problems
11:15–11:45	Zhi Zhao Hangzhou Dianzi University	Preconditioned Iterative Methods for Large-Scale Symmetric Nonnegative Inverse Eigenvalue Problems
11:45–14:00	Lunch	
Chair	Buyang Li The Hong Kong Polytechnic University	
14:00–14:30	Weiwei Sun Beijing Normal–Hong Kong Baptist University	Loosely Coupled Schemes for Fluid-Structure Interactions
14:30–15:00	Jilu Wang Harbin Institute of Technology, Shenzhen	Optimal-order convergence of finite element method for the nematic liquid crystal model
15:00–15:30	Fangyan Yao The Hong Kong Polytechnic University	Continuous Formulation of Numerical Schemes for Dispersive Equations
15:30–16:00	Coffee Break	
Chair	Zaikun Zhang Sun Yat-sen University	
16:00–16:30	Yuesheng Xu Old Dominion University	Neural Harmonic Analysis: Bridging Classical Expansions and Multi-Grade Deep Learning
16:30–17:00	Xiaoxia Liu South China University of Technology	Plug-and-play Proximal Block Coordinate Descent Method for Hyperspectral Anomaly Detection
17:00–17:30	Haizhang Zhang Sun Yat-sen University	Exponential Approximation Rates of Tensor Neural Networks Across Activations
18:00–20:00	Free Time (No Scheduled Activities)	

9 of May, 2026 - Saturday, TU107

Chair	Yanping Lin The Hong Kong Polytechnic University	
9:15–9:45	Tao Lin Virginia Polytechnic Institute and State University	Geometry-Conforming Immersed Finite Elements on a Triangular Mesh
9:45–10:15	Waixiang Cao and Hailong Guo Beijing Normal University and Peking University Chongqing Research Institute of Big Data	Recent Developments in Superconvergence Theory and Its Applications
10:15–10:45	Coffee Break	
Chair	Yanping Lin The Hong Kong Polytechnic University	
10:45–11:15	Amiya Kumar Pani Birla Institute of Technology and Science, Pilani	On Vlasov-Navier-Stokes' System: Some Theoretical and Computational Issues
11:15–11:45	Shaozhong Deng University of North Carolina at Charlotte	Green's functions for Poisson's equation in inhomogeneous media with diffuse interfaces
11:45–12:00	Closing Remarks	
12:00–14:00	Lunch	

Titles and Abstracts

Advances and Challenges in Algebraic Eigenvalue Problems

Zhaojun Bai

University of California, Davis

Algebraic eigenvalue problems are the cornerstones of linear algebra, basic computational sciences and engineering. They arise in applications ranging from electronic and band structure calculations in physics and chemistry, dynamic analyses of supramolecular systems in biology to structural and vibration analysis in civil and mechanical engineering. Continuing challenges of eigenvalue problems come from increasingly large problem sizes and large numbers of required eigenpairs, and urgent needs of rapid and robust solvers due to the fact that algebraic eigenvalue problems are often in the inner-loop (kernels) of scientific computing and can be the bottlenecks of simulation efficiency. In this talk, I will discuss some recent advances and challenges in theory, algorithms and applications of algebraic eigenvalue problems. In particular, I will describe eigenvector-dependent nonlinear eigenvalue problems (NEPv). NEPv poses intriguing challenges for analysis and computation, and is a much less explored topic.

Recent Developments in Superconvergence Theory and Its Applications

Waixiang Cao

Beijing Normal University

In this talk, some recent developments in both natural superconvergence and superconvergence by post-processing of C^m , $0 \leq m \leq 2$, Galerkin methods are reviewed. A survey of superconvergence results for C^m element methods (including the C^m Petrov–Galerkin method and the collocation method) for second- and fourth-order elliptic equations is presented. Superconvergence by post-processing on both Euclidean and non-Euclidean domains, as well as its applications in eigenvalue enhancement and the development of new finite element methods, will also be discussed.

Solving Convolution-type Integral Equations with High-frequency Using Neural Operators

Raymond Hon-fu Chan

Lingnan University

Convolution-type integral equations arise from various fields, e.g., finite impulse response filters in signal processing and deblurring problems in image processing. When solving these equations, conventional numerical methods, like the multigrid method, can only efficiently solve the low-frequency components in the error, but not the high-frequency components. In this paper, we apply neural operators to address this

issue. We propose a novel training strategy that trains neural operators to solve the high-frequency components efficiently. Then, we combine the neural operators with some classical iterative solvers, like the weighted Jacobi method, to obtain an efficient hybrid iterative algorithm for the integral equations. We also analyze the generalization error of our training strategy and the convergence of the hybrid iterative algorithm. We test our algorithms on large-scale and ill-conditioned linear systems discretized from one- and two-dimensional convolution-type integral equations. Our proposed algorithm significantly outperforms the multigrid method and the preconditioned conjugate gradient method in both iteration numbers and computational time. Besides, the iteration number of our algorithm is more robust to the changes in the size and condition numbers of the underlying linear systems than conventional numerical methods. Though we mainly focus on the integral equations, our method can be directly applied to all kinds of linear problems.

Joint work with Lingfeng Li, Hetao Institute of Mathematics and Interdisciplinary Sciences.

Differential Stochastic Variational Inequalities with Parametric Optimization

Xiaojun Chen

The Hong Kong Polytechnic University

The variational inequality (VI) provides a broad unifying setting for the study of equilibrium problems and optimization. The differential variational inequality and stochastic variational inequality are generalizations of the VI and promising modelling paradigms when dynamics and uncertainties are involved in data analysis and decision making. We first discuss the mathematical formulations and recent results of the differential VI and stochastic VI. Next we introduce the differential stochastic VI with parametric optimization (DSVIO), an ordinary differential equation whose right-hand side is defined by a stochastic VI and solutions of several stochastic optimization problems. The DSVIO provides a powerful modelling framework for various applications in data science and artificial intelligence. We provide sufficient conditions for the existence of a solution pair for the DSVIO in the space of absolutely continuous functions and the space of measurable functions. We discuss a convergent sample average approximation and time-stepping discretization scheme for numerical solutions of the DSVIO. Finally, we show applications of the DSVIO for optimizing multimodal large model-based embodied intelligence systems for the elderly mobility.

Green's functions for Poisson's equation in inhomogeneous media with diffuse interfaces

Shaozhong Deng

University of North Carolina at Charlotte

Green's functions for Poisson's equation in inhomogeneous media with material interfaces have many practical applications. We focus on media with diffuse interfaces, where the material constant varies

smoothly and continuously within a narrow transition region between distinct materials. We present a unified and general framework for constructing Green's functions for Poisson's equation in such settings. The framework applies to all eleven orthogonal coordinate systems in which the three-dimensional Laplace equation is separable. Within this approach, we discuss how to design so-called quasi-harmonic diffuse interfaces, derive formulations for constructing the corresponding Green's functions, and develop a robust numerical method for their computation in media with general diffuse interfaces. Several practically relevant separable coordinate systems are briefly surveyed at the level of definition and basic facts relevant for implementing the unified framework in these coordinate systems.

Recent Developments in Superconvergence Theory and Its Applications

Hailong Guo

Peking University Chongqing Research Institute of Big Data

In this talk, some recent developments in both natural superconvergence and superconvergence by post-processing of C^m , $0 \leq m \leq 2$, Galerkin methods are reviewed. A survey of superconvergence results for C^m element methods (including the C^m Petrov–Galerkin method and the collocation method) for second- and fourth-order elliptic equations is presented. Superconvergence by post-processing on both Euclidean and non-Euclidean domains, as well as its applications in eigenvalue enhancement and the development of new finite element methods, will also be discussed.

Spherical Zone t -Designs and Approximation

Chao Li

The Hong Kong Polytechnic University

A spherical t -design is a finite set of points on the unit sphere

$$S^2 := \{\mathbf{x} \in \mathbb{R}^3 : \|\mathbf{x}\|_2 = 1\}$$

which provides an equal weight cubature rule, integrating exactly all spherical polynomials of degree at most t . We constructed spherical zone t -designs, a finite set of points on a spherical zone

$$\mathcal{Z} := \{\mathbf{x} \in S^2 : a \leq \mathbf{x} \cdot \mathbf{z} \leq b\}$$

where $\mathbf{z} \in S^2$ and $-1 \leq a \leq b \leq 1$ that provides an equal weight cubature rule on the zone with polynomial exactness t . The construction is achieved by combining spherical t -designs and trapezoidal rules on $[0, 2\pi]$ with precision t . Furthermore, we extended optimal asymptotic bounds for spherical t -designs on S^2 , the work of Bondarenko, Radchenko, and Viazovska, to spherical zone t -designs. We proved that for each $n \geq Ct^2$, there exists a spherical zone t -design on $\mathcal{Z}$ with n points, where C is a constant dependent only on a, b . We applied the spherical zone t -designs to numerical integration, hyperinterpolation and sparse approximation on subsets of the sphere. Theoretical approximation error bounds were presented. Some numerical examples were given to illustrate the theoretical results and show the efficiency of the proposed spherical zone t -designs.

Collapse of the Fermion Sign Problem and the Superconducting Phase

Hai-Qing Lin

Zhejiang University

We demonstrate that the fermion sign problem in quantum Monte Carlo simulations of strongly correlated system such as the Hubbard model encodes the physics of competing orders. Using Eigenvalue-Guided Monte Carlo (EGMC) with sign-sector decomposition, we show that eigenvalue complexity $\text{Var}(n_{\text{neg}})$ peaks at the pseudogap temperature T^* and drops substantially in the superconducting phase. Crucially, sector-resolved measurements on lattices from 4×4 to 12×12 reveal d-wave pairing in both sign sectors, providing evidence for superconductivity independent of the partition function ratio.

Geometry-Conforming Immersed Finite Elements on a Triangular Mesh

Tao Lin

Virginia Polytechnic Institute and State University

This presentation introduces geometry-conforming immersed finite element (GC-IFE) spaces on triangular meshes for solving elliptic interface problems. The basis functions of the proposed GC-IFE spaces are constructed using a mapping derived from the Frenet-Serret apparatus of the interface's differential geometry. This mapping straightens the curved interface and enables the exact imposition of interface jump conditions. We discuss three procedures for constructing high-degree GC-IFE bases: an initial formulation using monomials, a generalized construction using orthogonal polynomials, and reconstruction methods designed to improve the conditioning of the associated mass matrices. The resulting GC-IFE spaces are locally conforming to the spaces in standard Discontinuous Galerkin (DG) schemes. Although the GC-IFE functions themselves are not polynomials due to the nonlinearity of the interface, the proposed GC-IFE spaces retain optimal approximation capabilities consistent with the underlying polynomial spaces. Numerical examples are provided to highlight features of these GC-IFE spaces.

Plug-and-play Proximal Block Coordinate Descent Method for Hyperspectral Anomaly Detection

Xiaoxia Liu

South China University of Technology

In this talk, we introduce an orthogonal constrained optimization model for hyperspectral anomaly detection. The model represents background information via eigen decomposition and characterizes anomalies using a generalized group sparsity measure. To enhance the robustness against Gaussian noise, we integrate a deep implicit proximal denoiser prior into a plug-and-play (PnP) framework applied to the eigenimages. We solve the resulting nonconvex nonsmooth optimization problem using a PnP-proximal

block coordinate descent (PnP-PBCD) method and provide convergence analysis. Experimental results demonstrate that the proposed method effectively detects anomalous objects, even under Gaussian noise contamination.

On Vlasov-Navier-Stokes' System: Some Theoretical and Computational Issues

Amiya Kumar Pani

Birla Institute of Technology and Science, Pilani

The mathematical model describing sprays and aerosols, bubbly flows, or suspension and sedimentation phenomena in two dimensions gives rise to the following coupled system of 2-D incompressible Navier-Stokes equation and a Vlasov-type equation:

$$\begin{aligned} \partial_t f + v \cdot \nabla_x f + \nabla_v \cdot \left((\mathbf{u} - v) f \right) &= 0 \quad \text{in } (0, T) \times \Omega_x \times \mathbb{R}^2, \\ f(0, x, v) &= f_0(x, v) \quad \text{in } \Omega_x \times \mathbb{R}^2 \\ \partial_t \mathbf{u} - \nu \Delta_x \mathbf{u} + (\mathbf{u} \cdot \nabla_x) \mathbf{u} + \nabla_x p &= \int_{\mathbb{R}^2} (v - \mathbf{u}) f \, dv \quad \text{in } (0, T) \times \Omega_x, \\ \nabla_x \cdot \mathbf{u} &= 0 \quad \text{in } (0, T) \times \Omega_x, \\ \mathbf{u}(0, x) &= \mathbf{u}_0(x) \quad \text{in } \Omega_x. \end{aligned}$$

Here, Ω_x denotes the two dimensional torus $\mathbb{T}^2$, ν is the viscosity. The unknowns are distribution function $f(t, x, v)$, the fluid velocity $\mathbf{u}(t, x)$, and the fluid pressure $p(t, x)$. In the first part of this talk, starting with one such model, we shall discuss theoretical issues like existence, uniqueness regularity and asymptotic results. In the second part, we examine Discontinuous Galerkin methods combined with dimension splitting through time marching scheme and it is shown that this proposed scheme preserves the order of convergence and also helps to solve a four dimensional problem with a sequence of two dimensional problems.

Stabilized surface finite element method for the optimal control problem of stationary convection-dominated diffusion equations

Dongwoo Sheen

Xinjiang University

The surface finite element method is applied to solve the optimal control problem for surface convection-dominated diffusion equations. In order to overcome numerical oscillations in the standard finite element solutions, we adopt the edge stabilization technique. We prove that the least squares stabilization of the gradient jumps across inter-surface elements suppresses numerical oscillations effectively and achieves stability in the computation. Parameter-dependent a priori error estimates are obtained both in energy- and L^2 -norm. Numerical experiments verify that the proposed method is not only capable of eliminating numerical oscillations effectively but also able to obtain solutions with high resolution.

Efficient and accurate spectral methods for PDEs in complex domains

Jie Shen

Eastern Institute of Technology, Ningbo

Traditional spectral methods achieve high-order convergence for problems with smooth solutions in regular domains. However, developing efficient and accurate spectral methods for the Stokes and Navier–Stokes equations, as well as for problems with corner singularities in complex domains, remains a significant challenge.

In this talk, we present recent advances in applying spectral methods to partial differential equations on complex domains: (i) We first develop fully decoupled, fast solvers for the generalized Stokes equations in circular and periodic pipe domains. We then employ a fictitious domain approach to design efficient algorithms for solving the Navier–Stokes equations in complex geometries; (ii) We combine the fictitious domain approach with the lightning algorithm to construct efficient and accurate spectral methods for a class of PDEs in complex domains with geometric singularities.

High order numerical methods for hyperbolic equations

Chi-Wang Shu

Brown University

Hyperbolic equations are used extensively in applications including fluid dynamics, astrophysics, electromagnetism, semi-conductor devices, and biological sciences. High order accurate numerical methods are efficient for solving such partial differential equations, however they are difficult to design because solutions may contain discontinuities. In this talk we will survey several types of high order numerical methods for such problems, including weighted essentially non-oscillatory (WENO) finite difference and finite volume methods, discontinuous Galerkin finite element methods, and spectral methods. We will discuss essential ingredients, properties and relative advantages of each method, and provide comparisons among these methods. Recent development and applications of these methods will also be discussed.

Loosely Coupled Schemes for Fluid-Structure Interactions

Weiwei Sun

Beijing Normal–Hong Kong Baptist University

There has been increasing interest in studying fluid-structure interaction (FSI) due to its diverse applications in many areas, particularly the blood flow in the human cardiovascular system, which can be modeled as incompressible flow passing through an elastic tube. In this talk, we present a review of basic models and algorithms for loosely coupled finite element schemes and our recent work. Loosely

coupled schemes that decouple the fluid velocity and structure displacement have been extensively studied for fluid-structure interactions (FSI) over the past decade. The schemes are popular in applications due to its ease of implementation, while the stability and error analysis of schemes are challenging. In a recent work, we propose a new stable fully-discrete loosely coupled scheme for the incompressible FSI thin-structure model. The scheme is based on simple backward Euler scheme in time direction and finite element approximation in spatial direction with a well-designed decoupling and a stress type stabilization in its weak formulation. We prove that the scheme is unconditional stable and present optimal error estimates in L^2 -norm in terms of a newly introduced coupled non-stationary Ritz projection. Moreover, we extend our method to FSI thick-structure model and high-order approximation in time. The methodology is applicable to numerous other FSI models and serves as a fundamental tool for advancing research in this field.

High-Order Product-type Runge-Kutta Methods for Gradient Flows with Degenerate Mobility

Tao Tang

Guangzhou Nanfang College

Energy dissipation remains a core challenge for systems of gradient flows with nonlinear degenerate mobility, where classical schemes struggle to balance high-order accuracy and energy stability. Moreover, conventional methods often fail to capture essential local physical structures or algebraic constraints, such as the maximum principle or unit-length constraints. To address these challenges, we propose a high-order product-type Runge-Kutta (PRK) framework combined with post-processing algorithms to simultaneously preserve global and local structures. We will demonstrate the effectiveness of the PRK framework in the numerical simulations.

Optimal-order convergence of finite element method for the nematic liquid crystal model

Jilu Wang

Harbin Institute of Technology, Shenzhen

This work focuses on error estimates of a linearly implicit backward Euler finite element method for the nematic liquid crystal model. Due to the strong nonlinearity of the system, the error analysis often exhibits a reduction in the convergence rate. To address this, we employ the duality argument and the discrete semigroup method to derive almost optimal-order convergence rates. Furthermore, we extend the analysis to the k -step backward difference formula (BDF) with $2 \leq k \leq 5$ for temporal approximation, obtaining nearly optimal error estimates. Numerical examples are presented to illustrate the convergence rates of the proposed numerical scheme and its effectiveness in capturing the annihilation of singularities in the nematic liquid crystal model.

Numerical Study of Nonlinear Options Pricing PDE/PIDE Models

Dongming Wei

Nazarbayev University

Finite element simulations of nonlinear Black-Scholes models, namely, Leland, RAPM, and the Merton PIDE in option pricing are presented to demonstrate that the finite element method is a practical choice for numerical simulations of problems in computational finance in combination with time integration FD schemes. Well-posedness and numerical analysis of the RAPM model are presented to demonstrate some stability results and the challenges involved in this class of problems.

A Unified Framework of Analysis for Structure-Preserving Mimetic Difference Method

Yan Xu

University of Science and Technology of China

We introduce a unified framework for the analysis of numerical schemes based on the mimetic difference (MD) method for a wide range of problems. Using a matrix-decomposition technique, we establish connections between second-order mimetic operators and higher-order mimetic operators. This approach enables us to construct reduction operators that preserve higher-order local truncation error properties while preserving the underlying structures. In addition, we build mimetic de Rham complexes that satisfy exactness and commutation relations. For Poisson's equation, diffusion-reaction equations, the acoustic equation, and Maxwell's equations, we develop mimetic difference schemes, derive a priori error estimates, and prove the structure-preserving properties of the schemes. For each problem, we provide numerical experiments to verify accuracy and the preserved structures.

Neural Harmonic Analysis: Bridging Classical Expansions and Multi-Grade Deep Learning

Yuesheng Xu

Old Dominion University

Multi-grade deep learning (MGDL) has emerged as a powerful and computationally efficient paradigm for training deep neural networks. By decomposing the global non-convex optimization of a deep model into a sequence of shallow, grade-wise subproblems, MGDL achieves superior numerical stability and interpretability. This talk explores the theoretical foundations of MGDL through the lens of harmonic analysis. We demonstrate that MGDL establishes a framework for "neural harmonic analysis", a nonlinear generalization of classical Fourier and wavelet theory. We will show how this framework provides a principled functional decomposition, allowing for progressive, multiscale refinement of target functions while circumventing the traditional optimization challenges associated with depth.

Continuous Formulation of Numerical Schemes for Dispersive Equations

Fangyan Yao

The Hong Kong Polytechnic University

This talk presents a continuous formulation of numerical schemes for nonlinear dispersive equations, with particular emphasis on the Korteweg–de Vries (KdV) equation and the nonlinear Schrödinger equation (NLS) in low-regularity regimes. By reformulating time-discrete schemes into suitable continuous representations, the discrete analysis can be embedded into the framework of continuous partial differential equations. This perspective allows us to exploit analytical tools from the theory of continuous PDEs to overcome stability difficulties caused by low-regularity initial data. By further incorporating harmonic analysis techniques and a resonance-preserving frequency-splitting (RFS) method, we obtain improved error estimates and enhanced convergence rates. In particular, for initial data in H^γ , the proposed approach achieves a convergence rate of order $3/2\gamma$ for the NLS, while maintaining favorable computational efficiency.

Optimization on the intersection of manifolds: orthogonal tangent directions and geometric methods

Ya-xiang Yuan

Chinese Academy of Sciences

Optimization problems constrained by the intersection of two manifolds have found broad applications in various fields. However, the coupling regions pose challenges for the development of efficient algorithms. To this end, we exploit the geometry of the manifold intersection to propose an infeasible method employing a retraction-based update based on two orthogonal directions, both of which are tangent to one of the manifolds. Specifically, the two directions are responsible for approaching the feasible intersection and minimizing the objective function, respectively. Under the assumption of intrinsic transversality, we prove an $O(1/K)$ convergence rate for both the feasibility and the optimality measures. Numerical experiments on spherical data fitting, hyperbolic embedding approximation, and compressed modes confirm the efficiency of the proposed method.

Exponential Approximation Rates of Tensor Neural Networks Across Activations

Haizhang Zhang

Sun Yat-sen University

Among various deep learning models, Tensor Neural Networks (TNNs) stand out for their elegant mathematical structure and significant applications in solving high-dimensional PDEs and eigenvalue problems. In this work, we explore the expressive power of TNNs by establishing unified exponential approximation

rates for TNNs employing commonly used activation functions. In particular, for TNNs with $O(m+m^{2/d})$ trainable parameters, we achieve an error rate of $O(\exp(-c_{d,f}m^{1/d}))$ when approximating periodic analytic functions, where $c_{d,f}$ is a positive constant depending on the target function f and the dimension d . This rate is optimal relative to existing results in the field. Our approach relies on a constructive error analysis framework using separable approximators, which breaks down the approximation task into two key steps: (i) building an appropriate separable approximator for the function space of interest, and (ii) constructing a TNN subnetwork that efficiently realizes this approximation. This strategy allows us to systematically establish approximation bounds for TNNs with a range of activation functions, including smooth activations and powers of ReLU (ReLU^q). Finally, we support our theoretical findings with numerical experiments that demonstrate the practical effectiveness of TNNs in approximating high-dimensional analytic functions.

Conforming Divergence-Free Rectangular Finite Elements for Axisymmetric Stokes Equations

Shangyou Zhang

University of Delaware

We construct 2D, rectangular, divergence-free, conforming finite elements for 3D axisymmetric Stokes problems. When the problem is reduced to 2D, we have two types of singularities at the axis. We introduce two types of variable substitutions and construct two families of finite elements accordingly, $Q_{k+1,k} \times Q_{k,k+1}/Q_k$ and $Q_{k+2,k} \times Q_{k+1,k+1}/Q_{k+1,k}$. Such a finite element method produces divergence-free solutions for the velocity. The stability and the quasi-optimal convergence are proved for both finite elements. Numerical tests confirm the theory and the pressure-robustness of the method.

Preconditioned Iterative Methods for Large-Scale Symmetric Nonnegative Inverse Eigenvalue Problems

Zhi Zhao

Hangzhou Dianzi University

In this talk, we address the symmetric nonnegative inverse eigenvalue problem (SNIEP), which seeks to construct a symmetric nonnegative matrix with a prescribed set of real eigenvalues. By reformulating the SNIEP as a nonlinear matrix equation over the Riemannian product manifold of symmetric matrices and the orthogonal group, we propose efficient Riemannian iterative methods for its solution. Our algorithms leverage novel preconditioners that exploit the problem's structure, significantly accelerating convergence. Under mild assumptions, we establish global convergence and analyze the local convergence rate. Numerical experiments are presented to demonstrate that the proposed methods are both efficient and robust in solving large-scale SNIEPs.