

反问题分析与计算研讨会

Workshop on Analysis and
Computation of Inverse Problems



哈尔滨工业大学 数学学院

School of Mathematics, Harbin Institute of Technology

中国 • 哈尔滨

2023年11月11-12日

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一、会议组织

反问题是现代数学物理和计算数学中的一个十分活跃的重要研究领域，相关应用已经遍及医学成像、雷达探测、地质勘探、光学、材料和控制等众多重要的科学技术领域。为促进应用反问题研究及相关领域的发展，加强学者间学术交流与合作，哈尔滨工业大学数学学院将于2023年11月11-12日举办“反问题分析与计算研讨会”。会议主题包括（但不限于）：反问题和不适定问题的理论和正则化方法、偏微分方程和反问题数值方法、统计反问题和求解反问题的机器学习技术等。

一、主办方：

哈尔滨工业大学数学学院、CSIAM反问题与成像专委会

二、组织委员会（按姓氏拼音排序）：

陈勇、付振武、郭玉坤、韩波、李莉、李扬、马坚伟、宋明辉、汪贤超

三、会议日程：

日期	内容	地点
11月10日下午	会议报道，酒店入住	哈特商务酒店一楼大厅
11月11日全天	开幕式，学术报告、交流	活动中心326报告厅
11月12日上午	学术报告、交流	
11月12日下午	自由讨论	

四、住宿：

哈特商务酒店(哈尔滨市南岗区西大直街108号)

五、联系人：

郭玉坤, ykguo@hit.edu.cn

汪贤超, xcwang@hit.edu.cn

二、会议信息 (Quick information)

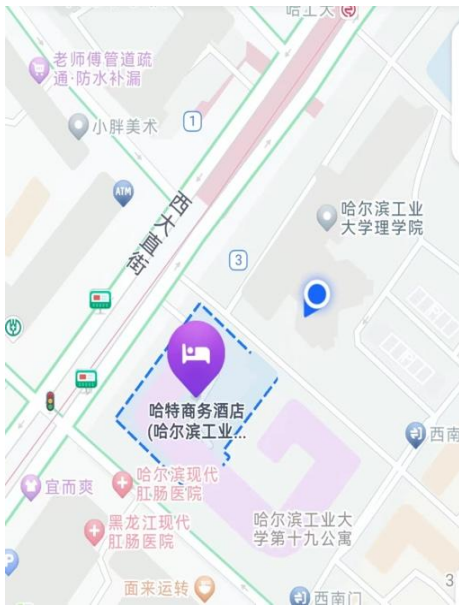
1. 会场

哈工大活动中心 326 报告厅 (哈特商务酒店步行至会场约需 8 分钟)



2. 住宿酒店

哈特商务酒店 (南岗区西大直街 108 号, 哈工大地铁站 3 号出口步行 60 米)



3. 交通信息

- 太平国际机场——哈特商务酒店 出租车约 37 公里，约 100 元
- 哈尔滨站 (南出站口)——哈特商务酒店
 - (1) 出租车：约 2.5 公里，约 10 元
 - (2) 地铁：哈尔滨站 2 号线 (气象台方向) → 博物馆站 1 号线 (新疆大街方向) → 哈工大站，3 号出口，票价 2 元。
- 哈尔滨西站——哈特商务酒店
 - (1) 出租车约 6.5 公里，约 20 元
 - (2) 地铁：哈尔滨西站 3 号线 (中华巴洛克街区方向) → 医大二院站 (1 号线哈尔滨东站方向) → 哈工大站，3 号出口，票价 3 元。

4. 就餐

时间:

2023年11月10日	17:30-20:00	晚餐
2023年11月11日	07:00-09:00	早餐
	12:10-14:00	午餐
	18:00-20:00	晚宴
2023年11月12日	07:00-09:00	早餐
	12:00-14:00	午餐

地点: 哈特商务酒店二楼大厅;

5. 注册报道

(1) 11月10日 14:00-18:00, 哈特商务酒店一楼大厅

(2) 11月11日 08:00-10:00, 活动中心 326 报告厅 (会场)

三、会议日程表

2023年11月11日，周六上午

时间	报告信息	主持人
08:30-09:00	开幕式及合影 (Opening Ceremony and Group Photo)	陈 勇
09:00-09:30	Theories and applications for multi-layered medium 邓又军 中南大学	马坚伟
09:30-10:00	Stochastic linear regularization methods: random discrepancy principle and applications 张 晔 深圳北理莫斯科大学	
10:00-10:30	茶 歇	
10:30-11:00	Stochastic convergence of regularized solutions for backward heat conduction problems 张文龙 南方科技大学	刘宏宇
11:00-11:30	Numerical method for the inverse interior scattering problem from phaseless data 吕俊良 吉林大学	
11:30-12:00	Determining multiple parameters in stationary mean field games system from full/partial boundary measurement 郑光辉 湖南大学	
12:10-14:00	午 餐	

三、会议日程表

2023年11月11日，周六下午

时间	报告信息	主持人
14:00-14:30	On an inverse problem for the plate equation with passive measurement 高忆先 东北师范大学	张 晔
14:30-15:00	Surface plasmon and metamaterial 吴 畏 吉林大学	
15:00-15:30	A linear time finite element method for Riesz fractional partial differential equations 赖军将 闽江学院	
15:30-16:00	茶 歇	
16:00-16:30	A highly efficient and accurate numerical method for the electromagnetic scattering problem with rectangular cavities 袁晓凯 吉林大学	邓又军
16:30-17:00	Various resonant phenomena for elastic metamaterials 李宏杰 清华大学	
17:00-17:30	Efficient synchronous retrieval of OAM modes and AT strength using multi-task neural network 孟品超 长春理工大学	
18:00-20:00	晚 宴	

三、会议日程表

2023年11月12日，周日

时间	报告信息	主持人
08:30-09:00	Visibility, invisibility and unique recovery of inverse electromagnetic problems with conical singularities 刁怀安 吉林大学	张德悦
09:00-09:30	Data-driven studies for inverse problems in imaging 李文彬 哈尔滨工业大学（深圳）	
09:30-10:00	Reconstruction of 3D human body 尹伟石 长春理工大学	
10:00-10:30	茶歇	
10:30-11:00	Linearization of the fixed angle inverse scattering 马世琪 吉林大学	郭玉坤
11:00-11:30	A fast averaged Kaczmarz iteration with convex penalty for inverse problems in Hilbert spaces 夏宇欣 哈尔滨工业大学	
11:30-11:40	闭幕式	汪贤超
12:00-14:00	午餐	
14:00-18:00	自由讨论	

四、报告摘要

(按姓氏首字母排序)

1. 刁怀安 吉林大学

题目: Visibility, invisibility and unique recovery of inverse electromagnetic problems with conical singularities

摘要: In this talk, we study time-harmonic electromagnetic scattering in two scenarios, where the anomalous scatterer is either a pair of electromagnetic sources or an inhomogeneous medium, both with compact supports. We are mainly concerned with the geometrical inverse scattering problem of recovering the support of the scatterer, independent of its physical contents, by a single far-field measurement. It is assumed that the support of the scatterer (locally) possesses a conical singularity. We establish a local characterisation of the scatterer when invisibility/transparency occurs, showing that its characteristic parameters must vanish locally around the conical point. Using this characterisation, we establish several local and global uniqueness results for the aforementioned inverse scattering problems, showing that visibility must imply unique recovery. In the process, we also establish the local vanishing property of the electromagnetic transmission eigenfunctions around a conical point under the Hölder regularity or a regularity condition in terms of Herglotz approximation.

2. 邓又军 中南大学

题目: Theories and applications for multi-layered medium

摘要: In this talk, we shall present some recent work on multi-layered medium. We shall first show some asymptotic results for inhomogeneous medium, and then multi-layered medium, which is a special case of inhomogeneous medium. On the other hand, we shall show how to design multi-layer structures of metamaterials which may greatly increase the resonance modes.

3. 高忆先 东北师范大学

题目: On an inverse problem for the plate equation with passive measurement

摘要: This talk focuses on an inverse problem associated with the plate equation which is derived from models in fluid mechanics and elasticity. We establish the unique identifying results in simultaneously determining both the unknown density and the internal sources from the passive boundary measurement. The proof mainly relies on the asymptotic analysis and harmonic analysis on integral transforms.

4. 赖军将 闽江学院

题目： A linear time finite element method for Riesz fractional partial differential equations

摘要： In this talk, we consider numerical methods for Riesz space fractional partial differential equations with a second order time derivative. We propose a Galerkin finite element scheme for both the temporal and spatial discretizations. We use the linear finite element to discrete in the temporal direction. For the proposed numerical method, we derive sharp stability estimates as well as optimal a priori error estimates. Extensive numerical experiments are conducted to verify the promising features of the newly proposed method.

5. 李宏杰 清华大学

题目： Various resonant phenomena for elastic metamaterials

摘要： In this talk, different kinds of structures are explored to effectively achieve the negative elastic metamaterials. First, the structure involving the bubbles embedded within the soft elastic materials will be discussed, offering an effective means to achieve the negative bulk modulus. Then the configuration incorporating hard inclusions embedded in the soft elastic matrix shall be investigated, enabling the attainment of negative values in the mass density.

6. 李文彬 哈尔滨工业大学 (深圳)

题目： Data-driven studies for inverse problems in imaging

摘要： We present our recent work in data-driven studies for inverse problems in imaging. The motivation is to deal with contaminations of random noises in imaging data, and the strategies of neural networks and learning approaches are considered. We will mainly talk about the work of uniformly convex neural networks and non-stationary iterated network Tikhonov (iNETT) method. The iNETT employs deep neural networks to build a data-driven regularizer for the solution of ill-posed inverse problems. To achieve theoretical convergence, we introduce uniformly convex neural networks to build the data-driven regularizer. Rigorous theories and detailed algorithms are proposed for the construction of convex and uniformly convex neural networks. Given a general neural network architecture, we prescribe sufficient conditions to achieve a trained neural network which is component-wise convex or uniformly convex; moreover, we provide concrete examples of realizing convexity and uniform convexity in the modern U-net architecture. With the tools of uniformly convex neural networks, the iNETT algorithm is developed and a rigorous convergence analysis is provided. Lastly, we show applications of the iNETT algorithm in 2D computerized tomography.

7. 吕俊良 吉林大学

题目： Numerical method for the inverse interior scattering problem from phaseless data

摘要： In this talk, I will consider the inverse problem to determine the shape and location of an acoustically sound-soft cavity, or sound-hard cavity, or impedance cavity with known impedance function from phaseless data for one single source incidence. Based on representing scattered field by single-layer potential, a numerical method is presented for finding the unknown boundary of scatterers. Furthermore, we propose a Newton-type algorithm to recover a real-valued surface impedance from phaseless data. The efficient implementation of the method is described and the feasibility of the approach is illustrated by several numerical examples.

8. 马世琪 吉林大学

题目： Linearization of the fixed angle inverse scattering

摘要： We study the fixed angle inverse scattering problem of determining a sound speed from scattering measurements corresponding to a single incident wave. The main result shows that a sound speed close to constant can be stably determined by just one measurement. Our method is based on studying the linearized problem, which turns out to be related to the acoustic problem in photoacoustic imaging. We adapt the modified time-reversal method from [P. Stefanov and G. Uhlmann, Thermoacoustic tomography with variable sound speed, Inverse Problems 25 (2009), 075011] to solve the linearized problem in a stable way, and we use this to give a local uniqueness result for the nonlinear inverse problem.

9. 孟品超 长春理工大学

题目： Efficient Synchronous Retrieval of OAM Modes and AT Strength in Atmospheric Turbulence using Improved Multi-Task Neural Networks

摘要： OAM 光束作为信息流载体进行编码，极大缓解通信系统的容量危机，其在大气信道中传输时，会受到大气湍流引起的折射率随机起伏的影响，导致光束相位畸变和光强弥散，从而引发严重的信号串扰。大气湍流具有的高度随机性，为保证通信质量，轨道角动量模式识别方法必须具有良好的稳定性。我们建立连续动力系统与神经网络 RUEM 的等价关系，保证所构造 RUEM 网络的稳定性，并提出一种嵌入 RUEM 的多任务神经网络模型，实现大气湍流 (AT) 环境中的湍流强度和自由空间光通信系统中的轨道角动量 (OAM) 模式的高效同步识别。数值试验结果显示，在 4 种湍流强度水平下，该网络识别准确率达到 99.37%，对于 10 种 OAM 模态，识别准确率为 99.05%。此外，我们还探讨了该网络在 2000m 信道传输场景的性能表现。

10. 吴畏 吉林大学

题目： Surface Plasmon and Metamaterial

摘要： Metamaterial is the name of a vast category of man-made material with properties that never occur on natural materials. It consists of assemblies of multiple repeatedly aligned unit structures made of metal or plastics. By adjusting properties of unit structures, we could expect a remarkable change of corresponding metamaterial in the absorption, enhancement or refraction to incident wave, of which we could take advantage to develop new materials possessing specific physical properties. In this talk, we would like to discuss the possibility of constructing metamaterial with surface plasmonic resonators. We will elaborate the mathematical principle behind them, and the actual phenomenon observed by physicists. We will also give an outlook of the potential to generalize the method applied here to other scenarios.

11. 夏宇欣 哈尔滨工业大学

题目： A fast averaged Kaczmarz iteration with convex penalty for inverse problems in Hilbert spaces

摘要： In this talk, we focus on developing a fast Kaczmarz-type method to solve inverse problems that can be written as systems of linear or nonlinear equations in Hilbert spaces. In order to capture the special feature of solutions, we incorporate nonsmooth convex functions into the averaged Kaczmarz iteration, leading to a new Kaczmarz-type method. In addition, aimed at further accelerating our proposed method, the choice of the step size is carefully discussed. Under the similar assumptions of the Kaczmarz-type method, we prove that our method is a convergent regularization method as long as it is terminated by an appropriate stopping rule. Finally, detailed numerical studies are presented for the limited data problem in photoacoustic tomography and the parameter identification problems to show the effectiveness of our method.

12. 尹伟石 长春理工大学

题目： Reconstruction of 3D Human Body

摘要： In this talk, we introduce the use of point cloud data to build a 3D human body. Assuming that the human body is the L^2 source, using the fundamental solution method to calculate the far-field data corresponding to the human body, and then extract the human feature information data from the point cloud. A data-driven neural network model can be built. After the input of the human body feature data, the corresponding far-field data can be obtained through the neural network model, and then the 3D human body is constructed by using Fourier method. This method can make users have a better sense of involvement and experience.

13. 袁晓凯 吉林大学

题目： A highly efficient and accurate numerical method for the electromagnetic scattering problem with rectangular cavities

摘要： This talk presents a robust numerical solution to the electromagnetic scattering problem involving multiple multi-layered cavities in both transverse magnetic and electric polarizations. A transparent boundary condition is introduced at the open aperture of the cavity to transform the problem from an unbounded domain into that of bounded cavities. By employing Fourier series expansion of the solution, we reduce the original boundary value problem to a two-point boundary value problem, represented as an ordinary differential equation for the Fourier coefficients. The analytical derivation of the connection formula for the solution enables us to construct a small-scale system that includes solely the Fourier coefficients on the aperture, streamlining the solving process. Furthermore, we propose accurate numerical quadrature formulas designed to efficiently handle the weakly singular integrals that arise in the transparent boundary conditions.

14. 张文龙 南方科技大学

题目： Stochastic convergence of regularized solutions for backward heat conduction problems

摘要： In this talk, we study the stochastic convergence of regularized solutions for backward heat conduction problems. These problems are recognized as ill-posed due to the exponential decay of eigenvalues associated with the forward problems. We derive an error estimate for the least-squares regularized minimization problem within the framework of stochastic convergence. Our analysis reveals that the optimal error of the Tikhonov-type least-squares optimization problem depends on the noise level, the number of sensors, and the underlying ground truth. Moreover, we propose a self-adaptive algorithm to identify the optimal regularization parameter for the optimization problem without requiring knowledge of the noise level or any other prior information, which will be very practical in applications. We present numerical examples to demonstrate the accuracy and efficiency of our proposed method. These numerical results show that our method is efficient in solving backward heat conduction problems.

15. 张 晔 深圳北理莫斯科大学

题目： Stochastic linear regularization methods: random discrepancy principle and applications

摘要： The a posteriori stopping rule plays a significant role in the design of efficient stochastic algorithms for various tasks in computational mathematics, such as inverse problems, optimization, and machine learning. Through the lens of classical regularization theory, this paper describes a novel analysis of Morozov's discrepancy principle for the stochastic generalized Landweber iteration and its continuous analog of generalized stochastic asymptotical regularization. Unlike existing results relating to convergence in probability, we prove the strong convergence of the regularization

error using tools from stochastic analysis, namely the theory of martingales. Numerical experiments are conducted to verify the convergence of the discrepancy principle and demonstrate two new capabilities of stochastic generalized Landweber iteration, which should also be valid for other stochastic/statistical approaches: improved accuracy by selecting the optimal path and the identification of multi-solutions by clustering samples of obtained approximate solutions.

16. 郑光辉 湖南大学

题目: Determining multiple parameters in stationary mean field games system from full/partial boundary measurement

摘要: In this talk, I will present some results for the utilization of the Dirichlet-to-Neumann (DN) map to uniquely identify the discount functions and cost function in a stationary mean field games (MFGs) system. This study features several technical novelties that make it highly intriguing and challenging. Firstly, it involves a coupling of two nonlinear elliptic partial differential equations. Secondly, the simultaneous recovery of multiple parameters poses a significant implementation challenge. Thirdly, there is the probability measure constraint of the coupled equations to consider. Finally, the limited information available from partial boundary measurements adds another layer of complexity to the problem. Considering these challenges and problems, we present an enhanced higher-order linearization method to tackle the inverse problem related to the MFGs system. Our proposed approach involves linearizing around a pair of zero solutions and fulfilling the probability measurement constraint by adjusting the positive input at the boundary. It is worth emphasizing that this technique is not only applicable for uniquely identifying multiple parameters using full-boundary measurements but also highly effective for utilizing partial-boundary measurements.

五、学院简介

哈尔滨工业大学数学学院前身是创建于 1958 年的计算数学专业, 1981 年开始培养基础数学和计算数学专业硕士, 1986 年获得基础数学博士学位授予权 (是国内最早的两所工科院校之一), 1987 年成立数学系, 2019 年成立数学学院。2001 年建立了数学学科博士后流动站, 2005 年数学学科成为一级学科硕士学位授权点, 2010 年数学学科成为一级学科博士授权点, 2011 年统计学成为一级学科博士授权点。基础数学是省重点学科 (2001 年) 和国防科工委重点学科 (2002 年); 应用数学是省重点学科 (2001 年)。数学学科 2011 年成为省一级重点学科。2013 年基础数学和应用数学成为工信部重点学科。1997 年入选教育部首批七个“工科基础课程 (数学) 教学基地”之一; 2020 年数学类专业入选教育部强基计划和基础学科拔尖学生培养计划 2.0 基地; 2020 年获批成立黑龙江应用数学中心。

在教育部第四轮学科评估中, 哈尔滨工业大学数学学科位列 A-, 统计学位列 B。在 2020 年 10 月《美国新闻和世界报导》(US News)发布的世界大学数学专业排名中, 我校数学学科排名全球第 80 位, 在内地高校 45 个机构中位于第 14 位。在 2021 年发布的世界大学学科排名 (QS World University Rankings) 中, 我校数学学科排名全球第 126 位, 在内地高校 36 个机构中位于第 8 位; 统计学排名全球第 101-150 位, 在内地高校 17 个机构中并列第 7 位。在最新的 ARWU 排名中, 数学学科位列全球第 76-100 位, 在内地高校 93 个机构中并列第 5 位。哈尔滨工业大学数学学科自 2013 年 5 月始终保持全球前 1%行列。