深圳北理莫斯科大学
УНИВЕРСИТЕТ МГУ–ППИ В ШЭНЬЧЖЭНЕ
SHENZHEN MSU-BIT UNIVERSITY

# 2023反问题正则化算法及应用研讨会

会议时间：2023年5月25-29日

**25 号周四报告信息**

Tumor treating fields: model validation and numerical inversion

龚荣芳教授 南京航空航天大学

In this talk, we focus on the mathematical modeling and numerical inversion of tumor treating fields (TTF) which is a relatively new tumor treatment method. Unlike many therapies such as chemotherapy and surgical treatment, TTF is non-invasive and has no side effects except slight skin irritation. As the first step of TTF, it is necessary to understand the distribution of electric field. Based on the classical Maxwell equation in electromagnetics, the mathematical model of the potential distribution in the body is established by adding electrodes on the surface to form the potential difference, and the correctness of the model is verified by COMSOL simulation. The effect of TTF mainly depends on the parameters such as the dielectric conductivity and position of the electrodes etc.. With fixed the size of electrodes and voltage on the boundary of brain, the field strength required for treatment can be achieved in the body by optimizing the position of the electrodes. The particle swarm optimization method is applied to solve the reduced optimal problem for realizing the optimization of electrodes' position. A series of numerical experiments are given for the validation of efficiency of the proposed methods.

# A general non-Lipschitz joint regularized model for multi-channel/modality image reconstruction

高益铭 副研究员 南京航空航天大学

Multi-channel/modality image joint reconstruction has gained much research interest in recent years. In this paper, we propose to use a non-convex and non-Lipschitz joint regularizer in a general variational model for joint reconstruction under additive measurement noise. This framework has good ability in edge-preserving by sharing common edge features of individual images. We study the lower bound theory for the non-Lipschitz joint reconstruction model in two important cases with Gaussian and impulsive measurement noise, respectively. In addition, we extend previous works to propose an inexact iterative support shrinking algorithm with proximal linearization for multi-channel image reconstruction (InISSAPL-MC) and prove that the iterative sequence converges globally to a critical point of the original objective function. For numerical implementation, we adopt primal dual method to the inner subproblem. Numerical experiments in color image restoration and two-modality undersampled magnetic resonance imaging (MRI) reconstruction show that the proposed non-Lipschitz joint reconstruction method achieves considerable improvements in terms of edge preservation for piecewise constant images compared to existing methods.

Some theoretical results for time-domain fluorescence diffuse optical tomography

孙春龙博士 南京航空航天大学

The time-domain fluorescence diffuse optical tomography (FDOT) is to recover the distribution of fluorophores in biological tissue from the time domain measurement on the boundary. With the Laplace transform and the knowledge of complex analysis, we build the uniqueness theorem of this inverse problem. Further, we identify the location of the distribution of fluorophores over a point, refer as a point target. We theoretically investigate what is the minimal number of measurements to determine the point target location, analyzing the determinant of sensitivity matrix.

**26 号周五报告信息**

Hearing the triangles

刘晓东 研究员 中国科学院数学与系统科学研究院

Since the landmark paper by Marc Kac in 1966, the question "Can one hear the shape of a drum?" has attracted and inspired many mathematicians. This forms the subject of the mathematical discipline called spectral geometry. We introduce a two-step numerical scheme for reconstructing the shape of a triangle by its Dirichlet spectrum. With the help of the asymptotic behavior of the heat trace, the first step is to determine the area, perimeter, and the sum of the reciprocals of the angles

of the triangle. The shape is then reconstructed, in the second step, by solving a nonlinear system of equations on the angles using the Newton iterative method. To our best knowledge, this is the first numerical simulation for the classical inverse spectrum problem in the plane. Numerically, we have used only finitely many eigenvalues to reconstruct the triangles. We give a counter example to show that, even if we have infinitely many eigenvalues, the shape of a quadrilateral may not be heard.

罗守胜 浙江师范大学

Superiorized iteration algorithm for CT image reconstruction and segmentation simultaneously

In this talk, we propose a segmentation model for x-ray computed tomography (CT) image reconstruction, which can be applied to traditional CT and dual energy CT image reconstruction problem. It is difficult to solve the model due the large scale of image system and the DECT nonlinear forward projection. In order to solve the model, a superiorized iteration algorithm is presented, which handles image segmentation and image reconstruction alternately. The two steps are combined by a superiorized perturbation step. The convergence of the iteration procedure is proved for traditional CT image reconstruction. Experiments on various data are performed. Comparisons with existing

methods show that the proposed method is better quantitatively and visually.

张植栋，中山大学

Title：稀疏边界观测下抛物方程中反源题

Abstract：本报告考虑的是抛物方程中的反源问题，其中未知源项具有较为一般的半离散格式，所使用的观测数据为解在边界的通量。出于节约成本的考虑，我们希望尽可能地缩小观测区域，这也是稀疏一词的由来。使用拉普拉斯变换、复分析等工具，我们严格证明了此反源问题的唯一性定理，即边界任意非空开集上的通量观测可以唯一确定拥有半离散格式的未知源项。在此之后，我们设计了一些数值算法并尝试了一些算例。在最后，我们给出一些关于此反源问题可能的后续工作。

陈德汗，华中师范大学

Title：Statistical linear inverse problems in Banach spaces

Abstract：This talk presents the new trends and recent developments of Tikhonov regularizations in Hilbert and Banach settings. We first present classical results of VSC in Hilbert settings. Then, we propose and analyze variational source conditions (VSC) for the Tikhonov regularization methods with Lp-penalties applied to an ill-posed operator equation in a Banach space. Our analysis is built on the celebrated Littlewood-Paley

theory and the concept of l^2-boundedness. With these two analytical principles, we validate the proposed VSC under a conditional stability estimate in terms of a dual Triebel-Lizorkin-type norm. On the other hand, we will presents the applications of VSCs in some inverse PDEs problems.

## 27 号报告信息

"SMBU Symposium on Inverse Problems (on tour in SUSTech, M7 in the 12th Conference on Inverse Problems, Imaging and Applications)"

| 5 月 27 日下午　第一教学楼 304 教室 | | | |
|---|---|---|---|
| M7：正则化算法及应用 | | | |
| 主持人 | 时间 | 报告人 | 题目 |
| 张晔 | 13:10-13:35 | 董国志 | Second-order flows as computational models for inverse problems and beyond |
| | 13:35-14:00 | 陈德汗 | Statistical linear inverse problems in Banach spaces |
| | 14:00-14:25 | 付振武 | Convergence analysis of a generalized Levenberg-Marquardt method for possibly non-smooth inverse problems |
| | 14:25-14:50 | 郜广宇 | A Fast Data-Driven Iteratively Regularized Method with Convex Penalty for Solving Ill-Posed Problems |
| | 14:50-15:15 | 徐晨 | Estimating the memory parameter for possibly non-linear and non-Gaussian time series with wavelets |
| | 15:15-15:40 | 谷瑞雪 | Heuristic rule for inexact Newton-Landweber iteration with convex penalty terms of nonlinear ill-posed problems |
| 15:40-16:00　茶歇 | | | |
| 张晔 | 16:00-16:25 | 孙鸿鹏 | An Investigation on Semismooth Newton based Augmented Lagrangian Method for Image Restoration |
| | 16:25-16:50 | 王薇 | Dual gradient method for ill-posed problems using multiple repeated measurement data |
| | 16:50-17:15 | 夏宇欣 | Convergence analysis of inexact Newton-Landweber iteration under H\"{o}lder stability |
| | 17:15-17:40 | 李龙 | Fluid Velocity Reconstruction by a Deep Neural Network Approximating Variational Data Assimilation |

29 号报告信息

邱越，重庆大学

**Title:** Physics-informed invertible neural network for the Koopman operator learning

**Abstract:** The Koopman operator is used to embed a nonlinear system into an infinite, yet linear system with a set of observable functions. However, manually selecting observable functions that span the invariant subspace of the Koopman operator based on prior knowledge is inefficient and challenging, particularly when little or no information is available about the underlying system. Furthermore, current methodologies tend to disregard the importance of the invertibility of observable functions, which leads to inaccurate results. To address these challenges, we propose the so-called FlowDMD, a Flow-based Dynamic Mode Decomposition that utilizes the Coupling Flow Invertible Neural Network (CF-INN) framework. FlowDMD leverages the intrinsically invertible characteristics of the CF-INN to learn the invariant subspaces of the Koopman operator and accurately reconstruct state variables. Numerical experiments demonstrate the superior performance of our algorithm compared to state-of-the-art methodologies.

常慧宾 天津师范大学

**Title:** 叠层相位恢复问题的快速重建算法

**Abstract:** 叠层成像技术近二十年来成为了一项重要的超分辨技术，2018 年科学家使用电子光源将该技术的成像分辨率（Abbe diffraction-limited resolution)提升至 0.39 埃米(Nature 2018)，创造了新的分辨成像记录。与经典的相干衍射成像不同，该技术具有高通量特性，如典型的二维薄样本成像需要同时处理达数万帧数据，高维问题规模还会高至少两个量级。我将简要介绍该技术背后的有关叠层相位恢复的数学原理，并进一步围绕盲复原算法进行讨论，重点介绍我和合作团队在盲重建算法、偏相干分析、背景噪声去除以及并行计算等方面的研究工作。最后将讨论高维重建问题的研究现状和面临的挑战。

李培军，普渡大学

**Title:** Stability for inverse random source problems

**Abstract:** In the field of inverse problems, the estimation of an unknown source term from indirect observations is a fundamental challenge. Random sources add another level of complexity to this problem due to their uncertainties. In this talk, we will focus on the stability estimates for inverse random source problems, specifically for the stochastic Helmholtz equation driven by a white noise. An overview will be provided on the existing results for estimating the stability of the solution in deterministic settings, and our recent findings will be presented for the stochastic case. We will also discuss the challenges involved in inverse

random source problems and highlight potential avenues for future research.