

第九届北京大学计算与应用数学拔尖博士生研讨会 暨第十二届北京计算数学研究生论坛

为促进计算与应用数学领域优秀博士生之间的互学互鉴，搭建展示成果、交流学习、了解前沿、自由讨论的学术平台，第九届北京大学计算与应用数学拔尖博士生研讨会暨第十二届北京计算数学研究生论坛将于2026年10月30日-10月31日在北京大学举行。期待与会者通过此次研讨，提升学术表达能力，拓宽研究视野，增强创新意识，激发科研热情，坚定攻坚克难的决心与信心，实现共同进步。

会议时间

2026年10月30日 09:00 至 17:30

2026年10月31日 09:00 至 17:30

会议地点

北京大学智华楼 101 王选报告厅

主办单位

国家自然科学基金委员会基础科学中心

北京大学数学科学学院

北京国际数学研究中心

北京大学国际机器学习研究中心

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大会报告人

许现民	中国科学院数学与系统科学研究院
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邀请报告人

陈天璐	浙江大学
戴景文	香港理工大学
邓茂林	香港中文大学
何鑫	武汉大学
侯頔	新加坡国立大学
黄奕程	中科院数学与系统科学研究院
李柄辉	北京大学
李树生	吉林大学
刘宇扬	北京大学
闵雅	四川大学
彭漫婷	南方科技大学
苏亮宇	西安交通大学
王辰扬	中国科学技术大学
王帅康	北京应用物理与计算数学研究所
王峥	上海交通大学
熊邝淼	复旦大学
杨星伟	北京师范大学
袁得恒	清华大学
张可欣	厦门大学
张蔚泓	香港科技大学

会议日程		
时 间	10 月 30 日	10 月 31 日
09:00-10:00	开幕式 大会报告 许现民	邀请报告 侯 嶝 王辰扬
10:00-10:30	茶 歇	
10:30-12:00	邀请报告 彭漫婷 戴景文 刘宇扬	邀请报告 邓茂林 熊邝淼 黄奕程
12:00-14:00	午 休	午 休
14:00-15:30	邀请报告 王 峥 苏亮宇 李柄辉	邀请报告 袁得恒 何 鑫 张蔚泓
15:30-16:00	茶 歇	
16:00-17:30	邀请报告 杨星伟 闵雅 李树生	邀请报告 王帅康 张可欣 陈天璐
17:30-19:00	晚 宴	

10月30日			
时 间	报告人	题目	主持人
09:00-09:15	开幕式		
09:15-10:00	大会报告 许现民	Model reduction based on the Onsager variational principle	张磊
10:00-10:30	合影与茶歇		
10:30-11:00	彭漫婷 南方科技大学	Recent Advances in Oscillation-Eliminating DG Methods for Hyperbolic Systems	苏华
11:00-11:30	戴景文 香港理工大学	An efficient and stable diffusion generated method for quadrilateral mesh generation in general domains	
11:30-12:00	刘宇扬 北京大学	植物生长中的动态应力反馈：数学建模与叶序形成机制	
12:00-14:00	午休		
14:00-14:30	王峥 上海交通大学	从数据到动力学：复杂系统的学习、重构与自主演化	王修远
14:30-15:00	苏亮宇 西安交通大学	一个结构化深度网络用于连续谱系统的表示和预测	
15:00-15:30	李柄辉 北京大学	理解大模型预训练动力学：从泛函尺度律视角	
15:30-16:00	茶歇		

16:00-16:30	杨星伟 北京师范大学	Unconditional Optimal Error Estimates and Energy Dissipation for a Projection Finite Element Method for the Harmonic Map Flow	郭宇扬
16:30-17:00	闵雅 四川大学	A Reynolds-Semi-Robust, Globally Divergence-Free E-HDG/IMEX-SAV Method for Variational Initial-State Data Assimilation of the Navier-Stokes Equations	
17:00-17:30	李树生 吉林大学	A linear dual-field finite element method for incompressible MHD, part I: cross-helicity and Alfvénic alignment in periodic domains	
17:30-19:00	晚宴 勺园中餐厅朗润厅		

10月31日			
时 间	报告人	题目	主持人
09:00-09:30	侯 頔 新加坡国立大学	Semidefinite Relaxations and Variable Fixing for Sparse Quadratic Programs	李晨毅
09:30-10:00	王辰扬 中国科学技术大学	A unified framework for high-order mimetic dif- ference methods and its application to the grad-div acoustic eigenvalue problem	
10:00-10:30	茶歇		

10:30-11:00	邓茂林 香港中文大学	离散 Calderón 问题：格点图上的唯一性理论	张振毅
11:00-11:30	熊邝森 复旦大学	基于衍射波的反散射问题	
11:30-12:00	黄奕程 中科院数学与系统科学研究院	A robust multigrid method for high wavenumber Helmholtz problems via ray equation correction	
12:00-14:00	午休		
14:00-14:30	袁得恒 清华大学	通信约束下的分布式统计学习	应骏达
14:30-15:00	何鑫 武汉大学	Phase Transition from Random Features to Fully Trainable Networks	
15:00-15:30	张蔚泓 香港科技大学	Prescribed-Basis Coefficient-to-Coefficient Neural Operator for Partial Differential Equations	
15:30-16:00	茶歇		
16:00-16:30	王帅康 北京应用物理与计算数学研究所	求解双曲守恒律的高效紧致时间单步高阶格式	李佳
16:30-17:00	张可欣 厦门大学	Two classes of fifth-order conservative Hermite WENO remapping methods for moving mesh solvers	
17:00-17:30	陈天璐 浙江大学	Large Time Behavior of Viscosity Solutions of Coupled Hamilton-Jacobi Systems	

Model reduction based on the Onsager variational principle

许现民

中国科学院数学与系统科学研究院

The Onsager principle is a fundamental law for irreversible processes in statistic physics. It has been used to develop theoretical models for many problems in soft matter, like the diffusion process, the dynamics of liquid crystal solution and the moving contact line problems, etc. Recently, the variational principle has been used as an approximation tool to derive reduced models for many complicated systems. In this talk, I will review the key idea of the method and its applications in various problems. I will also present some recent progress on applications the Onsager variational principle in numerical analysis. We will show that the variational formulation makes it convenient to design numerical schemes and to do numerical analysis.

个人简介：许现民本科毕业于南开大学，博士毕业于北京大学，曾先后赴牛津大学、香港科技大学和亚琛工业大学进行长期学术访问或博士后研究，现为中科院数学与系统科学研究院研究员。其主要研究兴趣是软物质科学中复杂多尺度多物理问题的可计算建模、理论分析和数值方法，研究对象包括两相流、非线性弹性材料、以及曲面偏微分方程等，近期主要研究基于 Onsager 变分原理的可计算建模与模型约化方法。

Recent Advances in Oscillation-Eliminating DG Methods for Hyperbolic Systems

彭漫婷

南方科技大学

Discontinuous Galerkin (DG) methods provide a compact, high-order accurate framework for hyperbolic conservation laws. However, high-order accuracy alone guarantees neither physical-constraint preservation nor entropy stability, and DG approximations may exhibit Gibbs-type spurious oscillations near discontinuities, including those arising from smooth initial data. In this talk, we trace recent developments from the oscillation-eliminating DG (OEDG) method through the convex oscillation-suppressing (COS) DG method to the EPO-DG method, showing how oscillation suppression can be progressively combined with bound preservation and entropy stability. Theoretical analysis of OEDG for linear advection equations, including optimal error estimates and superconvergence, as well as applications to general relativistic hydrodynamics and the Allaire five-equation model with the Mie – Grüneisen equation of state, will also be discussed.

We further extend these ideas to central DG (CDG) methods, which evolve the solution on staggered meshes and avoid the need for Riemann solvers. Starting with the oscillation-eliminating CDG (OECDG) method, we exploit the staggered structure to construct compact primal – dual OE damping. We then use Riemann-fan averages to identify a common structure shared with DG methods and construct EPO-CDG to achieve entropy stability, bound preservation, and oscillation suppression simultaneously. Unlike SBP-based DG approaches that rely on interface numerical fluxes, this formulation establishes entropy stability in CDG without introducing such fluxes. Beyond the established optimal error estimates for CDG methods, we prove, to our knowledge, the first superconvergence theorem for the baseline CDG scheme applied to linear advection equations, laying the groundwork for future analysis of the proposed methods and related CDG schemes.

个人简介：彭漫婷，南方科技大学数学系博士研究生，师从吴开亮教授。主要研究双曲型系统的高阶保结构、抑制伪振荡的间断 Galerkin 方法。相关成果发表于 *Mathematics of Computation*、*Journal of Computational Physics*、*SIAM Journal on Scientific Computing* 等国际期刊。主持国家自然科学基金青年学生基础科研项目（博士研究生），入选中国科协青年科技人才培养工程博士生专项计划，曾获 CSIAM 年会学生论坛优秀报告奖。

An efficient and stable diffusion generated method for quadrilateral mesh generation in general domains

戴景文

香港理工大学

We introduce a robust and computationally efficient framework for generating high-quality quadrilateral meshes on general two-dimensional domains. The proposed method computes cross fields by minimizing a modified, relaxed Ginzburg – Landau energy functional. A key innovation is the extension of the original problem to a larger, regular auxiliary domain, which transforms the primary computational procedure into an iterative scheme comprising only two straightforward operations: global linear diffusion via the Fast Fourier Transform (FFT) and point-wise normalization. This strategy eliminates the conventional reliance on an intermediate triangular mesh or on solving nonlinear optimization problems over the irregular domain. We present a rigorous theoretical proof that the iterative algorithm ensures unconditional monotonic decay of the objective functional. Extensive numerical experiments demonstrate the method’s robustness across a wide spectrum of complex geometries, its substantial computational efficiency afforded by the FFT-based diffusion, and its consistent production of high-quality quadrilateral meshes. This work provides a reliable, theoretically sound alternative to established mesh generation techniques, with significant potential for impact in practical scientific computing applications.

个人简介：戴景文，2023 毕业于西北工业大学信息与计算科学专业，现为香港理工大学应用数学系博士研究生，导师为乔中华教授。主要研究兴趣为：网格生成与自适应方法。

植物生长中的动态应力反馈：数学建模与叶序形成机制

刘宇扬

北京大学

应力介导下的反馈机制是植物生长过程中很重要的物理学机制，也是当前计算生物学和植物发育学领域的核心挑战之一。植物器官的形态发生不仅受到生物化学信号的调控，也与组织内部的力学作用密切相关。本报告首先介绍一种基于动态应力反馈的植物生长数学模型，该模型结合非线性弹性理论，将膨压驱动的组织形变、应力诱导的皮质微管重排以及纤维素微纤丝引起的各向异性刚度变化耦合起来，实现对植物器官动态生长过程的模拟。随后，我们以植物叶序，即叶片沿茎轴的规律性排列为例，结合数值模拟与生物实验，探讨机械信号在植物形态发生中的调控作用。研究表明，动态应力反馈不仅能够限制新生器官的生长范围，还可以参与决定新器官的起始位置，为传统的生长素调控机制提供一条并行的生物物理途径。此外，我们还发现适当的反馈强度对于维持稳定的叶序至关重要。

个人简介：刘宇扬，北京大学数学科学学院计算数学专业 2024 级博士生，由数学科学学院的张平文老师和北京国际数学研究中心的张磊老师联合培养，主要研究方向为生物数学和数据同化。

从数据到动力学：复杂系统的学习、重构与自主演化

王峥

上海交通大学

如何从有限观测中学习并自主再现复杂动力学，是连接机器学习与非线性科学的重要问题。本报告以储备池计算及相关递归学习模型为切入点，讨论离散观测、非线性表征、模型学习与自主动力学之间的联系，重点关注数据驱动模型对源系统吸引子结构、稳定性特征与长期行为的重构能力及其理论基础。报告将结合理论分析与典型动力系统，介绍从局部预测走向整体动力学重构的研究思路，探讨观测信息、模型结构与学习机制如何共同影响重构效果，并进一步讨论向高维及无限维系统推广的可能路径，为复杂系统建模与科学机器学习提供新的分析视角。

个人简介：研究兴趣主要集中于复杂动力系统与机器学习的交叉领域，关注数据驱动建模、储备池计算、非线性动力学及吸引子重构等问题。当前研究围绕有限观测条件下的动力学学习与自主重构展开，注重结合数学分析、模型构造与计算验证，探索学习模型保持源系统几何结构和长期行为的条件与机制，并关注相关方法在高维系统及无限维动力系统中的应用拓展。

一个结构化深度网络用于连续谱系统的表示和预测

苏亮宇

西安交通大学

常见复杂动力系统常由不可数模态构成而非有限模态，传统离散数值方法通常难以直接处理这类连续模态，针对该难题，我们提出了一个结构化的神经网络模型——CocycleNet，其兼具表达能力，稳定性与一定可解释性。特别是，为克服长时序预测中的数值发散问题，我们推导了乘法遍历定理（MET）的一个实用充分条件，并将其作为约束整合至模型结构中。借助结构化生成器参数化与复数潜空间表示，CocycleNet 实现了从数据驱动的动力学结构自动提取，它能够在不预设先验知识的情况下，解析相干模态、表征随能量演变的谱特性，并解构复杂动力学背后的低维流形组织。并且大幅提升了现有 SoTA 的有效预测长度，更精确再现了系统底层的几何结构与统计分布规律。

个人简介：苏亮宇，现为西安交通大学数学与统计学院博士研究生，师从徐宗本教授。2021 年本科毕业于西安交通大学应用数学专业，主要研究方向为动力系统与人工智能的交叉研究以及数据驱动动力系统仿真和预测研究等。

理解大模型预训练动力学：从泛函尺度律视角

李柄辉

北京大学

尺度律（Scaling Law）已成为指导现代人工智能发展的核心准则。它不仅确立了“大规模参数是实现模型通用性的必要条件”这一共识，更揭示了资源投入能稳定提升系统性能的规律。在工程实践中，经验性的尺度律已被广泛用于指导实际大模型的训练。然而，现有的经验尺度律仍面临三大局限：

缺乏动态视角：无法刻画训练的完整动力学过程；

忽视超参影响：难以定量反映学习率、批大小等关键超参数对训练效率的影响；

现象解释力不足：无法解释实际训练中的重要观测（如采用 WSD 学习率调度时，损失曲线呈现出的显著两阶段特性）。

针对上述局限性，本系列研究从第一性原理出发，基于幂律核回归模型，推导出了能够精确刻画模型训练完整损失动力学的泛函尺度律（Functional Scaling Law）。泛函尺度律表明，模型训练可解耦为“信号学习”与“噪声积累/遗忘”两个动力学过程，整体的损失曲线行为由两者间的动态平衡所决定。更进一步，基于泛函尺度律框架，我们从理论层面分析了模型训练中的学习率调度与批大小调度的最优方案，并在真实大模型预训练中验证了理论结果的有效性。

个人简介：李柄辉，北京大学国际机器学习研究中心 2023 级博士生，本科毕业于北京大学图灵班。研究方向为深度学习理论，重点关注大模型预训练机理、优化理论及尺度律。目前，已以第一作者或共同第一作者身份在 NeurIPS、ICLR、ICML、COLT 等国际顶级学术会议上发表论文 11 篇，其中关于泛函尺度律的两篇论文分别入选 NeurIPS 2025 和 NeurIPS 2026 Spotlight 论文。此外，入选中国科协青年人才托举工程博士生专项计划。

Unconditional Optimal Error Estimates and Energy Dissipation for a Projection Finite Element Method for the Harmonic Map Flow

杨星伟

北京师范大学

We propose and analyze a linearly implicit, mass-lumped finite element method for the heat flow of harmonic maps into the unit sphere. The method consists of a linear predictor followed by a nodal projection and therefore preserves the unit-length constraint exactly at all finite element nodes. On Cartesian tensor-product meshes consisting of rectangles or cuboids, we establish optimal error estimates without any coupling condition between the time step Δt and the mesh size h : the method converges at the rate $O(\Delta t + h^2)$ in $l^\infty(0, T; L^2)$. To the best of our knowledge, such optimal-order estimates without coupling Δt and h have not previously been available for fully discrete finite element methods that approximate the full vector-valued problem while enforcing the unit-length constraint exactly at every node. On the same meshes, the nodal projection is nonexpansive in the discrete Dirichlet energy induced by the quadrature-based stiffness form; combined with the predictor energy estimate, this yields an unconditional discrete energy dissipation law. The scheme is based on a cross-product reformulation of the equation and can be reformulated as either a mass-lumped discretization of the original formulation with a correction term enforcing nodal orthogonality or the corresponding mass-lumped normalized tangent-plane scheme. Numerical experiments confirm the predicted convergence rate and the discrete energy decay.

个人简介：杨星伟，北京师范大学计算数学专业博士二年级学生，导师为蔡勇勇教授。主要研究方向为非凸约束梯度流（如调和热流方程，Landau-Lifshitz 方程）的保结构有限元方法设计与分析。

A Reynolds-Semi-Robust, Globally Divergence-Free E-HDG/IMEX-SAV Method for Variational Initial-State Data Assimilation of the Navier-Stokes Equations

闵雅

四川大学数学学院

This paper develops an embedded-hybridized discontinuous Galerkin (E-HDG) method combined with a first-order implicit-explicit scalar auxiliary variable (IMEX-SAV) time discretization for variational initial-state data assimilation governed by the unsteady incompressible Navier-Stokes equations. We adopt an optimize-then-discretize strategy. The spatial discretization uses discontinuous piecewise polynomials of degrees k and $k - 1$ for the element velocity and pressure, respectively, a continuous degree- k velocity trace, and a discontinuous degree- k pressure trace. The resulting state and adjoint velocities, as well as the reconstructed initial velocity, are globally divergence-free. The forward IMEX-SAV state scheme is unconditionally energy stable. Under suitable regularity and local-trajectory assumptions whose bounds introduce no explicit negative powers of the viscosity, the mesh-dependent condition $\Delta t \lesssim h^2$, and a contractivity condition on the Tikhonov parameter, we establish local existence and uniqueness of the fully discrete OTD optimality system and Reynolds-semi-robust L^2 error estimates of order $O(h^k + \Delta t)$ for the state, adjoint and reconstructed initial velocities; the constants contain no explicit negative powers of the viscosity. Numerical experiments confirm convergence on smooth tests and demonstrate machine-precision discrete incompressibility, effective nonlinear-solver behavior, and stable performance in small-viscosity regimes.

个人简介：闵雅，就读于四川大学，谢小平老师的博士生，主要研究偏微分方程最优控制问题的非标准有限元方法。

A linear dual-field finite element method for incompressible MHD, part I: cross-helicity and Alfvénic alignment in periodic domains

李树生

吉林大学

Cross helicity, together with total energy, determines the Elsässer energies and thus quantifies departures from Alfvénic alignment in incompressible MHD. We construct a linear finite element method for periodic domains that reproduces the cross-helicity balance. We connect the discrete energy and cross-helicity conservation laws to Alfvénic alignment through a nonnegative Elsässer-energy representation, establishing preservation of the corresponding exact relation when either Elsässer energy is initially zero in the unforced ideal case. We reassign the two discrete approximations of the magnetic field to the integer and half-integer time levels and modify the Lorentz-induction couplings. The resulting scheme uses linear staggered updates and retains the energy balances, strong and weak divergence-free properties, and magnetic- and fluid-helicity balances. Numerical experiments illustrate the role of the cross-helicity balance in preserving an aligned state in the ideal case and in alignment dynamics under weak dissipation.

个人简介：2022 级吉林大学计算数学博士，主要研究方向是偏微分方程特征值问题的数值方法。

Semidefinite Relaxations and Variable Fixing for Sparse Quadratic Programs

侯頔

新加坡国立大学

Sparse quadratic optimization arises in applications such as sparse regression, portfolio selection, and feature selection, where only a limited number of variables can be nonzero. These problems are challenging because of the combinatorial sparsity constraint and the potentially nonconvex objective. Strong lower bounds and effective problem reduction are therefore essential for global optimization. In this talk, I will present a framework that combines semidefinite relaxation, efficient computation, and safe presolving for sparse quadratic programs. I will introduce a sparsity-cone formulation that provides strong lower bounds through a compact semidefinite relaxation, and describe a low-rank augmented Lagrangian method for solving it. I will then show how information from the relaxation can certify that certain variables must be zero at optimality and exclude support patterns that cannot contain an optimal solution. Numerical experiments will illustrate the strength of the relaxation, the scalability of the algorithm, and the benefits of these certificates for mixed-integer optimization. This is joint work with Thai P.D. Nguyen, Kim-Chuan Toh, and Guanyi Wang.

个人简介：侯頔，新加坡国立大学数学系博士后，2026 年获该校数学博士学位。曾获新加坡国立大学理学院杰出研究生奖、数学系最佳研究生奖、校长研究生奖学金等。主要研究方向为半定规划与大规模矩阵优化，致力于非凸低秩算法及其在混合整数优化、多项式优化和数据科学中的应用。相关论文发表于 *Operations Research*、*Mathematical Programming*、*Mathematics of Operations Research*、*Mathematical Programming Computation* 等期刊。

A unified framework for high-order mimetic difference methods and its application to the grad-div acoustic eigenvalue problem

王辰扬

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We introduce a unified analytical framework for high-order mimetic difference schemes for a broad class of partial differential equations. The core of the framework lies in an operator decomposition technique that systematically characterizes the relationship between high-order and second-order mimetic operators. A central feature of the framework is the construction of a mimetic de Rham complex that forms an exact sequence and commutes with the corresponding continuous de Rham complex, taking vital importance in preserving physical structures. Building on this structure-preserving formulation, we establish theoretical estimates for a variety of model problems, both showing a priori error estimate and proving the structure preservation. Finally, we propose the application of the mimetic difference method for the grad-div acoustic eigenvalue problem. We apply a mimetic difference discretization and utilize the exactness of the mimetic de Rham complex to design a curl-curl type kernel compensation operator to effectively manage the infinite-dimensional kernel of the grad-div operator. We also design the preconditioner to achieve high-efficiency computation.

个人简介：王辰扬，中国科学技术大学博士研究生，导师为徐岩教授。主要研究方向为模拟差分方法与偏微分方程数值解法。

离散 Calderón 问题：格点图上的唯一性理论

邓茂林

香港中文大学

离散 Calderón 问题研究如何通过边界电压与电流测量，恢复电阻网络各条边上的电导率，是电阻抗成像问题的离散对应。本报告介绍格点图上离散 Calderón 问题的唯一性理论，涵盖多维标准格点图、具有长程相互作用的非局部格点图以及 A_n 型晶格图。报告将重点阐述如何利用边界狄利克雷-诺伊曼映射确定角点激发空间，并结合离散唯一延拓与逐层重构方法，证明电导率恢复的唯一性并构造重构算法。此外，报告还将讨论含顶点非线性项模型的推广，并展示二维非局部格点图与三维格点图上的数值重构结果。

个人简介：2020 年 9 月至 2024 年 6 月，浙江大学数学系，本科。

2024 年 8 月至今，香港中文大学数学系，博士研究生（本科直博生）。

基于衍射波的反散射问题

熊邗淼

复旦大学

除反射与折射之外，波的另一种偏折形式是衍射。特别地，当入射波传播至障碍物的角点和锥点时，会在该处激发向全方向传播的衍射波。与受几何光学约束的反射波不同，衍射波具有全方向传播的特性，因此利用衍射波进行探测可以显著降低对接收器位置和大小要求，并能在反射阴影区域中实现目标反演。此外，衍射系数作为描述障碍物奇异结构对衍射波影响的重要物理量，蕴含了角点、锥点附近的局部几何信息，在雷达探测和计算电磁学等领域具有重要的应用价值。我们围绕奇异障碍物的反散射问题，考虑在有限观测条件下，通过衍射信息恢复障碍物的位置以及几何结构。具体针对二维多边形障碍物以及三维锥形障碍物，分别给出了基于衍射波数据的显式反演方法并证明了反演的唯一性。该方法首次系统地利用衍射波及衍射系数进行奇异障碍物的几何反演，大幅放宽了接收器布设所需的几何约束，并为反射阴影区域中的目标反演建立了新的理论框架。通过直接提取衍射波所包含的几何信息，该方法还可以避免复杂的方程求解，从而减少反演所需的数据量和计算成本。

个人简介：熊邗淼，复旦大学上海数学中心 2024 级博士研究生，研究方向为数学物理反问题、散射理论与谱理论。研究生阶段主要围绕有限观测条件下基于衍射波的反散射问题开展研究，现与合作者完成了二维多边形障碍物和三维凸锥障碍物的显式反演与唯一性分析，形成两篇预印本。以“基于衍射波的反散射问题”为题，在第十五届全国反问题、成像及其应用会议（IPIA 2026）和上海市工业与应用数学学会 2026 年学术会议等会议作报告，其中在 IPIA 2026 获优秀研究生报告奖。

A robust multigrid method for high wavenumber Helmholtz problems via ray equation correction

黄奕程

中科院数学与系统科学研究院

We develop a ray-equation correction multigrid (RECMG) method for finite element discretizations of the two-dimensional Helmholtz equation with a positive constant wavenumber and impedance boundary conditions. The central idea is to represent a near-nullspace oscillatory error as $e(\mathbf{x}) = a(\mathbf{x})e^{i\mathbf{w}\cdot\mathbf{x}}$, thereby transforming it into the slowly varying, low-frequency amplitude a , which is corrected through the associated ray equation. Under the stated geometric and regularity assumptions, and provided that $k^2h \leq c$, we establish a conditional convergence result for the idealized phase-matched correction with exact ray-equation inversion. In the pollution-controlled regime $k^3h^2 = O(1)$, the complete multigrid algorithm admits a strict $O(N_h)$ work bound. Numerical experiments on structured square meshes, an L-shaped domain, and unstructured meshes show that all completed cases reduce the relative algebraic error below 10^{-6} within two or three RECMG sweeps.

个人简介：黄奕程，中国科学院数学与系统科学研究院在读博士生，导师是郑伟英老师，主要研究高频散射问题的适定性和离散系统的快速求解。主要工作在四川南充博士生论坛、EASIAM（韩国）年会上进行过报告。

通信约束下的分布式统计学习

袁得恒

清华大学

在经典的统计学习问题中，通常假设所有训练数据都集中在同一个中心位置。然而，在联邦学习等许多实际场景中，数据由分布式传感器采集，需要通过通信带宽受限的信道传输给学习者。分析这一模型的理论极限是近年来的研究热点。我们的工作研究分布式有通信约束下的一个分布估计问题。在一定的正则性假设下，我们刻画了一般参数区域下的极小极大最优速率，并发现当每个终端的样本从稀疏变为稠密时，最优速率会出现相变。以往工作只关注样本稠密，或每个终端仅有单个样本的情形，本文完整解决了它们遗留的这一问题。由我们的结果可以直接得到多种特殊情形的最优速率，例如密度估计、高斯回归、二元回归、泊松回归和异方差回归模型。

个人简介：袁得恒是清华大学数学科学系的在读博士研究生，2022年本科毕业于清华大学。他的研究兴趣包括机器学习与信息论中的数学问题，在 IEEE TIT、IEEE TCOM、NeurIPS、ICML 等数学、机器学习与信息论交叉领域的顶级期刊和会议上发表论文 10 篇。

Phase Transition from Random Features to Fully Trainable Networks

何鑫

武汉大学数学与统计学院

Constructing accurate and computationally tractable approximation spaces is a fundamental task in scientific computing. Partially trainable neural networks bridge fixed random features and fully adaptive representations. This paper quantifies a phase transition pattern in approximation bounds and observes analogous behavior in training errors: a rapid but smooth initial improvement followed by diminishing returns, with a sharper transition under greater initialization mismatch. Under polynomial spectral decay with exponent $\alpha > 1$ and leverage compatibility, we establish a squared L_2 approximation rate $\mathcal{O}((\kappa_P \log(m/\delta)/m)^\alpha)$ for two-layer networks of width m and trainable proportion P , where $\kappa_P = (P/\kappa_1^* + (1-P)/\kappa_0^*)^{-1}$. The bound holds uniformly over the unit ball of a reproducing kernel Hilbert space (RKHS) with probability at least $1 - \delta$. The constants κ_0^* and κ_1^* quantify the fixed and trainable groups' sampling mismatches relative to the target RKHS. For spherical biased-ReLU features in dimension d , we verify these assumptions with $\alpha = (d+2)/(d-1)$ and $\kappa_0^* = 4\sqrt{2}\tau(d+1)/d$ for initialization scale $\tau \geq 1$, and $\kappa_1^* = 1$ under ridge leverage sampling. In particular, for $d = 5$ and $\tau = 10$, a trainable proportion of approximately 4.1% captures 90% of the reduction in the approximation bound from $P = 0$ to $P = 1$. A structured three-layer example further illustrates how a few trainable first-layer neurons exploit fixed downstream blocks through non-linear composition. Numerical experiments across diverse settings, including networks with up to 15 layers, exhibit similar phase transitions in training errors.

个人简介：武汉大学数学与统计学院 2025 级博士生，导师吕锡亮教授，研究方向：深度神经网络的逼近理论。

Prescribed-Basis Coefficient-to-Coefficient Neural Operator for Partial Differential Equations

张蔚泓

香港科技大学

Operator learning provides a data-driven approach to approximating solution operators of partial differential equations, but its effectiveness depends strongly on how input and output functions are represented. Point-value representations can make the trainable map mesh-dependent and high-dimensional; snapshot-based POD/PCA reductions require aligned data and basis construction, while learned representations introduce additional trainable encoders, decoders, or neural bases. We propose the Fixed-Basis Coefficient-to-Coefficient Network (FB-C2CNet), which learns PDE solution maps in fixed, data-independent approximation spaces using prescribed bases as function encoders and decoders. Input observations are encoded by regularized least-squares projection onto bases such as finite element, random-feature, or radial-basis-function bases. A neural network maps the resulting input coefficients to output coefficients, and the fixed decoder reconstructs the solution at arbitrary target locations. This separation of basis selection from network training avoids neural basis learning and snapshot-based basis extraction, reduces the dimension of the trainable map, and lowers training cost. With suitable prescribed bases, FB-C2CNet also accommodates scattered, non-aligned, and sample-dependent observations. We analyze the stability–bias trade-off of regularized coefficient encoding and the intrinsic projection error determined by the output space. Experiments on elliptic, nonlinear time-dependent, weak-solution, high-dimensional, and inverse Stokes boundary-recovery problems demonstrate competitive accuracy with reduced trainable dimension and training cost, including for high-resolution and irregularly sampled data.

个人简介：张蔚泓，目前是香港科技大学数学系应用数学专业博士三年级，本科毕业于武汉大学。研究方向是 AI for Science，包括神经网络方法求解 PDE，算子学习等。

求解双曲守恒律的高效紧致时间单步高阶格式

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本研究提出了一种高效的时间单步高阶格式，该格式将近似 Lax-Wendroff (ALW) 过程与 ADER-SHWENO 格式 [Luo 等, 2024. J. Comput. Phys. 504, 112886] 相结合，在保持五阶时空精度的同时实现了显著的计算加速。主要创新点包括：（1）采用基于有限差分的 ALW 近似替代通量雅可比矩阵计算，避免了精度提升带来的指数级成本增长；（2）通过 SHWENO 重构时仅需节点守恒量，简化了空间重构过程，无需计算空间导数及相关的线性化黎曼问题；（3）借助张量积多项式构造和拉格朗日基函数的分裂微分，实现多维问题的解耦计算。数值验证表明，新格式相比基准 ADER-SHWENO 方法计算时间缩短约 50%（一维）和 90%（二维），且保持五阶精度。关键的是，基准测试证实该格式支持更大的 CFL 条件数，且无需通过辅助方程处理内部自由度，性能优于 ALW-DG/ALW-FR 方法。

个人简介：王帅康，北京应用物理与计算数学研究所计算数学专业博士生（四年级），导师陈艺冰研究员，研究方向为计算流体力学。

Two classes of fifth-order conservative Hermite WENO remapping methods for moving mesh solvers

张可欣

厦门大学数学科学学院

We propose two classes of fifth-order remapping methods built on Hermite weighted essentially non-oscillatory (HWENO) reconstruction. Remapping methods are designed to conservatively interpolate the solution from one mesh onto a possibly uncorrelated new one. Different classes of remapping methods have their respective advantages and disadvantages, and are suited to different application scenarios. We focus on overlay-intersection-based methods and pseudo-time-PDE-based methods. The goal of these works is to show that our remapping methods maintain high-order accuracy of HWENO reconstruction while preserving some desired properties, such as robustness, conservation, positivity, high resolution, and high efficiency. A series of numerical results is given to verify the efficiency and effectiveness of the HWENO remapping methods on 1D lined meshes and 2D quadrilateral meshes. Furthermore, we apply the HWENO remapping methods to the fifth-order finite volume rezoning moving mesh HWENO (RMM-HWENO) method for hyperbolic conservation laws. Numerical results of the compressible Euler equations are also presented to show the performance of the HWENO remapping methods in the RMM-HWENO simulation.

个人简介：张可欣，厦门大学在读博士，研究方向为计算流体力学中的高精度数值方法，重点关注 Hermite WENO (HWENO) 格式、自适应移动网格方法。参与国家重点研发计划“极端条件下复杂流动的高精度算法与理论分析”，并在第九届景润青年学术周、京津冀+计算数学年会等会议作报告。

Large Time Behavior of Viscosity Solutions of Coupled Hamilton-Jacobi Systems

陈天璐

浙江大学

We propose novel monotone and high-order approximation schemes for solving generic static weakly coupled Hamilton-Jacobi systems, and we further study the large time behavior of the corresponding time-dependent coupled HJ systems to show that the monotone scheme produces a convergent viscosity solution. Built upon the large-time behavior of the time-dependent system, the method employs a Gauss-Seidel sweeping strategy to integrate Lax-Friedrichs numerical Hamiltonians with high-order WENO approximations. Theoretically, we prove that the monotone approximation scheme converges to the viscosity solution of a class of convex HJ systems of nonlinearly coupled Hamiltonians equipped with the Dirichlet boundary condition. Numerically, we verify that the numerical solution produced by the monotone approximation scheme converges to the viscosity solution with first-order accuracy, and we further demonstrate the accuracy and robustness of the proposed high-order approximation schemes in handling more challenging scenarios, such as obstacle problems and large-deviation models.

个人简介：浙江大学数学科学学院计算数学博士生。

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