应用反问题的理论与数值方法网络研讨会

Workshop on Theoretical Analysis and Numerical Methods for Applied Inverse Problems

上海财经大学・数学学院

计算科学与金融数据研究中心

2020 年 5 月 10 日，16 日

数学学院简介

上海财经大学数学学科是随着上海财经大学的发展而不断成长起来的，进入新世纪后获得了快速发展。2000 年 8 月成立应用数学系，2014 年 7 月撤系建院。学院下设数学与应用数学和信息与计算数学两个本科专业，数学与应用数学专业下设财经数学实验班。2001 年开始招收信息与计算科学本科生、概率论与数理统计硕士生。2002 年、2004 年和 2007 年，数学与应用数学本科专业、运筹学与控制论和应用数学硕士点相继开始招生。2002 年开始在金融数学与金融工程（二级学科）博士点下招收培养博士生。2011 年在统计学（一级学科）博士点下，自主设置应用概率（二级学科）博士点，招收培养博士生；同时设应用概率硕士点，取消原有的概率论与数理统计硕士点。2016 年成立“计算科学与金融数据研究中心”。2017 年财经数学实验班开始招生；2017 年成功申报并经批准设立数学（一级学科）硕士学位授予权，涵盖基础数学、应用数学与计算科学、概率论与数理金融、最优化与控制等二级学科。

数学学院拥有雄厚的师资力量，注重学生的国际化、综合化培养，与国内外知名高校、研究机构进行学生的联合培养。数学学院的毕业生具备深厚的数学基础知识，同时掌握经济、金融、管理等应用科学的相关内容，深受用人单位青睐，历年毕业生就业率均接近 100%。学生就业方向多样，就业质量高，2017 年学院国内外升学率近 60%，升学高校包括哈佛大学、剑桥大学、伦敦政治经济学院、哥伦比亚大学、复旦大学等知名学府；研究生毕业生多集中于银行、证券等金融机构，以及教育、科研机构等。

计算科学与金融数据研究中心简介

计算科学与金融数据研究中心（以下简称“中心”）于2016年11月在上海财经大学正式成立，目前挂靠上海财经大学数学学院。

“中心”以“产学研合作”为主题，旨在针对行业现状与时代发展要求，以扎实理论为基础，以实用价值为导向，培养时代所需要复合型人才；坚持多学科多领域交叉学习与应用，通过和企业界开展交流合作，充分利用社会化资源，培养具有数学背景、大数据思维方式的财经类高层次人才。

“中心”目前拥有统计反演、金融数学与金融工程、智能算法、数据建模与数据分析等科研团队，聚焦“统计反演建模及计算研究”、“金融数据建模及计算研究”及“人工智能中关键基础算法研究”等领域的研究，围绕当前计算科学与金融数学领域的重大热点、难点问题，在基础理论、数学建模、算法设计、数值模拟等方面开展科学研究、技术研发和应用创新等工作。“中心”引入具有丰富企业管理经验和实践能力的专家，包括资深IT公司技术高管、金融机构总监等，他们在大数据分析、智能计算、算法应用等领域有深厚的专业素养和独特的见解。“中心”聘请若干名国内外著名专家学者担任的“中心”特聘流动教授，指导科研创新团队的建设及教学方案的设置与改革。

“中心”已与国内外众多知名高校和企业开展合作研究，通过科研成果转化，促进数学与交叉学科的深度应用，推动财政与经济领域数学建模与智能算法研究。我们力争将“中心”建设成计算科学与工程领域国际知名、国内领先的产学研合作示范基地。

目 录

一、会议简介

应用反问题是一类现代数学物理领域中一个非常重要的研究课题，它不仅是近三十年发展最快的应用数学领域之一，而且在海洋探测、石油勘探、医学成像、无损探测、信号处理、金融等众多科技领用应用广泛。为促进该研究领域的发展，并加强研究者的学术交流，上海财经大学数学学院联合计算科学与金融数据研究中心于 2020 年 5 月 10 日，16 日通过 ZOOM 网络会议，召开“应用反问题理论与数值方法网络研讨会”，该会议由计算科学与金融数据研究中心承办。

会议的主要目标是探讨反问题领域的最新发展和前景。会议将汇集全国各地参与反问题数学理论、数值算法以及应用实践方面的科学研究人员和专家。讨论的课题包括反问题和不适定问题的理论和正则化方法、求解声学、电动力学、层析成像、电法勘探、地震学、重力测量学、输运理论、大气和海洋物理以及环境保护、反问题的数值方法；生物学、医学、经济学、金融数学和社会学、自然科学中的高性能计算；大数据：数学问题和实际应用、预测和数据挖掘等问题。

学术委员会：（按姓氏拼音排序）

主席：包刚（浙江大学）、程晋（复旦大学）

委员：刘继军（东南大学）、马富明（吉林大学）、徐定华（上海财经大学）、张波（中国科学院数学与系统科学研究院）

组织委员会：

刘可伋、江渝、许伯熹

会议时间：2020 年 5 月 10 日 9:00 — 11:20，14:00 — 16:00

2020 年 5 月 16 日 9:00 — 11:20，14:00 — 16:00

联系人： **刘可伋** 138 1888 4207

二、ZOOM 网络会议操作指南

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三、会议日程表

2020 年 5 月 10 日，周日，上午

ZOOM 会议室 ID：96175246060，密 码：284588 会议室链接：https://zoom.com.cn/j/96175246060		
9:00—9:20	开幕式	院领导及学术委员会主席致辞
1、主持人：刘可伋		
时间	报告人	题 目
9:20—9:40	陆 帅	When randomness meets inverse problems
9:40—10:00	李功胜	扩散方程系数反问题的数值解法
10:00—10:20	胡广辉	融合样本数据和散射模型的反演算法
10:20—10:40	休 息，更换 ZOOM 会议室	
ZOOM 会议室 ID：92166854696，密 码：275886 会议室链接：https://zoom.com.cn/j/92166854696		
10:40—11:00	高忆先	Scattering problems for electromagnetic wave and elastic wave in time-domain
11:00—11:20	郭玉坤	Qualitative and quantitative methods for solving an interior inverse scattering problem

2020 年 5 月 10 日，周日，下午

2、主持人：江 渝		
时间	报告人	题 目
ZOOM 会议室 ID：99467645718，密 码：609718 会议室链接：https://zoom.com.cn/j/99467645718		
14:00—14:20	杨家青	Recovering a bounded obstacle for inverse exterior Stokes problems by the LSM
14:20—14:40	季 霞	Inverse acoustic scattering with phaseless far-field data
14:40—15:00	邓又军	On identifying magnetized anomalies using geomagnetic monitoring
15:00—15:20	休 息，更换 ZOOM 会议室	
ZOOM 会议 ID：91375971401，密 码：313431 会议室链接：https://zoom.com.cn/j/91375971401		
15:20—15:40	闫 亮	An adaptive surrogate modeling based on deep neural networks for Bayesian inverse problems
15:40—16:00	贾骏雄	Variational Bayes' approach for functions and applications to some inverse problems

2020 年 5 月 16 日，周六，上午

3、主持人：刘可伋		
时间	报告人	题 目
ZOOM 会议室 ID：94059635994，密 码：459297 会议室链接：https://zoom.com.cn/j/94059635994		
9:00—9:20	赖 俊	Scattering and inverse scattering for electromagnetic structures with axis-symmetry
9:20—9:40	王泽文	Posteriori selection strategies of regularization parameters for Lanczos generalized derivatives
9:40—10:00	刘晓东	Inverse scattering problems with multi-frequency sparse data
10:00—10:20	休 息，更换 ZOOM 会议室	
ZOOM 会议室 ID：93539427436，密 码：739398 会议室链接：https://zoom.com.cn/j/93539427436		
10:20—10:40	邓醉茶	Inverse source problem for degenerate parabolic equations and numerical implementation
10:40—11:00	王海兵	Analysis of the acoustic waves reflected by a cluster of small holes in the time-domain
11:00—11:20	张 磊	Electromagnetic inverse scattering problems in complex backgrounds

2020 年 5 月 16 日，周六，下午

4、主持人：许伯熹		
时间	报告人	题 目
ZOOM 会议室 ID：96722909317，密 码：366516 会议室链接：https://zoom.com.cn/j/96722909317		
14:00—14:20	徐 翔	TBA
14:20—14:40	曲风龙	Inverse scattering by an inhomogeneous cavity
14:40—15:00	王 薇	The two-point gradient methods for nonlinear inverse problems based on Bregman projections
15:00—15:20	休 息，更换 ZOOM 会议室	
ZOOM 会议室 ID：93930393743，密 码：197600 会议室链接：https://zoom.com.cn/j/93930393743		
15:20—15:40	钟 敏	A regularization method for the numerical differentiation under random distributed noise
15:40—16:00	张海文	Uniqueness and direct imaging method for inverse scattering by locally rough surfaces with phaseless near-field data

四、报告摘要

1. 陆帅，复旦大学

题目: When randomness meets inverse problems

摘要: In this talk, we report some recent results on inverse problems associated with randomness. The first part focuses on the continuous asymptotical regularization on the statistical inverse problems in presence of white noise, where infinite-dimensional stochastic integration shall be treated carefully. The second part considers the convergence analysis on the random projection of discrete inverse problems and we briefly explain how to handle the randomness there.

2. 李功胜，山东理工大学

题目: 扩散方程系数反问题的数值解法

摘要: 主要介绍扩散方程反问题中的系数反演方法，包括梯度型迭代算法，变分伴随算法，变分迭代算法与同伦摄动算法等，并应用于分数阶扩散方程的系数反问题求解。

3. 胡广辉，北京计算科学研究中心

题目: 融合样本数据和散射模型的反演算法

摘要: 声波、弹性波和电磁波在传播过程中遇到不均匀介质或障碍，波场与这些物质将发生相互作用从而导致物理学上的散射现象。由于散射场携带了散射体的位置、形状和物理参数等多方面的信息，从远离目标的有限测量数据重构这些未知信息构成了反散射问题的研究内容。 在这个报告中，通过对比传统的求解反散射问题的确定性和非确定性的计算方法，借助于人工智能领域和数据科学的新思想，我们描述一种融合样本数据和散射模型的新型研究框架。在这个框架下，可以通过分析目标散射体的测量数据和适当的样本数据的相互作用，采用确定性的数值计算方法重构目标的物理属性和几何参数。做为一个应用特例，我们考虑用单个波的远场数据反演阻尼类型（满足第三类边界条件）的障碍物形状的反问题。

4. 高忆先，东北师范大学

Title: Scattering problems for electromagnetic wave and elastic wave in time-domain

Abstract: The time-domain scattering problems have recently attracted considerable attention due to their capability of capturing wide-band signals and modeling more general material and nonlinearity. In this talk, we will present some recent results about electromagnetic scattering problem and acoustic–elastic interaction scattering problems in time-domain. This talk is based on the joint work with Gang Bao, Peijun Li, Yang Yang and Bo Zhang.

5. 郭玉坤，哈尔滨工业大学

Title: Qualitative and quantitative methods for solving an interior inverse scattering problem

Abstract: The interior inverse scattering problems, as well as their exterior counterparts, arise naturally in various realistic applications. In this talk, I shall talk about two numerical schemes for solving the inverse cavity scattering problem of determining its shape from the interior acoustic measurements. As an example of qualitative methods, the reciprocity gap sampling method is employed to reconstruct the shape of the cavity from interior Cauchy data. For the quantitative method, an optimization approach based on the Fourier-Bessel expansion will be utilized to recover the target cavity. Several numerical examples will be presented to illustrate the effectiveness of both methods.

6. 杨家青，西安交通大学

Title: Recovering a bounded obstacle for inverse exterior Stokes problems by the LSM

Abstract: This talk is concerned with an inverse problem of determining a bounded obstacle imbedded in the the stationary Stokes flow in the exterior domain. We proposed a framework of the LSM to recover the shape and location of the obstacle by taking near-field measurements. Some numerical results are presented to illustrate the feasibility and effectiveness of the algorithm.

7. 季霞，中国科学院数学与系统科学研究院

Title: Inverse acoustic scattering with phaseless far-field data

Abstract: The well-known translation invariance property of the phaseless far-field patterns with incident plane waves make it is impossible to reconstruct the location of the underlying scatterers even for multiple incident directions and frequencies. To overcome this difficulty, we take the superpositions of plane waves and point sources as the incident fields. The point sources have fixed source location with at most three different scattering strengths. By adding a reference sound-soft obstacle into the scattering system, we show some uniqueness results with phaseless far-field data. Of possibly even more interest are the phase retrieval technique and direct sampling methods, without using the reference obstacle. With the help of the point sources, we propose a simple and stable phase retrieval algorithm and design some novel direct sampling methods using the phaseless data directly. The novel phase retrieval algorithm can then be combined with the classical sampling methods for scatterer reconstruction. Finally, we present a variant of numerical examples in two dimensions to verify the effectiveness and robustness of the proposed algorithms.

8. 邓又军，中南大学

Title: On identifying magnetized anomalies using geomagnetic monitoring

Abstract: We propose and investigate the inverse problem of identifying magnetized anomalies beneath the Earth using the geomagnetic monitoring. Suppose a collection of magnetized anomalies presented in the shell of the Earth. The presence of the anomalies interrupts the magnetic field of the Earth, monitored above the Earth. Using the difference of the magnetic fields before and after the presence of the magnetized anomalies, we show that one can uniquely recover the locations as well as their material parameters of the anomalies. Our study provides a rigorous mathematical theory to the geomagnetic detection technology that has been used in practice.

9. 闫亮，东南大学

Title: An adaptive surrogate modeling based on deep neural networks for Bayesian inverse problems

Abstract: In Bayesian inverse problems, surrogate models are often constructed to speed up the computational procedure, as the parameter-to-data map can be very

expensive to evaluate. However, due to the curse of dimensionality and the nonlinear concentration of the posterior, traditional surrogate approaches (such us the polynomial-based surrogates) are still not feasible for large scale problems. To this end, we present in this work an adaptive multi-fidelity surrogate modeling framework based on deep neural networks (DNNs), motivated by the facts that the DNNs can potentially handle functions with limited regularity and are powerful tools for high dimensional approximations. More precisely, we first construct offline a DNNs-based surrogate according to the prior distribution, and then, this prior-based DNN-surrogate will be adaptively & locally refined online using only a few high-fidelity simulations. In particular, in the refine procedure, we construct a new shallow neural network that view the previous constructed surrogate as an input variable -- yielding a composite multi-fidelity neural network approach. This makes the online computational procedure rather efficient. Numerical examples are presented to confirm that the proposed approach can obtain accurate posterior information with a limited number of forward simulations.

10. 贾骏雄，西安交通大学

Title: Variational Bayes' approach for functions and applications to some inverse problems

Abstract: Bayesian approach as a useful tool for quantifying uncertainties has been widely used for solving inverse problems of partial differential equations (IPPDE). One of the key difficulties for employing Bayesian approach is how to extract information from the posterior probability measure. Variational Bayes' method (VBM) is one of the most activate research topics in the field of machine learning, which has the ability to extract posterior information approximately by using much lower computational resources compared with the sampling type method. In this talk, we generalize the usual finite-dimensional VBM to infinite-dimensional space, which makes the usage of VBM for IPPDE rigorously. General infinite-dimensional mean-field approximation theory has been established, and has been applied to abstract linear inverse problems with Gaussian and Laplace noise assumption. Finally, two numerical examples are given which illustrate the effectiveness of the proposed approach.

11. 赖俊，浙江大学

Title: Scattering and inverse scattering for electromagnetic structures with axis-symmetry

Abstract: Fast, high-accuracy algorithms for electromagnetic and elastic scattering from axisymmetric objects are of great importance for modeling physical phenomena in optics, materials science (e.g. meta-materials), and many other fields of applied science. In this talk, we develop an FFT-accelerated separation of variables solver that can be used to efficiently invert integral equation formulations of Maxwell's equations for scattering from axisymmetric bodies. Using a standard variant of Muller's integral representation of the fields, our numerical solver rapidly and directly inverts the resulting second-kind integral equation. The solver is also extended to geometries with non-smooth generating curves and the scattering from large cavities. In the end, we also discuss the application of the high order solver in the inverse scattering to recover the object with axis-symmetry.

12. 王泽文，东华理工大学

Title: Posteriori selection strategies of regularization parameters for Lanczos generalized derivatives

Abstract: In this talk，we mainly studies how to select reasonable step-sizes (regularization parameters) in Lanczos' generalized derivatives. Four posterior selection strategies, in which two strategies need to know the noise level while the other two do not, are proposed with the convergence estimates of regularization solutions (Lanczos' generalized derivatives). Numerical experiments show that the last three posterior selection strategies, i.e. Posterior Selection Strategies II - IV, are feasible for Lanczos' generalized derivatives. By the way, we will briefly introduce another recent work：Cauchy problem of non-homogenous stochastic heat equation and application to inverse random source problem.

13. 刘晓东，中国科学院数学与系统科学研究院

Title: Inverse scattering problems with multi-frequency sparse data

Abstract: The inverse scattering theory has been a fast-developing area for the past forty years. Majority of studies focuses on inverse time harmonic wave scattering problems at a fixed frequency. At the same time, the measurements should be taken all around the unknown objects. However, from the practical point of view, we have only

limited aperture data. In particular, the measurements are only available at isolated directions/points. To make the inverse scattering problems solvable, measurements should be taken with multiple frequencies. This is practically relevant because it is easier to vary frequency than to use arrays of receivers/sources. We introduce some of our recent progress on the theory and numerical methods in this direction.

14. 邓醉茶，兰州交通大学

Title: Inverse source problem for degenerate parabolic equations and numerical implementation

Abstract: Many problems coming from physics, biology, fluid mechanics and finance can be described by degenerate parabolic equations. In this talk, we considered an inverse source problem for degenerate parabolic equations, where the diffusion coefficient are zero on the whole boundary. Based on some appropriate conditions imposed on the degenerate coefficient, the strong maximum principle for degenerate parabolic equations is established and the uniqueness of the solution is also proved. Then, some iteration algorithms are proposed to numerically solve the inverse problem.

15. 王海兵，东南大学

Title: Analysis of the acoustic waves reflected by a cluster of small holes in the time-domain

Abstract: Consider the time-domain acoustic scattering problem by a cluster of small holes (i.e. sound-soft obstacles). Based on the retarded boundary integral equation method, we derive the asymptotic expansion of the scattered field as the size of the holes goes to zero. Under certain geometrical constraints on the size and the minimum distance of the holes, we show that the scattered field is approximated by a linear combination of point-sources where the weights are given by the capacitance of each hole and the causal signals (of these point-sources) can be computed by solving a, retarded in time, linear algebraic system. A rigorous justification of the asymptotic expansion and the unique solvability of the linear algebraic system are shown under natural conditions on the cluster of holes. As an application of the asymptotic expansion, we derive, in the limit case when the holes are densely distributed and occupy a bounded domain, the equivalent effective acoustic medium (an equivalent mass density characterized by the capacitance of the holes) that generates, approximately, the same scattered field as the cluster of holes. Finally, we numerically

verify the asymptotic expansions by comparing the asymptotic approximations with the numerical solutions of the scattered fields via the finite element method.

16. 张磊，黑龙江大学

Title: Electromagnetic inverse scattering problems in complex backgrounds

Abstract: In this talk, we mainly focus on the electromagnetic inverse scattering problems in complex backgrounds. The composite scattering and inverse scattering of rough surfaces and obstacles are studied. We will show some results of scattering and inverse scattering problem. Finally, we will introduce our ongoing research work.

17. 徐翔，浙江大学

Title: TBA

Abstract: TBA

18. 曲风龙，烟台大学

Title: Inverse scattering by an inhomogeneous cavity

Abstract: In this talk I will introduce some uniqueness results on the recovery of both the interior part of the inhomogeneous cavity as well as the refractive index described by a piecewise constant function for the inverse cavity scattering problems. A factorization method in reconstructing the interior part of the inhomogeneous cavity will also be shown.

19. 王薇，嘉兴学院

Title: The two-point gradient methods for nonlinear inverse problems based on Bregman projections

Abstract: In this talk, we propose and analyze a projected two-point gradient method for solving nonlinear inverse problems. The approach is based on the Bregman projection onto stripes the width of which is controlled by both the noise level and the

structure of the operator, and the two-point gradient method is efficient for acceleration. The method allows to use L^1-liked penalty terms, which is significant in sparsity reconstructions. We present a proof for the regularizing properties of the method, some parameter identification examples are presented to illustrate the effectiveness of the proposed method. This is a joint work with Min Zhong (Southeast University).

20. 钟敏，东南大学

Title: A regularization method for the numerical differentiation under random distributed noise

Abstract: Differentiation is one of the most important concepts in calculus, which has been used almost everywhere in many fields of mathematics and applied mathematics. In this paper, a regularization method is proposed for the function and differentiation reconstruction from randomly distributed noisy observations. The unique solvability of the method is proved and a number of conditions are given to characterize the solution. The regularization parameter strategy is discussed and the rigorous upper bound estimation of confidence interval of the error in L^2 norm is established. Some numerical examples are provided to illustrate the effectiveness and computational performance of the method.

21. 张海文，中国科学院数学与系统科学研究院

Title: Uniqueness and direct imaging method for inverse scattering by locally rough surfaces with phaseless near-field data

Abstract: We consider the inverse scattering problem by a locally rough surface with phaseless near-field data. A uniqueness result is obtained for the inverse problem. Further, a direct imaging method is proposed to reconstruct the locally rough surface from the phaseless near-field data. Finally, numerical experiments are carried out to demonstrate the effectiveness of our imaging algorithm.

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