

“应用数学-前沿与展望”研讨会

2025 年 6 月 27 - 29 日

会议学术委员会

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主办单位

中国科学技术大学数学科学学院

中国科学技术大学几何与物理研究中心

会议秘书

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会议地点

中国科学技术大学东区物质科研楼三楼会议室

住宿酒店

安徽饭店 (蜀山区芜湖路18号)

会议班车

班车接送时间表

(安徽饭店 $\rightleftharpoons$ 科大东区)

日期	发车时间 (安徽饭店)	发车时间 (科大东区)
6月28日	7:50	17:50
6月29日	8:00	12:45

会议日程

6月28日（周六）			
时间	报告人	标题	主持人
08:20-08:30	领导致辞		左达峰
08:30-08:40	数学科学学院发展介绍		
08:40-08:50	几何与物理研究中心发展介绍		
08:50-09:00	合影		
09:00-09:30	丁剑	Detecting correlation in stochastic block models	韩德仁
09:35-10:05	周栋焯	大脑神经元的约化建模与类脑网络设计	许志强
10:05-10:35	休息		
10:35-11:05	孟德宇	Continuous Representation-Induced Regularization Methods for Multi-Dimensional Data Recovery	赵鹏
11:10-11:40	陆帅	Function and derivative approximation by shallow neural networks	徐振礼
午餐			
14:20-14:50	葛颢	Improved Whole-genome Amplification and Bayesian Linkage Analyses Enable High-Accuracy Non-Invasive Preimplantation Genetic Testing from Spent Embryo Culture Medium	李启寨
14:55-15:25	刘伟 （武汉大学）	Concentration inequalities and exponential convergence for mean-field weakly interacting particle system and McKean-Vlasov equation	刘伟 （江苏师范大学）

15:25-15:55	休息		
15:55-16:25	李进开	Uniform boundedness versus instantaneous blow-up of physical entropy of the compressible idea gases	张举勇
16:30-17:00	孙桂全	网络反应扩散系统斑图动力学	吕锡亮
17:05-17:35	孔新兵	Data synchronization at high frequencies	刘党政
晚餐			

6月29日(周日)			
时间	报告人	标题	主持人
08:30-09:00	明平兵	Barron type space and application in neural network approximation and Schrodinger equations	杨志坚
09:05-09:35	赖俊	Shape Taylor Expansions for Wave Scattering Problems	任景莉
09:40-10:10	蒋凯	丢番图误差的算法和理论	马立明
10:10-10:40	休息		
10:40-11:10	林伟	复杂系统与人工智能互驱的应用数学研究	熊涛
11:15-11:45	邵嗣烘	寻找第四类数值方法	徐岩
午餐			

题目及摘要

6月28日（周六）

主持人：韩德仁

09:00-09:30 丁剑（北京大学）

题目： Detecting correlation in stochastic block models

摘要： A basic goal for random graph matching is to recover the vertex correspondence between two correlated graphs from an observation of these two unlabeled graphs. Random graph matching is an important and active topic in combinatorial statistics: on the one hand, it arises from various applied fields such as social network analysis, computer vision, computational biology and natural language processing; on the other hand, there is also a deep and rich theory that is of interest to researchers in statistics, probability, combinatorics, optimization, algorithms and complexity theory. An important task before matching is to test whether two graphs are indeed correlated (ie, the detection problem). In this talk, I will present some recent progress on detecting correlations between two graphs sampled from stochastic block models, featuring the algorithmic and computational issues. Our work is inspired by recent work on detecting correlations for Erdos-Renyi graphs. This is based on joint work with Guanyi Chen, Shuyang Gong and Zhangsong Li.

主持人：许志强

09:35-10:05 周栋焯（上海交通大学）

题目： 大脑神经元的约化建模与类脑网络设计

摘要： 类脑智能研究既是科学前沿，也是国家脑计划和人工智能发展规划的核心内容，而作为大脑信息处理的基本单元即单个神经元的动力学建模是实现脑计算的定量理解和发展脑启发的人工智能的第一步。然而，现有的点神经元模型在捕捉与神经信息处理至关重要的复杂树突效应方面存在不足，不能够反映真实神

经元强大的树突计算能力。我们通过建立包含树突结构的电缆理论的渐近分析框架，将基于偏微分方程组的电缆神经元模型简化成基于常微分方程的点神经元模型，我们的生物物理模型引入了额外的突触整合电流，它源自于空间树突上的突触电流之间的非线性相互作用。此外，我们的模型有效刻画了具有复杂树突结构的神经元的胞体的电压响应，能够实现复杂的树突计算功能。此外，我们通过渐近分析框架推导出一个双线性整合法则，并建立了一个真实神经元与人工神经元之间的简单而有效的映射关系，该映射在模拟真实神经元胞体动力学的准确性、训练复杂度、参数量以及动态时序数据处理等方面都明显优于现有的模型。我们的工作为研究具有空间树突结构的神经元动力学与功能提供了一个系统的理论和计算框架，为设计脑启发的人工神经网络提供了新的思路。

主持人：赵鹏

10:35-11:05 孟德宇（西安交通大学）

题 目： Continuous Representation-Induced Regularization Methods for Multi-Dimensional Data Recovery

摘要： Most classical regularization-based methods for multi-dimensional imaging data recovery can solely represent multi-dimensional discrete data on meshgrid, which hinders their potential applicability in many scenarios beyond meshgrid. To break this barrier, we propose a series of continuous functional representation methods, which can continuously represent data beyond meshgrid with powerful representation abilities. Specifically, the suggested continuous representation manner, which maps an arbitrary coordinate to the corresponding value, can continuously represent data in an infinite real space. Such an ameliorated representation regime always facilitates better efficiency, accuracy, and wider range of available domains (e.g., non-meshgrid data) of regularization based methods. In this talk, we will introduce how to revolutionize the conventional low-rank, TV, non-local self-similarity regulation methods into their continuous ameliorations, i.e., Low-Rank

Tensor Function Representation (termed as LRTFR), neural domain TV (termed as NeurTV), and Continuous Representation-based NonLocal method (termed as CRNL), respectively. We will also show extensive multi-dimensional data recovery applications arising from image processing (like image inpainting and denoising), machine learning (like hyperparameter optimization), and computer graphics (like point cloud upsampling) to validate the favorable performances of our method for continuous representation.

主持人：徐振礼

11:10-11:40 陆帅（复旦大学）

题目：Function and derivative approximation by shallow neural networks

摘要：We investigate a Tikhonov regularization scheme tailored explicitly for shallow neural networks within the context of solving a classic problem: approximating an unknown function and its derivatives in a unit cubic domain based on noisy measurements. The proposed Tikhonov regularization scheme incorporates a penalty term that takes three distinct yet intricately related network (semi)norms: the extended Barron norm, the variation norm, and the Radon-BV seminorm. These choices of the penalty terms are contingent upon the specific architecture of the neural network being utilized. We establish the connection between various network norms and particularly trace the dependence of the dimensionality index, aiming to deepen our understanding of how these norms interplay with each other. We revisit the universality of function approximation through various norms, establish rigorous error-bound analysis for the Tikhonov regularization scheme, and explicitly elucidate the dependency of the dimensionality index, providing a clearer understanding of how the dimensionality affects the approximation performance and how one designs a neural network with diverse approximating tasks. The numerical experiments verify the theoretical analysis. It is a joint work with Yuanyuan Li (Fudan University).

主持人：李启寨

14:20-14:50 葛颢（北京大学）

题目： Improved Whole-genome Amplification and Bayesian Linkage Analyses Enable High-Accuracy Non-Invasive Preimplantation Genetic Testing from Spent Embryo Culture Medium

摘要： Traditional preimplantation genetic testing for in vitro fertilization requires invasive trophoctoderm biopsy, which may harm the embryo. Non-invasive preimplantation genetic testing utilizing cell-free DNA from spent embryo culture medium is a potential alternative but faces challenges to clinical application due to trace DNA content, maternal cell contamination, and high allele drop-out rates. We applied an improved single-cell linear genome amplification method to 89 spent embryo culture medium samples from 14 families affected by rare monogenic diseases. A Bayesian linkage analysis method was developed to improve diagnostic accuracy in non-invasive preimplantation genetic testing for monogenic disorders, and an imputation method was established to reconstruct the embryonic genome for assessing polygenic disease risk. DNA in all 89 spent medium samples was successfully amplified, with 35% average direct genome coverage. Gaps were due to absence of embryonic paternal or maternal allelic DNA rather than amplification failure. Analysis of 125 disease-causing alleles yielded a report rate of 75.2% (94/125) for monogenic disorders, and all reported samples displayed full concordance with paired trophoctoderm biopsy, discarded embryos, or amniotic fluid samples. To aid clinical decisions, diagnoses are assigned confidence classifications. For a subset of samples, reconstruction of embryonic genomes allowed calculation of type II diabetes risk, which was consistent with risk calculations derived from corresponding discarded embryos, trophoctoderm biopsy, or amniotic fluid samples. Our approach alleviates major limitations of non-invasive preimplantation genetic testing for monogenic and polygenic disorders, offering a path to broad clinical application.

主持人：刘伟（江苏师范大学）

14:55-15:25 刘伟（武汉大学）

题目： Concentration inequalities and exponential convergence for mean-field weakly interacting particle system and McKean-Vlasov equation

摘要： In this talk, we will show concentration inequalities, exponential convergence in the Wasserstein metric, and uniform-in-time propagation of chaos for the mean-field weakly interacting particle system related to McKean-Vlasov equation. By means of the known approximate componentwise reflection coupling and with the help of some new cost function, we obtain explicit estimates for those three problems, avoiding the technical conditions in the known results. Our results apply to possibly multi-well confinement potentials, and interaction potentials W with bounded second mixed derivatives which are not too big, so that there is no phase transition. Several examples are provided to illustrate the results.

主持人：张举勇

15:55-16:25 李进开（华南师范大学）

题目： Uniform boundedness versus instantaneous blow-up of physical entropy of the compressible ideal gases

摘要： As one of the basic physical states, mathematical analysis on the entropy is a basic question in the mathematical theory of the compressible fluids. Far field vacuum, which means that the density decays to zero at the far field, is a natural phenomenon due to the conservation of mass. In the presence of vacuum, no matter in the interior or at the far fields, the physical entropy for polytropic gases behave singularly, and it is thus a challenge to study its dynamics. In this talk, it will be shown that both the uniform boundedness and instantaneous blow-up may happen to the entropy of the compressible ideal gases, depending on the decaying rate of the initial density to vacuum at the far field. In particular, it turns out that for the heat conducting compressible ideal gases in one dimension the quadratic decaying rate is the critical rate below which the uniform boundedness can be propagated and

otherwise the instantaneous blow-up will happen. This talk is based on a series works jointed with Professor Zhouping Xin.

主持人：吕锡亮

16:30-17:00 孙桂全（中北大学）

题目：网络反应扩散系统斑图动力学

摘要：相比于连续空间下基于标准布朗运动的反应扩散方程，网络反应扩散系统能更精确地刻画种群分布的离散型、扩散的异质性与大尺度移动性等动力学特征。为此，本报告给出了网络反应扩散系统的数学刻画，揭示了网络平均度与斑图结构之间的定性定量关系，并基于最优控制理论讨论斑图结构的控制策略问题，应用于传染病的研究。

主持人：刘党政

17:05-17:35 孔新兵（东南大学）

题目：Data synchronization at high frequencies

摘要：We revisit the problem of synchronizing the high-frequency data discretely sampled from high-dimensional Ito semi-martingales. Different from existing methods (e.g., previous tick approach), we deem it as a matrix completion problem of which the target is to inference the low-rank structure of the data generative process and recover the data points asynchronous to others. While the matrix completion via the sampling projection operator is not directly applicable, we tackle the problem by cleverly minimizing the nuclear norm of the potential increment matrix under the constraint of a large stochastic linear system on increments over durations of the asynchronous data set. We theoretically prove that the constrained optimization problem has a unique solution with high probability. We also provide a consistent rate for the completed potential increment matrix. An interesting finding is that the statistical accuracy depends not only on the sample sizes of sparse series but also on those of dense series, in contrast to many tick approaches that lead to efficiency loss.

Extensive simulation studies and applications demonstrate the superiority of our methods over existing data synchronization procedures and algorithms.

6月29日（周日）

主持人：杨志坚

08:30-09:00 明平兵（中国科学院数学与系统科学研究院）

题目： Barron type space and application in neural network approximation and Schrodinger equations

摘要： We shall discuss various Barron type spaces arising from neural network. The relations among them will be clarified, and we also establish the relationship among the spectral Barron space and the classical function spaces such as Besov space, Sobolev space and Bessel potential space, which answer the question proposed by Girosi and Anzellotti in 1993. As an application, certain new approximation results for the shallow neural network and deep neural network with the Barron class as the target function space will be proved. We shall also report the well-posedness of the Schrodinger eigenvalue problems in Barron space. This is a joint work with Yulei Liao (National University of Singapore) and Hao Yu (AMSS).

主持人：任景莉

09:05-09:35 赖俊（浙江大学）

题目： Shape Taylor Expansions for Wave Scattering Problems

摘要： Shape derivative is an important analytical tool for studying scattering problems involving perturbations in scatterers. Many applications, including inverse scattering, optimal design, and uncertainty quantification, are based on shape derivatives. However, computing high order shape derivatives is challenging due to the complexity of shape calculus. In this talk, we will introduce a comprehensive method for computing shape Taylor expansions in two dimensions using recurrence formulas. The approach is developed under sound-soft, sound-hard, impedance, and transmission boundary conditions. Additionally, we apply the shape Taylor expansion

to uncertainty quantification in wave scattering, enabling high order moment estimation for the scattered field under random boundary perturbations. Numerical examples are provided to illustrate the algorithms of computing shape Taylor expansions.

主持人：马立明

09:40-10:10 蒋凯（湘潭大学）

题目：丢番图误差的算法和理论

摘要：数是数学研究的基石，亦是理解自然现象的基础。实数由零测度的有理数集和满测度的无理数集共同构成。由此推断，无理数起主导作用的体系理应更为普遍。然而，由于计算机难以存储和表示无理数，在对无理数起主导作用体系进行数值计算时会产生丢番图误差，即有理数逼近无理数之误差。这类误差会对计算结果的准确性可能起决定性影响。在本报告中，我们将分析丢番图误差机理及其对数值计算的影响，建立任意维丢番图频率准周期函数的逼近理论；进而提出能避免丢番图误差的新型算法--投影法和有限点恢复法，将高精度数值计算的范围从有理数域拓展到实数域，并利用无理数的遍历性和算术性质，建立算法的数学理论。

主持人：熊涛

10:40-11:10 林伟（复旦大学）

题目：复杂系统与人工智能互驱的应用数学研究

摘要：本报告主要介绍人工智能算法和复杂系统研究的发展进程，并介绍最近我们的一些工作进展，特别会聚焦低功耗智能计算架构实现以及系统动力学调节等问题。

主持人：徐岩

11:15-11:45 邵嗣烘（北京大学）

题目：寻找第四类数值方法

摘要：微分方程数值解近百年的发展汇成了三大类基本的数值离散方法：50年代的有限差分，60年代的有限元和70年代的谱方法。这三类方法的收敛性都依赖于解的正则性，要达到最优的收敛阶需要精心调配网格，导致在求解高维问题时会遇到维度灾难。当数据和智能科学的热潮涌来时，情况变得更糟糕，因为可能再也没有微分方程可解了，而是需要直接去面对数据，正则性可能无从谈起，高维度更是与生俱来。本报告将就上述困境开展试验性的初步探讨并通过寻找第四类数值方法来尝试突破困境的可能性。

数学科学学院简介

数学科学学院的前身为数学系由著名数学家华罗庚教授于 1958 年创建并担任首任系主任。2011 年 5 月，数学科学学院正式成立，首任院长为马志明院士。学院是全国首批理科人才培养基地、中国科学院博士生重点培养基地，拥有首批数学一级学科博士学位授予权（涵盖所有数学博士点），以及首批国家重点学科、教育部一级重点学科、教育部一流建设学科以及国家级一流本科专业。

历经六十余载发展，学院已形成一支实力雄厚、结构合理的师资队伍。现有全职教授 56 人、副教授 34 人，其中包括 2 位中科院院士、2 位国家级教学名师、17 位国家级高层次人才以及 26 位国家级青年人才。学院人才辈出，培养出 5 位中科院院士、2 位发展中国家科学院院士、40 余位国家级高层次人才，还有 4 位华罗庚数学奖得主、5 位陈省身数学奖得主、5 位冯康科学计算奖得主，多位校友获邀在国际数学家大会上作报告。

学院始终将人才培养置于重要位置，2022 年创立中法数学中心，致力于深化与法国高校及科研机构在数学领域的合作，涵盖人才培养、学术交流与科研等方面。依托中法英才班、华罗庚英才班、强基班等特色培养模式，学院培育出大量杰出人才。学子在各类竞赛中屡创佳绩，为数学学科的发展贡献卓著。

学院科研与教学成果丰硕。近年来，在诸多重要数学问题上取得原创性突破，7 篇研究成果发表于四大顶尖国际学术期刊，荣获 2 项国家自然科学奖、2 项中国科技十大进展、4 项国家教学成果奖。学院下设安徽应用数学中心、中科院吴文俊数学重点实验室、国家数学与交叉科学中心（合肥分中心）、“现代分析与离散结构”安徽省基础学科研究中心、安徽省图形计算与感知交互重点实验室等多个研究平台。

几何与物理研究中心简介

中国科学技术大学几何与物理研究中心成立于 2019 年，是中国科学技术大学的一个新型教学与科研机构。中心在中国科学技术大学东区和上海研究院均设有办公地点，目前共有科研教学人员 18 名。

几何与物理研究中心旨在立足于中国科学技术大学深厚的数理传统，创建一个适合于基础数学与物理学的基础理论研究的开放型学术平台。中心针对基础理论研究特点，创造宽松的学术研究环境，展开广泛的合作交流，以期创造世界领先的数学成果和培养世界一流的数学研究人才。中心将首先集中资源于微分几何、量子场论、代数几何和拓扑学等方向，构建上述方向世界领先的研究平台。

近年来，中心研究团队在几何分析、偏微分方程、复几何等领域取得了一系列成果。在深耕科研的同时，中心积极组织和参与各类学术交流活动，为推动国内外几何与物理学科的合作和发展作出了自己的贡献。

我们诚挚邀请国内外几何与物理领域的优秀学者加盟，携手共创美好未来！

地图

