Hong Kong Workshop on Inverse Problems and Imaging (November 29, 2022)

Workshop Booklet

Workshop Schedule

Venue: HKUST Jockey Club Institute for Advanced Study, The Hong Kong University of Science & Technology

Time	Event
09:30 - 10:00	**Registration**
10:00 - 10:05	**Opening Remaks** Gunther UHLMANN (The Hong Kong University of Science and Technology (IAS Si Yuan Professor))
Session 1	
10:05 - 10:35	**S1-#1:** **Introduction &** **Direct Sampling Methods for General Inverse Problems** Jun ZOU (The Chinese University of Hong Kong)
10:35 - 10:55	**S1-#2:** **Direct Sampling Methods for Simultaneously Recovering Inhomogeneous Inclusions of Different Nature** Fuqun HAN (The Chinese University of Hong Kong)
10:55 - 11:05	***Break*** ***(To comply with the current preventive measures of COVID-19 of the University,*** ***no food or drink will be served during the break.)***
Session 2	
11:05 - 11:10	**S2-#1:** **Introduction** Hongyu LIU (City University of Hong Kong)
11:10 - 11:30	**S2-#2:** **Shape Reconstructions by Using Plasmon Resonances with Enhanced Sensitivity** Minghui DING (City University of Hong Kong)
11:30 - 11:55	**S2-#3:** **Effective Medium Theory for Embedded Obstacles in Elasticity with Applications to Inverse Problems** Qingle MENG (City University of Hong Kong)
11:55 - 12:00	***Group Photo Taking (Venue: Lobby, G/F)***
12:00 - 14:00	***Lunch (For invited participants only ; Venue: China Garden Restaurant)***
Session 3	
14:00 - 14:05	**S3-#1:** **Introduction** Bangti JIN (The Chinese University of Hong Kong)
14:05 - 14:25	**S3-#2:** **Parameter identification for Subdiffusion from Observation at an Unknown Terminal Time** Zhi ZHOU (The Hong Kong Polytechnic University)
14:25 - 14:45	**S3-#3:** **Identification of Potential in Diffusion Equations: Conditional Stability and Discrete Approximation** Zhengqi ZHANG (The Hong Kong Polytechnic University)
14:45 - 15:05	**S3-#4:** **Identification of Potential and Diffusion Coefficient with Two Internal Observations** Siyu CEN (The Hong Kong Polytechnic University)
15:05 - 15:15	***Break*** ***(To comply with the current preventive measures of COVID-19 of the University,*** ***no food or drink will be served during the break.)***
Session 4	
15:15 - 15:20	**S4-#1:** **Introduction** Jianfeng CAI (The Hong Kong University of Science and Technology)
15:20 - 15:35	**S4-#2:** **A Preconditioned Riemannian Gradient Descent Algorithm for Low-Rank Matrix Recovery** Fengmiao BIAN (The Hong Kong University of Science and Technology)
15:35 - 15:50	**S4-#3:** **An Asymptotically Sharp Upper Bound for the Column Subset Selection Problem** Zili XU (The Hong Kong University of Science and Technology)
15:50 - 16:05	**S4-#4:** **Learning Laplacian Constrained Graphical Models: Sparsity, Algorithms, and Theory** Jiaxi YING (The Hong Kong University of Science and Technology)
16:05 - 16:15	***Break*** ***(To comply with the current preventive measures of COVID-19 of the University,*** ***no food or drink will be served during the break.)***
Session 5	
16:15 - 16:30	**S5-#1:** **Introduction** Shing-Yu LEUNG (The Hong Kong University of Science and Technology)
16:30 - 16:40	**S5-#2:** **A Simple Embedding Method for Scalar Hyperbolic Conservation Laws on Implicit Surfaces** Chun Kit HUNG (The Hong Kong University of Science and Technology)
16:40 - 16:50	**S5-#3:** **A Multi-Level Set Method for Modelling Dynamic Interfaces with an Application to an Elliptic Inverse Problem** Kin Ting Ken HUNG (The Hong Kong University of Science and Technology)
16:50 - 16:55	***Break*** ***(To comply with the current preventive measures of COVID-19 of the University,*** ***no food or drink will be served during the break.)***
Session 6	
16:55 - 17:00	**S6-#1:** **Introduction** Hai ZHANG (The Hong Kong University of Science and Technology)
17:00 - 17:15	**S6-#2:** **A New Super-Resolution Algorithm for Multiple Measurements** Zetao FEI (The Hong Kong University of Science and Technology)
17:15 - 17:30	**S6-#3:** **Mathematical Theory of In-Gap Bound State in a Two-Dimensional Waveguide** Jiayu QIU (The Hong Kong University of Science and Technology)
17:30 - 17:45	**S6-#4:** **An Inverse Problem for the Relativistic Boltzmann Equation** Antti KUJANPÄÄ (The Hong Kong University of Science and Technology (IAS Postdoctoral Fellow))

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Talk Abstracts

(*Listed in alphabetical order of speakers' last name)

A Preconditioned Riemannian Gradient Descent Algorithm for Low-Rank Matrix Recovery

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Low-rank matrix recovery problem frequently arises in signal processing, machine learning, and imaging science. Riemannian gradient descent (RGD) algorithm is one of the most efficient algorithms to solve it. In this talk, we introduce a preconditioned Riemannian gradient descent (PRGD) for low-rank matrix recovery, where the preconditioner is simple and easy to compute. We establish the theoretical recovery guarantee of PRGD under the assumption of the restricted isometry property. Our experiments show that PRGD is capable of accelerating RGD by up to ten times in solving low-rank matrix recovery problems such as matrix completion.

Identification of Potential and Diffusion Coefficient with Two Internal Observations

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In this talk we analyze the inverse problem of recovering the potential and diffusion coefficient in an elliptic problem with two internal observations. We establish a weighted conditional stability estimates. We also show an error analysis of the reconstruction method which is based on Tikhonov regularization and finite element discretization. Numerical results are provided to support the analysis.

Shape Reconstructions by Using Plasmon Resonances with Enhanced Sensitivity

Minghui DING

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This talk discusses the shape reconstructions of sub-wavelength objects from near-field measurements. We develop a novel reconstruction scheme using plasmon resonances. First, we establish a sharp quantitative relationship between the sensitivity of the reconstruction and the plasmon resonance. Second, the variational regularization method, alternating iteration method, and Laplace approximation method are introduced to reconstruct the object. Finally, the numerical performance verifies the proposed method. This talk is based on joint works with professor Hongyu Liu (CityU) and associate professor Guanghui Zheng (HNU).

A New Super-Resolution Algorithm for Multiple Measurements

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In this talk, we first review the theory on computational resolution limit for a single measurement. We then consider the case of multiple measurements and propose a new super-resolution algorithm. The computational resolution limit for the new algorithm is also revealed.

Direct Sampling Methods for Simultaneously Recovering Inhomogeneous Inclusions of Different Nature

Fuqun HAN

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In this talk we shall address some effective direct sampling methods for simultaneously recovering inhomogeneous inclusions arising from two different physical coefficients in the typical elliptic PDE model and the electromagnetic system.

A Simple Embedding Method for Scalar Hyperbolic Conservation Laws on Implicit Surfaces

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Partial differential equations (PDEs) on surfaces arises in many applications, while analytic solutions are generally unavailable. This presentation introduces a novel embedding method for solving scalar hyperbolic conservation laws on surfaces. By representing the surface implicitly by its signed distance function, we construct a PDE in a small neighborhood of the surface using the push-forward operator, whose solution is given by the constant normal extension of the solution to the surface PDE. Also, we provide a simple way to compute the push-forward operator, which involves only the signed distance function and its Hessian matrix.

A Multi-Level Set Method for Modelling Dynamic Interfaces with an Application to an Elliptic Inverse Problem

Kin Ting Ken HUNG

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The level set method is a numerical method for computing the motion of a single interface. The essence of the method consists of a level set function, which provides a numerical representation of a single interface through the zero level set of the function, and an associated partial differential equation, which governs the interface motion. This work considers the simultaneous evolution of multiple interfaces. We will introduce an extension to the original level set method, called the multi-level set method. Then we will look into concrete examples of dynamic interface and inverse problems.

An Inverse Problem for the Relativistic Boltzmann Equation

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The talk is about the following article: Balehowsky, T., Kujanpää, A., Lassas, M., & Liimatainen, T. (2022). An Inverse Problem for the Relativistic Boltzmann Equation. Communications in Mathematical Physics, 396(3), 983-1049. https://doi.org/10.1007/s00220-022-04486-8

Effective Medium Theory for Embedded Obstacles in Elasticity with Applications to Inverse Problems

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In this talk, we mainly consider a time-harmonic elastic wave scattering from a general inhomogeneous medium with an embedded impenetrable obstacle, which is strongly motivated by the partial-data inverse boundary problem and the inverse scattering problem of recovering complex scatterers consisting of mediums and buried obstacles. We first explore the scattering model with embedded obstacle can be effectively approximated by a scattering model with an isotropic elastic medium with particular material parameters, then we derive a sharp estimate to rigorously verify such an effective approximation. This result in this talk is joint works with Zhengjiang Bai (XMU), Huaian Diao (JLU) and Hongyu Liu (CityU).

Mathematical Theory of In-Gap Bound State in a Two-Dimensional Waveguide

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In this talk, we present a result on the existence of bound state in a waveguide that consists of two half-infinite periodic structures separated by an interface. The two periodic structures are perturbed from a periodic one with a Dirac point and processes a common band gap at the Dirac point. The derived bound state can be viewed as a bifurcation from the Dirac point.

An Asymptotically Sharp Upper Bound for the Column Subset Selection Problem

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In this talk we study the spectral norm version of the column subset selection problem: given a matrix A and a positive integer k < rank(A), select exactly k columns of A which minimize the approximation error, i.e., the spectral norm of the residual matrix after projecting A onto the space spanned by the selected columns. First, we employ the method of interlacing polynomials, which was introduced by Marcus-Spielman-Srivastava, to derive an asymptotically sharp upper bound on the smallest approximation error. Second, we extend our first result to a column partition problem, which aims to partition the columns of A into r > 1 subsets, such that A can be well approximated by the columns from several different subsets. We show that the machinery of interlacing polynomials also works in this setting, and the relevant expected characteristic polynomials are related to the r-characteristic polynomials.

Learning Laplacian Constrained Graphical Models: Sparsity, Algorithms, and Theory

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In this talk, I will discuss the problem of learning sparse Gaussian graphical models whose precision matrices are Laplacian matrices. Like in the classical graphical lasso problem, recent works made use of the l1-norm with the goal of promoting sparsity in learning Laplacian constrained graphical models. However, through empirical evidence, we observe that the l1-norm fails to impose a sparse solution to this problem. From a theoretical perspective, we prove that a large regularization parameter will unexpectedly result in a solution that represents a complete graph, i.e., every pair of vertices is connected by an edge. To address this issue, we propose a nonconvex penalized maximum likelihood estimation method and establish model selection consistency. Numerical experiments involving synthetic and real-world data sets demonstrate the effectiveness of the proposed method.

Identification of Potential in Diffusion Equations: Conditional Stability and Discrete Approximation

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We investigate the conditional stability of recovering a space-dependent potential in a (sub)diffusion equation from noisy final-time data. Next, a completely discrete scheme is developed by using the Galerkin finite element method in space and the finite difference method in time, and then a fixed point iteration is applied to the recovery. We show the linear convergence of the iteration algorithm by the contraction mapping theorem and present a thorough error analysis. The numerical experiments are provided to illustrate our theoretical results.

Parameter Identification for Subdiffusion from Observation at an Unknown Terminal Time

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Time-fractional subdiffusion equations represent an important class of mathematical models with a broad range of applications. The related inverse problems of recovering space-dependent parameters, e.g., initial condition, space dependent source or potential coefficient, from the terminal observation have been extensively studied in recent years. However, all existing studies have assumed that the terminal time at which one takes the observation is exactly known. In this talk, we present uniqueness and stability results for three canonical inverse problems, e.g., backward problem, inverse source and inverse potential problems, from the terminal observation at an unknown time. The subdiffusive nature of the problem indicates that one can simultaneously determine the terminal time and space-dependent parameter.

Direct Sampling Methods for General Inverse Problems

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In this talk we shall review the current developments of the direct sampling methods for solving general inverse problems.