SUSTech CAM Mini-Workshop

June 13-14, 2020

1 Intoduction

This workshop aims to bring together experts working on computational and applied mathematics to exchange the latest research progress, discuss new research directions and foster research collaborations.

2 Host

Department of Mathematics, Southern University of Science and Technology

3 Organizing Committee

Xiaoming Wang 王晓明, Southern University of Science and Technology
Jingzhi Li 李景治, Southern University of Science and Technology

4 Time Table

Date	Event	Venue
13 June	Online workshop talks	Zoom ID: 65324513741
14 June	Online workshop talks	Zoom ID: 65324513741

5 Supporting sponsor

High-Calibre University Grant (Phase II), Guangdong Provincial Key Laboratory for Computational Science and Material Design, Southern University of Science and Technology

6 Assistant

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7 Workshop Program

Time	June 13, 2020 (Saturday)	
	Morning session Chair: Jingzhi Li 李景治	
9:00–9:45	Hongyu Liu 刘宏宇	Local and global structures of transmission eigenfunctions and applications to super-resolution imaging and electromagnetic mirage
9:45–10:30	Rongliang Chen 陈荣亮	Scalable Parallel Algorithms and Software for Engineering and Scientific Computing
10:30–11:00	Break	
11:00–11:45	Youjun Deng 邓又军	Localized resonance and its applications in imaging and cloaking
	Afternoon session Chair: Hongyu Liu 刘宏宇	
14:00–14:45	Huaian Diao 刁怀安	On generalized Holmgren's principle to the Lamé operator with applications to inverse elastic problems
14:45–15:30	Genqian Liu 刘跟前	Determination of isometric real-analytic metric and spectral invariants for elastic Dirichlet-to-Neumann map on Riemannian manifolds
15:30–16:00	Break	
16:00–16:45	Kai Zhang 张凯	Numerical method for the Maxwell equations with random interfaces
16:45–17:30	Yukun Guo 郭玉坤	Some recent advances in the unique determinations in phaseless inverse scattering theory

Time	June 14, 2020 (Sunday)
	Morning session Chair: Huaian Diao 刁怀安
9:00–9:45	Hongyu Liu 刘宏宇	Mathematical theory of MAD technology
9:45–10:30	Weiyang 杨伟	Design and finite element simulation of information open electromagnetic cloak device
10:30–11:00	Break
11:00–11:45	Chao Wang 王超	A mixed finite element scheme for quad-curl source and eigenvalue problems
	Afternoon session Chair: Youjun Deng 邓又军
14:00–14:45	Xiliang Lu 吕锡亮	A Robust Decoder for 1-bit Compressed Sensing: Least Squares
14:45–15:30	Ming Ju 明矩	Lloyd algorithm and its application
15:30–16:00	Break
16:00–16:45	Wenlong Zhang 张文龙	The applications of group sparse method in inverse problems
16:45–17:30	Jiachuan Zhang 张佳川	A posteriori error estimator for weak Galerkin finite element method with hierarchical bases of the Stokes problem

8   Titles and Abstracts (in alphabetical order)

Scalable Parallel Algorithms and Software for Engineering and Scientific Computing

Professor Rongliang Chen 陈荣亮
Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences

Abstract: The high-performance computing (HPC) hardware is very powerful now, e.g. the world's most powerful supercomputer Summit reaches 148.6   Petaflopss, but the HPC algorithms and software development are far   behind the development of hardware, especially for the engineering level   HPC algorithms and software. In this talk, with a short introduction of the history of the world/China's supercomputer and the state of the art of the HPC software, I will introduce some of our recent works on the scalable parallel algorithms and software development for engineering applications.

Localized resonance and its applications in imaging and cloaking

Professor Youjun Deng 邓又军
Central South University

Abstract: In this talk, we shall introduce the notions of localized resonances. Usually these problems are related to the spectral of the Neumann-Poincare operators in different models. As an example, we provide a mathematical framework for localized plasmon resonance of nanoparticles. Using layer potential techniques associated with the full Maxwell equations, we derive small-volume expansions for the electro-magnetic fields, which are uniformly valid with respect to the nanoparticle's bulk electron relaxation rate. Then, we discuss the scattering and absorption enhancements by plasmon resonant nanoparticles. Finally, we show the applications of localized resonance in imaging and cloaking.

On generalized Holmgren's principle to the Lamé operator with applications to inverse elastic problems

Professor Huaian Diao 刁怀安
Northeast Normal University

Abstract: Consider the Lamé operator $L(u) := \mu\Delta u + (\lambda + \mu)\nabla(\nabla \cdot u)$ that arises in the theory of linear elasticity. This paper studies the geometric properties of the (generalized) Lamé eigenfunction u. We introduce the so-called homogeneous line segments of u in Ω, on which u, its traction or their combination via an impedance parameter is vanishing. We give a comprehensive study on characterizing the presence of one or two such line segments and its implication to the uniqueness of u. The results can be regarded as generalizing the classical Holmgren's uniqueness principle for the Lamé operator in two aspects. We establish the results by analyzing the development of analytic microlocal singularities of u with the presence of the aforesaid line segments. Finally, we apply the results to the inverse elastic problems in establishing two novel unique identifiability results. It is shown that a generalized impedance obstacle as well as its boundary impedance can be determined by using at most four far-field patterns. Unique determination by a minimal number of far-field patterns is a longstanding problem in inverse elastic scattering theory.

Some recent advances in the unique determinations in phaseless inverse scattering theory

Professor Yukun Guo 郭玉坤
Harbin Institute of Technology

Abstract: This talk is concerned with some recent developments in the inverse scattering problems with phaseless data. Based upon our previous studies on the uniqueness issues in phaseless inverse acoustic scattering theory, this talk is served as a brief overview. I will outline the relevant rudiments comprising prototypical model problems, major progress so far as well as the rationale behind the basic techniques, in an attempt to sort out the essential ideas and shed further lights on this field.

Determination of isometric real-analytic metric and spectral invariants for elastic Dirichlet-to-Neumann map on Riemannian manifolds

Professor Genqian Liu 刘跟前
Beijing Institute of Technology

Abstract: For a compact Riemannian manifold (Ω, g) with smooth boundary $\partial\Omega$, we explicitly give local representation and full symbol expression for the elastic Dirichlet-to-Neumann map Ξ_g by factorizing an equivalent elastic equations. We prove that for a strong convex or extendable real-analytic manifold Ω with boundary, the elastic Dirichlet-to-Neumann map Ξ_g uniquely determines metric g of Ω in the sense of isometry. We also give a procedure by which we can explicitly calculate all coefficients $a_0, a_1 \cdots, a_{n-1}$ of the asymptotic expansion $\sum_{k=1}^{\infty} e^{-t\tau_k} \sim \sum_{m=0}^{n-1} a_m t^{m+1-n} + o(1)$ as $t \to 0^+$, where τ_k is the k-th eigenvalue of the elastic Dirichlet-to-Neumann map (i.e., k-th elastic Steklov eigenvalue). The coefficients a_m are spectral invariants and provide precise information for the boundary volume $\mathrm{vol}(\partial\Omega)$ of the elastic medium Ω and the total mean curvature as well as other total curvatures of the boundary $\partial\Omega$. These conclusions give answer to two open problems.

Local and global structures of transmission eigenfunctions and applications to super-resolution imaging and electromagnetic mirage

Professor Hongyu Liu 刘宏宇
City University of Hong Kong

Abstract: The interior transmission eigenvalue problems are a type of non-elliptic and non-self-adjoint spectral problems that arise in the wave scattering theory. It connects to many aspects of the direct and inverse scattering theory. In this talk, I shall discuss some of our recent discoveries on the global and local structures of the transmission eigenfunctions. We shall also consider their applications to super-resolution imaging and electromagnetic mirage.

Mathematical theory of MAD technology

Professor Hongyu Liu 刘宏宇
City University of Hong Kong

Abstract: In this talk, I shall describe the recent progress of our mathematical study on the magnetic anomaly detections (MAD) using geomagnetic monitoring. We formulate the problem as different inverse problems in several scenarios of practical interest. We establish the unique identifiability results and the corresponding arguments are constructive which readily yield numerical reconstruction schemes. The results may have potential applications in submarine detection and underground minerals identification.

A Robust Decoder for 1-bit Compressed Sensing: Least Squares

Professor Xiliang Lu 吕锡亮
Wuhan University

Abstract: In 1-bit compressive sensing (1-bit CS) where a target signal is coded into a binary measurement, one goal is to recover the signal from noisy and quantized samples. Due to the presence of nonlinearity, noise, and sign ips, it is quite challenging to decode from the 1-bit CS. In this talk, we consider a least squares approach under the overdetermined and underdetermined settings. For overdetermined system, we show that, up to a constant c, with high probability, the least squares solution approximates the signal. For underdetermined system, we prove that, up to a constant c, with high probability, the L1 -regularized least-squares solution approximate the true sparse signal well. A Newton type method, the so-called primal and dual active set (PDAS) algorithm, is applied to solve the nonsmooth optimization problem. It only requires solving a small least squares problem on the active set, which is extremely effcient for recovering sparse signals through continuation. Numerical experiments are presented to illustrate the robustness of the proposed model and the effciency of the algorithm.

Lloyd algorithm and its application

Professor Ju Ming 明矩
Huazhong University of Science and Technology

Abstract: As an important clustering algorithm, Lloyd algorithm has been widely used in data science and statistics. In this lecture, we will review its application and conclusions in computational science, including reduced order modeling , mathematical modeling and uncertainty quantification.

A mixed finite element scheme for quad-curl source and eigenvalue problems

Doctor Chao Wang 王超
Southern University of Science and Technology

Abstract: The quad-curl problem arises in the resistive magnetohydrodynamics (MHD) and the electromagnetic interior transmission problem. In this report we study a new mixed finite element scheme using standard edge elements to approximate both the solution and its curl for quad-curl problem on Lipschitz polyhedral domains. We impose element-wise stabilization instead of stabilization along mesh interfaces. Via a discrete energy norm stability due to element-wise stabilization, we prove optimal convergence under a low regularity condition. We also extend the mixed finite element scheme to the quad-curl eigenvalue problem and provide corresponding convergence analysis based on that of source problem. Numerical examples are provided to show the viability and accuracy of the proposed method for quad-curl source problem.

Design and finite element simulation of information open electromagnetic cloak device

Professor Wei Yang 杨伟
Xiangtan University

Abstract: In this talk, we first introduce the design principle and applications of the information open electromagnetic cloak device, and then we design two layered information open electromagnetic cloak devices based on linear and nonlinear transformations. By the finite element simulations, we find that the information open electromagnetic cloak device obtained by the level layered design method has better cloak effect than the equidistant layered design.

A posteriori error estimator for weak Galerkin finite element method with hierarchical bases of the Stokes problem

Doctor Jiachuan Zhang 张佳川
Southern University of Science and Technology

Abstract: Based on a posteriori error estimator with hierarchical bases, an adaptive weak Galerkin finite element method (WGFEM) is proposed for the Stoke's problem. For the error estimator, we need solve a linear algebraic system only with diagonal entries corresponding to the degree of freedoms, which reduces the computational cost sharply. The upper bound and lower bound of error estimator are also shown to addresses the reliability of the adaptive method. Numerical simulations are provided to demonstrate the effectiveness and robustness of our algorithm.

Numerical method for the Maxwell equations with random interfaces

Professor Kai Zhang 张凯
Jilin University

Abstract: A robust numerical method via the shape derivatives and low-rank approximation is developed for computations of three-dimensional Maxwell's equations with random interfaces. Based on a shape calculus, we estimate the statistical moments of the stochastic Maxwell equations in terms of perturbation magnitude. In order to capture the oscillations with high resolution near the interface, we adopt the adaptive edge element with third order polynomials to solve the deterministic equations approximating the expectation. For the second moment, an efficient low-rank approximation based on pivoted Cholesky decomposition is proposed to compute the two-point correlation function to approximate the variance of stochastic Maxwell's equations. Numerical experiments are presented to illustrate our theoretical results. This is the jointed work with Dr. Y.L. Hao (ZKNU), Prof. J.Z. Li(SUSTC), and Dr. F.D. Kang (CityU).

The applications of group sparse method in inverse problems

Doctor Wenlong Zhang 张文龙
Southern University of Science and Technology

Abstract: In this talk, we present novel reconstruction methods for multifrequency electrical impedance tomography and multi wavelength diffuse optical spectroscopic imaging. They are based on linearization and group sparsity. We consider an isotropic conductivity and diffusion distributions with a finite number of unknown inclusions. We also discuss the reconstruction for an imperfectly known boundary and show that, with multi-frequency or wavelength data, the method can reduce the influence of modelling errors and still recover the PDE coefficients. Extensive numerical experiments are presented to support our analysis.

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9 The list of participants

Xinlin Cao 曹鑫林 (Hong Kong Baptist University)

Rongliang Chen 陈荣亮 (Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences)

Youjun Deng 邓又军 (Central South University)

Huaian Diao 刁怀安 (Northeast Normal University)

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