International Conference on
Computational Mathematics and Inverse Problems
Kliakhandler Conference

Aug. 15-19, 2016, Michigan Tech., Houghton, MI.

Table 1: Conference Program

	Monday(Aug.15)	Tuesday(Aug.16)	Wednesday(Aug.17)	Thursday(Aug.18)	Friday(Aug.19)
8:30 - 8:50	Registration				
8:50 - 9:00	Opening Remark				
Chair	Gockenbach, M.	Falk, R.	Colton, D.	Monk, P.	Li, P.
9:00-9:40	Colton, D.	Zou, J.	Kirsch, A.	Demkowicz, L.	Liu, J.
9:40-10:20	Falk, R.	Boffi, D.	Coyle, J.	Wang, J.	Ren, K.
10:20-10:40	Coffee Break	Coffee Break	Coffee Break	Coffee Break	Coffee Break
Chair	Kirsch, A.	Boffi, D.	Rossi, L.	Demkowicz, L.	Li, J.
10:40-11:20	Darrigrand, E.	Lehoucq, R.	Gockenbach, M.	Li, J.	Zheng, C.
11:20-12:00	Hyvnen, N.	Huttunen, T.	Boubendir, Y.	Li, P.	Zheng, W.
12:00-12:40			Cakoni, F.		
12:00-2:00	Lunch Break	Lunch Break	Lunch Break	Lunch Break	Lunch Break
Chair	Cakoni, F.	Sayas, F.		Wang, J.	Zheng, C.
2:00-2:40	Nigam, N.	Griesmaier, R.	Conference Tour:	Bacuta, C.	Yang, Y., Qu. F.
2:40-3:20	Sayas, F.	Li, H.	Quincy Mine *	Rossi, L.	Yang, J. Ong, B.
3:20-3:40	Coffee Break	Coffee Break		Coffee Break	Coffee Break
Chair	Huttunen, T.	Nigam, N.		Bacuta, C.	Ren, K.
3:40-4:00	Muniz, W.	Liu, X.		Cui, J.	Kapita, S
4:00-4:20	Meng, S.	Li, X.		Mu, L.	de Teresa, I.
4:20-4:40	Guo, Y.	Selgas, V.		Labovsky, L.	Huang, R.
4:40-5:00	Luostari, T.	Kleefeld, A.		Zhang, H.	Marcinek, P.
6:00-			Banquet		

* **Extended Quincy Mine Tours (quincymine.com):** This tour would last approximately three hours and requires extensive walking around the site including the steep tramroad (no vehicles will be used). This tour is available year round but is dependent on weather and availability of staff. This guided tour begin at the #2 Shaft house, include additional above ground sites on the property such as the engine house, hoist tour, then a walk down the tramroad to the mine entrance a muddy walk in the mine. The tour would then hike back up the tramroad and end at the Hoist House. Rates are $25 per adult, $12.50 per child 6-12.

Conference Venue: Fisher 138.

Contact: Jiguang Sun, jiguangs@mtu.edu, 302-450-6077

Monday, Aug. 15

8:30 - 8:50 Registration

8:50 - 9:00 Opening Remark - Bruce Seely, Dean, College of Sciences and Arts, MTU.

9:00 - 10:20 Chair: Mark Gockenbach

9:00 - 9:40 David Colton, University of Delaware
Stekloff Eigenvalues in Inverse Scattering

9:40 - 10:20 Richard Falk, Rutgers University, U.S.A.
Numerical Computation of Hausdorff Dimension

10:20-10:40 Coffee Break/Group Photo

10:40 - 12:00 Chair: Andreas Kirsch

10:40 - 11:20 Eric Darrigrand, IRMAR - Université de Rennes-1, France
Schwarz preconditioner for the coupling of integral representation and finite element method

11:20 - 12:00 Nuutti Hyvonen, Aalto University, Finland
Recovering from an inaccurately known measurement set-up by polynomial collocation in EIT

12:00 - 2:00 Lunch Break

2:00 - 3:20 Chair: Cakoni, Fioralba

2:00 - 2:40 Nigam, Nilima, Simon Fraser University, Canada
A Bayesian approach to eigenvalue optimization

2:40 - 3:20 Sayas, Francisco-Javier, University of Delaware
Hybridizable Discontinuous Galerkin Methods for Elastodynamics

3:20-3:40 Coffee Break

3:40 - 5:00 Chair: Huttunen, Tomi

3:40 - 4:00 Muniz, Wagner, Federal University of Santa Catarina, Brazil
A high order collocation scheme for EM scattering from buried objects

4:00 - 4:20 Shixu, Meng, IMA
Spectral analysis of the interior transmission eigenvalue for Maxwell's equations

4:20 - 4:40 Guo, Yukun, Harbin Institute of Technology, China
A direct method for inverse acoustic scattering in the time domain

4:40 - 5:00 Luostari, Teemu, University of Eastern Finland, Finland
Remote sensing of forests in Bayesian framework

Tuesday, Aug. 16

9:00 - 10:20 Chair: Falk, Richard

9:00 - 9:40 Zou, Jun, The Chinese University of Hong Kong, China

Adaptive finite element methods for some linear and nonlinear inverse problems

9:40 - 10:20 Boffi, Daniele, Università di Pavia, Italy

A posteriori error analysis for the Maxwell eigenvalue problem

10:20-10:40 Coffee Break

10:40 - 12:00 Chair: Boffi, Daniele

10:40 - 11:20 Lehoucq, Richard, Sandia National Laboratories, U.S.A.

A Mixed Finite Element Method for Constraining and Regularizing the Optical Flow Constraint

11:20 - 12:00 Huttunen, Tomi, University of Eastern Finland, Finland

Applications of the ultra weak variational formulation

12:00 - 2:00 Lunch Break

2:00 - 3:20 Chair: Sayas, Francisco-Javier

2:00 - 2:40 Griesmaier, Roland, Universität Würzburg, Germany

Uncertainty principles for far field patterns with applications to inverse source problems

2:40 - 3:20 Li, Hengguang, Wayne State University

An anisotropic mesh for vertex/edge singularities of 3D elliptic problems

3:20-3:40 Coffee Break

3:40 - 5:00 Chair: Nigam, Nilima

3:40 - 4:00 Liu, Xiaodong, Chinese Academy of Sciences, China

A Fast and Robust Sampling Method for Shape Reconstruction in Inverse Acoustic Scattering Problems

4:00 - 4:20 Li, Xiaosheng, Florida International University, U.S.A.

Inverse Problems in Unbounded Domains with Impedance Boundary Condition

4:20 - 4:40 Selgas, Virginia, Universidad de Oviedo, Spain

A time domain Linear Sampling Method for a waveguide

4:40 - 5:00 Kleefeld, Andreas, Die Brandenburgische Technische Universität, Germany

Numerical computations of interior transmission eigenvalues for scattering objects with cavities

Wednesday, Aug. 17

9:00 - 10:20 Chair: Colton, David

9:00 - 9:40 Kirsch, Andreas, Karlsruhe Institute of Technology, Germany

Inverse Problems for Abstract Evolution Equations With Applications in Electrodynamics and Elasticity

9:40 - 10:20 Coyle, Joseph, Monmouth University, U.S.A.

A High-Order DG FEM Related to Transport Equations

10:20-10:40 Coffee Break

10:40 - 12:00 Chair: Rossi, Louis

10:40 - 11:20 Gockenbach, Mark, Michigan Technological University, U.S.A.

The generalized singular value expansion and the analysis of linear inverse problems

11:20 - 12:00 Boubendir, Yassine, NJIT, U.S.A.

Asymptotic Expansions of the Helmholtz Equation Solutions in the Case of Convex Obstacles

12:00 - 12:40 Cakoni, Fioralba, Rutgers University, U.S.A.

Homogenization of the Scattering Problem for Highly Oscillating Anisotropic Media of Bounded Support

Thursday, Aug. 18

9:00 - 10:20 Chair: Monk, Peter

9:00 - 9:40 Demkowicz, Leszek, The University of Texas at Austin, U.S.A.
The double adaptivity algorithm

9:40 - 10:20 Wang, Junping, National Science Fundation, U.S.A.
Primal-Dual Weak Galerkin Finite Element Methods

10:20-10:40 Coffee Break

10:40 - 12:00 Chair: Demkowicz, Leszek

10:40 - 11:20 Li, Jichun, University of Nevada, Las Vegas, U.S.A.
A Superconvergence analysis of edge elements and applications in metamaterial simulation

11:20 - 12:00 Li, Peijun, Purdue University, U.S.A.
Inverse Random Source Scattering Problems

12:00 - 2:00 Lunch Break

2:00 - 3:20 Chair: Wang, Junping

2:00 - 2:40 Bacuta, Constantin, University of Delaware, U.S.A.
Saddle point least squares discretization for mixed variational formulations of PDEs

2:40 - 3:20 Rossi, Louis, University of Delaware, U.S.A.
Achieving high order accuracy with smoothed particle hydrodynamic methods

3:20-3:40 Coffee Break

3:40 - 5:00 Chair: Bacuta, Constantin

3:40 - 4:00 Cui, Jintao, Hong Kong Polytechnic University, China
Multigrid Methods for Two-Dimensional Maxwell's Equations based on Hodge Decomposition

4:00 - 4:20 Mu, Lin, Oak Ridge National Laboratory, U.S.A.
Weak Galerkin Finite Element Methods and Applications

4:20 - 4:40 Labovsky, Alexander, Michigan Technological University, U.S.A.
Improving the accuracy of fluid-fluid interaction problems with the legacy codes

4:40 - 5:00 Zhang, Haiwen, Chinese Academy of Sciences, China
A novel integral equation for scattering by locally rough surfaces and application to the inverse problem: the Neumann case

Friday, Aug. 19

9:00 - 10:20 Chair: Li, Peijun

9:00 - 9:40 Liu, Jijun, Southeast University, China
On Spectral Computations for Transmission Eigenvalue Problems

9:40 - 10:20 Ren, Kui, University of Texas at Austin, U.S.A.
Mathematical Modeling of Semiconductor-Electrolyte Solar Cells

10:20-10:40 Coffee Break

10:40 - 12:00 Chair: Li, Jichun

10:40 - 11:20 Zheng, Chunxiong, Tsinghua University, China
Optimal error estimates for Gaussian beam approximations to the Schrodinger equation

11:20 - 12:00 Zheng, Weiying, Chinese Academy of Sciences, China
Perfectly matched layer method for electromagnetic scattering problems in layered media

12:00 - 2:00 Lunch Break

2:00 - 3:20 Chair: Zheng, Chunxiong

2:00 - 2:20 Yang, Yang, Michigan Technological University, U.S.A.
Discontinuous Galerkin methods for Chemotaxis models

2:20 - 2:40 Qu, Fenglong, Yantai University, China
Uniqueness results and the factorization method in the inverse scattering problem for an inhomogeneous cavity

2:40 - 3:00 Yang, Jiaqing, Xi'an Jiaotong University, China.
An approximate factorization method for inverse medium scattering with unknown buried objects

3:00 - 3:20 Ong, Benjamin, Michigan Technological University, U.S.A.
An Incremental SVD Algorithm for Distributed Data

3:20-3:40 Coffee Break

3:40 - 4:20 Chair: Ren, Kui

3:40 - 3:50 Kapita, Shelvean, IMA, U.S.A.
Plane Wave Discontinuous Galerkin Methods for Acoustic Scattering

3:50 - 4:00 de Teresa, Irene, University of Delaware, U.S.A.
Approximate transmission conditions for the scattering of electromagnetic waves in the presence of delamination

4:00 - 4:10 Huang, Ruihao, Michigan Technological University, U.S.A.
A recursive integral method for transmission eigenvalues

4:10 - 4:20 Marcinek, Pawel, Oakland University
Analysis and Simulations of Debonding of Bonded Rods Caused by Mechanical Stresses, Humidity and Thermal Effects

1. Bacuta, Constantin

   - bacuta@udel.edu
   - Saddle point least squares discretization for mixed variational formulations of PDEs
   - We investigate new PDE discretization approaches for solving variational formulations with different types of trial and test spaces. The general mixed formulation we consider assumes a stability LBB condition and a data compatibility condition at the continuous level. For our proposed discretization method a discrete $\inf - \sup$ condition is automatically satisfied by natural choices of test spaces (first) and corresponding trial spaces (second). For the proposed discretization and iterative approach, nodal bases for the trial space are not required, and a multilevel algorithm can be adopted to speed up the approximation process. The level change criterion is based on matching the order of the the iteration error with the the order of the expected discretization error. Applications of the method include discretization of second order PDEs with oscillatory or rough coefficients and first order systems of PDEs, such as $div - curl$ systems and time-hamonic Maxwell equations. This is joint work with Francisco Sayas and Kjajdi Qirko.

2. Boffi, Daniele

   - daniele.boffi@unipv.it
   - A posteriori error analysis for the Maxwell eigenvalue problem
   - A posteriori error analysis for eigenvalue problems raises interesting questions, which have received partial answers only recently. A fundamental issue concerns how to design adaptive schemes for the approximation of multiple eigenvalues or when clusters of eigenvalues are present. The convergence and quasi-optimality of the adaptive approximation of the Laplace eigenvalue problem in mixed form has been recently studied (joint work with D. Gallist, F. Gardini, and L. Gastaldi). The analysis is cluster robust and makes use of standard finite element schemes based on Raviart-Thomas element in two and three space dimensions. The equivalence with a suitable eigenvalue problem in mixed form suggests how to extend the result from mixed Laplacian to the Maxwell eigenvalue problem (joint work with L. Gastaldi, R. Rodriguez, and I. Sebestova).

3. Boubendir, Yassine

   - boubendi@gmail.com
   - Asymptotic Expansions of the Helmholtz Equation Solutions in the Case of Convex Obstacles
   - In this talk, we will review some of the well-known asymptotic expansions of solutions of the Helmholtz equation. Then, we will present some new expansions based on local approximations of the Dirichlet to Neumann operator. The goal is the derivation of appropriate ansatz that can be used in the design of high-frequency integral equation solvers.

4. Cakoni, Fioralba

   - fc292@math.rutgers.edu
   - Homogenization of the Scattering Problem for Highly Oscillating Anisotropic Media of Bounded Support
   - We discuss the homogenization of a transmission problem arising in the scattering theory for bounded inhomogeneities with periodic coefficients modeled by the anisotropic Helmholtz equation. The coefficients are assumed to be periodic functions of the fast variable, specified over the unit cell with small characteristic size. By way of multiple scales expansion, we establish higher-order bulk and boundary corrections of the leading-order homogenized transmission problem, providing rigorous estimates. We also present explicit boundary corrections for the transmission problem when the scatterer is a unit square and its limit as the cell size goes to zero. At the end we briefly consider the homogenization of the corresponding transmission eigenvalue problem and show that the transmission eigenvalues, which can be determined from the scattering data, can be used to reconstruct the effective material properties of the highly oscillating periodic media. This is joint work with B. Guzina and S. Moscow.

5. Colton, David

    - colton@udel.edu
    - Stekloff Eigenvalues in Inverse Scattering
    - We consider a problem in non-destructive testing in which small changes in the (possibly complex valued) index refractive index of an inhomogeneous medium of compact support are to be determined from changes in the measured far field data due to incident plane waves. The problem is studied by considering a modified far field operator F whose kernel is the difference of the measured far field pattern due to the scattering object and the far field pattern of an auxiliary scattering problem with Stekloff boundary condition on the boundary of a domain either containing the scatterer or equal to the the support of the scatterer. Numerical examples are given showing the effectiveness of determining changes to the refractive index in this way. This is joint work with F. Cakoni, S.Meng and P.Monk

6. Coyle, Joseph

    - jcoyle@monmouth.edu
    - A High-Order DG FEM Related to Transport Equations
    - A discontinuous Galerkin finite element method related to transport equations with nonlinearities will be discussed. The motivation is based, in part, on modeling age-structured populations. The presentation will include a brief derivation of the method and associated convergence rates while the main focus will be on implementation and numerical results. In particular, the impact of an unstructured mesh, the nonsymmetric nature of the system matrix and solution techniques related to the potentially nonlinear system will be addressed

7. Cui, Jintao

    - jintao.cui@polyu.edu.hk
    - Multigrid Methods for Two-Dimensional Maxwell's Equations based on Hodge Decomposition
    - In this work, we investigate the numerical solution for two-dimensional Maxwell's equations on graded meshes. The approach is based on the Hodge decomposition. The solution u of Maxwell's equations is approximated by solving standard second order elliptic problems. The quasi-optimal error estimates for both u and curl of u in the L_2 norm are obtained on graded meshes. We then prove the uniform convergence of the W-cycle and full multigrid algorithms for the resulting discrete problems. The performance of these methods is illustrated by numerical results. Similar numerical approach can also be applied to solve the fourth order curl problems. We will report the convergence results for multigrid algorithms.

8. Darrigrand, Eric

    - eric.darrigrand-lacarrieu@univ-rennes1.fr
    - Schwarz preconditioner for the coupling of integral representation and finite element method
    - The use of integral representations as an exact boundary condition for the finite element resolution of wave propagation problems in exterior domain induces algorithm difficulties. We focus on the resolution of 3D Maxwell equations by a coupling of finite elements and integral representation (CEFRI). The justification of an algorithm described in literature, using an interpretation as a Schwarz method, reveals the finite element term of Schwarz method as a preconditioner for Krylov iterative solvers. An analytical study of the case of a spherical perfect conductor indicates the efficiency of such approach. The application of the preconditioner leads to a superlinear convergence of the GMRES predicted by the analytical study and verified numerically. The combination of the Ultra-Weak Variational Formulation and an integral representation was previously explored with P. Monk by using Fast Multipole Method. The link between the various approaches will be given.

9. de Teresa, Irene

- irene@udel.edu
- Approximate transmission conditions for the scattering of electromagnetic waves in the presence of delamination
- I will present an approximate model for the scattering of electromagnetic waves in the presence of a thin opening (or delamination) at the interface of two materials. We substitute the thin opening by a portion of the interface where the fields satisfy appropriate transmission conditions. The results will be used to analyze the inverse problem of reconstructing the delamination.

10. Demkowicz, Leszek

- leszek@ices.utexas.edu
- The double adaptivity algorithm (Leszek Demkowicz and Norbert Heuer)
- The ideal DPG method [2] reproduces the stability of the continuous problem and guarantees optimal convergence for any well posed problem. The broken test spaces methodology makes it computationally efficient and can be applied to any well posed variational formulation [2]. The practical DPG method approximates the Riesz (error) representation function ψ using an enriched test space. Needless to say, the ultimate success of the practical DPG method hinges on controlling the error in resolving ψ. For standard, "mathematician" test norms, the resolution of ψ is relatively easy and the damage due to the error in ψ can be estimated via the construction of appropriate Fortin operators [2,3]. For challenging singular perturbation problems, and test norms involving the perturbation parameter, resolution of ψ is challenging but not because of stability (as for the original problem) bur rather approximtability issues.

  The double adaptivity idea of Cohen, Dahmen and Welper [1] calls for introducing an inner adaptivity loop to control the error in ψ. The adaptively determined enriched test space is "custom made" for the particular load and the trial space, and it does not imply the discrete stability. And yet the ultimate method converges.

  I will present a series of 1D and 2D double adaptivity experiments for convection dominated diffusion. Out of many possible variational formulations, the ultraweak formulation stands out as the corresponding optimal test norm is known explicitly, and it is robustly equivalent to the adjoint graph norm (with a properly scaled L^2-term). Consequently, the DPG method delivers an orthogonal projection in an energy norm robustly equivalent to the trial L^2-norm. The adjoint graph norm, however, is difficult to resolve, and the double adaptivity comes in as a natural means to cope with the problem.

  The inner adaptivity loop requires a robust a-posteriori error estimate for the discretization of Riesz representation function ψ. A residual estimate seems to be a natural (if not the only possible) option. For a broken test space, the residual is equal to the sum of element residuals, so the residual estimation is naturally reduced to a single element K. Cumbersome construction of Clement-like interpolation operators, necessary for standard conforming methods, reduces to a simple orthogonal projection in the test norm. The element residual estimate leads to a number of multiscale generalized eigenvalue problems involving the test norm, $L^2(K)$, $L^2(K)$ and $H^{-1}(K)$ norms. The eigenvalue problems are solved off line, harvesting appropriate "interpolation" constants for different values of diffusion ϵ, element size h, enriched element order r, and advection vector components. The precomputed constants enter then the residual estimate.

  Ideally, one should use two independent meshes, one for the original unknown u, and the second for Riesz representation ψ. The dynamically determined mesh for ψ depends upon approximate solution u_h (and, therefore, the first mesh). For practical reasons, we attempt to use the same mesh for both unknowns, enriching only the order of approximation for ψ. If the maximum order is reached, we force h-refinements and restart the whole problem. 1D and 2D numerical experiments indicate that, for small diffusion, the adaptivity process is driven entirely by the resolution of ψ, i.e. the inner adaptivity loop. This is rather disappointing as we would like to see a robust solution for very coarse meshes (which is critical for nonlinear problems).

  In the end, we will present experiments based on the ideas of Broersen and Stevenson [4] based on evolving a pure convection to a convection-diffusion problem. With a proper selection of a variational formulation, the underresolved Riesz representation function ψ for the confusion problem, represents a perfect approximation for the corresponding Riesz representation function for the pure convection problem. The game involves also relaxing the full stop outflow boundary conditions which must evolve with the mesh. The numerical results are promising but, at the moment, we do not have a full understanding of the underlying mathematics. We hope to understand it better by the time of the conference.

[1] A. Cohen, W. Dahmen, and G. Welper, "Adaptivity and variational stabilization for convection-diffusion equations," ESAIM Math. Model. Numer. Anal., 46(5):1247–1273, 2012.

[2] C. Carstensen, L. Demkowicz and J. Gopalakrishnan, "Breaking spaces and forms for the DPG method and applications including Maxwell equations," Comput. Math. Appl., in review, see also ICES Report 15-18.

[3] S. Nagaraj, S. Petrides and L. Demkowicz, "Construction of DPG Fortin operators for second order problems", ICES Report 2015-22, submitted.

[4] D. Broersen and R. A. Stevenson, "A robust Petrov-Galerkin discretisation of convection-diffusion equations," Comput. Math. Appl., 68(11):1605–1618, 2014

11. Falk, Richard

    - falk@math.rutgers.edu
    - Numerical Computation of Hausdorff Dimension
    - We show how finite element approximation theory can be combined with theoretical results about the properties of the eigenfunctions of a class of linear Perron-Frobenius operators to obtain accurate approximations of the Hausdorff dimension of some invariant sets arising from iterated function systems.

      The theory produces rigorous upper and lower bounds on the Hausdorff dimension. Applications to the computation of the Hausdorff dimension of some Cantor sets arising from real and complex continued fraction expansions are described.

12. Gockenbach, Mark

    - msgocken@mtu.edu
    - The generalized singular value expansion and the analysis of linear inverse problems
    - The generalized singular value expansion (GSVE) is a simultaneous decomposition of two operators on Hilbert space, analogous to the generalized singular value decomposition (GSVD) of two matrices. This talk will introduce the GSVE and illustrate its utility in analyzing linear inverse problems and regularization by seminorms.

13. Griesmaier, Roland

    - roland.griesmaier@uni-wuerzburg.de
    - Uncertainty principles for far field patterns with applications to inverse source problems
    - Classical uncertainty principles in signal processing limit the amount of simultaneous concentration of a signal with respect to time and frequency. In this talk we discuss adaptations of such principles related to direct and inverse source problems for the Helmholtz equation. In particular we establish stability estimates for the far field splitting problem and for the data completion problem, and we give sufficient conditions for these inverse problems to be well-conditioned.

14. Guo, Yukun

    - ykguo@hit.edu.cn
    - A direct method for inverse acoustic scattering in the time domain

- This talk is concerned with the inverse scattering problems of imaging unknown/inaccessible scatterers by transient acoustic near-field measurements. Based on the analysis of the migration method, we propose efficient and effective sampling schemes for imaging small and extended scatterers from knowledge of time-dependent scattered data due to incident impulsive point sources. Though the inverse scattering problems are known to be nonlinear and ill-posed, the proposed imaging algorithms are totally "direct" involving only integral calculations on the measurement surface. Theoretical justifications will be presented and numerical results will be shown to demonstrate the effectiveness and robustness of our methods. This is a joint work with Dietmar Hömberg, Guanghui Hu, Jingzhi Li and Hongyu Liu.

15. Huang, Ruihao

    - ruihaoh@mtu.edu
    - A recursive integral method for transmission eigenvalues
    - The transmission eigenvalue problem arose in the inverse scattering theory for inhomogeneous media and has important applications in a variety of inverse problems for target identification and nondestructive testing. The problem is numerically challenging because of the non-selfadjointness and complicated spectrum. In this talk, we introduce a mixed finite element method to discretize the problem. For the resulting matrix eigenvalue problem, we propose a novel recursive contour integral method. Using the spectrum projection, it decides if a given region contains an eigenvalue. Then it subdivides the region iteratively until the eigenvalue is nailed down in a small region smaller than the given precision. The method does not require any a priori information and is highly parallel. Numerical examples show that the method is effective and robust.

16. Huttunen, Tomi

    - tomi.huttunen@uef.fi
    - Applications of the ultra weak variational formulation
    - The ultra weak variational formulation (UWVF) was proposed as a method to include non-polynomial basis functions to the numerical approximation of wave problems. Subsequently, the UWVF has been used for a wide range of applications including the simulation ultrasound surgery (the Helmholtz equation for inhomogeneous media), radar cross-sections for "stealth targets" (the Maxwell equations) and the head-related transfer functions (HRTFs) for 3D audio (the Helmholtz equation for homogeneous media). Being a discontinuous Galerkin method, the UWVF method can be parallelized efficiently. The parallelization to a large number of processors, along with UWVF's need of coarse spatial discretization (the element size can be several wavelengths), allowed the first simulation of HRTF over the entire audible frequency range. These simulations paved the way to model based personalization of 3D headphone audio. This talk introduces several applications of the UWVF method, summarizes recent developments and outlines some potential new improvements.

17. Hyvönen, Nuutti

    - nuutti.hyvonen@aalto.fi
    - Recovering from an inaccurately known measurement set-up by polynomial collocation in EIT
    - The objective of electrical impedance tomography is to reconstruct the internal conductivity of a physical body based on measurements of current and potential at a finite number of electrodes attached to its boundary. Although the conductivity is the quantity of main interest in impedance tomography, a real-world measurement configuration includes other unknown parameters as well: the information on the contact resistances, electrode positions and body shape is almost always incomplete. In this work, the dependence of the electrode measurements on all aforementioned model properties is parametrized via polynomial collocation. The availability of such a parametrization enables efficient simultaneous reconstruction of the conductivity and other unknowns by a Newton-type output least squares algorithm, which is demonstrated by two-dimensional numerical experiments based on both simulated and experimental data.

18. Kapita, Shelvean

- kapita@udel.edu
- Plane Wave Discontinuous Galerkin Methods for Acoustic Scattering
- Plane Wave DG Methods can be used to approximate the solution of the Helmholtz equation on a bounded domain. To approximate a scattering problem, we introduce the Dirichlet-to-Neumann mapping on the artificial boundary. Error estimates with respect to mesh size and truncation order of the DtN mapping are shown.

19. Kirsch, Andreas

- andreas.kirsch@kit.edu
- Inverse Problems for Abstract Evolution Equations With Applications in Electrodynamics and Elasticity
- In this talk I will give some uniqueness results for the refractive index and the transmission coefficient of an inhomogeneous cavity based on some estimates for the corresponding interior transmission problems and some $L_P(1 < P < 2)$ estimates for the direct scattering problem. We will also introduce the factorization method for the inhomogeneous cavity.

20. Kleefeld, Andreas

- a.kleefeld@fz-juelich.de
- Numerical computations of interior transmission eigenvalues for scattering objects with cavities
- In this talk, numerical results are presented to show that we are able to successfully detect interior transmission eigenvalues with the inside-outside duality approach for a variety of obstacles with and without cavities in three dimensions. In this context, we also discuss the advantages and disadvantages of the inside-outside duality approach from a numerical point of view. Furthermore, we derive the integral equations necessary to extend the algorithm of Kleefeld to compute highly accurate interior transmission eigenvalues for scattering objects with cavities, which we will then use as reference values to examine the accuracy of the inside-outside duality algorithm.
  This is joint work with Stefan Peters.

21. Labovsky, Alexander

- aelabovs@mtu.edu
- Improving the accuracy of fluid-fluid interaction problems with the legacy codes
- We present a method for solving a fluid-fluid interaction problem (two convection-dominated convection-diffusion problems adjoined by an interface), which is a simplified version of the atmosphere-ocean coupling problem. The method resolves some of the issues that can be crucial to the fluid-fluid interaction problems: it is a partitioned time stepping method, yet it is of high order accuracy in both space and time (the two-step algorithm considered in this report provides second order accuracy); it allows for the usage of the legacy codes (which is a common requirement when resolving flows in complex geometries), yet it can be applied to the problems with very small viscosity/diffusion coefficients. This is achieved by combining the defect correction technique for increased spatial accuracy (and for resolving the issue of high convection-to-diffusion ratio) with the deferred correction in time (which allows for the usage of the computationally attractive partitioned scheme, yet the time accuracy is increased beyond the usual result of partitioned methods being only first order accurate) into the defect-deferred correction method (DDC). The results are readily extendable to the higher order accuracy cases by adding more correction steps. Both the theoretical results and the numerical tests provided demonstrate that the computed solution is unconditionally stable and the accuracy in both space and time is improved after the correction step. In the second part of the talk we apply this method to the Navier-Stokes equations in different regimes and comment on the usefulness of our approach as the Reynolds number increases.

22. Lehoucq, Richard
   - rblehou@sandia.gov
   - A Mixed Finite Element Method for Constraining and Regularizing the Optical Flow Constraint
   - My presentation introduces a mixed finite element method for estimation of the velocity in the optical flow constraint, i.e., an advection equation. The resulting inverse problem is well-known to be undetermined because the velocity vector cannot be recovered from the scalar field advected unless further restrictions on the flow, or motion are imposed. If we suppose, for example, that the velocity is solenoidal, a well-defined least squares problem with a minimizing velocity results. Equivalently, we have imposed the constraint that the underlying motion is isochoric. Unfortunately, the resulting least squares system is ill-posed and so regularization via a mixed formulation of the Poisson equation is proposed. Standard results for the Poisson equation demonstrate that the regularized least squares problem is well-posed and has a stable finite element approximation. A numerical example demonstrating the procedure supports the analyses. The example also introduces a closed form solution for the unregularized, constrained least squares problem so that the approximation can be quantified. This is joint work with Dan Turner.

23. Li, Hengguang
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   - An anisotropic mesh for vertex/edge singularities of 3D elliptic problems
   - We discuss a new construction of 3D anisotropic meshes to improve the effectiveness of the finite element approximation for elliptic boundary value problems with singular solutions from vertices and edges.

24. Li, Jichun
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   - Superconvergence analysis of edge elements and applications in metamaterial simulation
   - The superconvergence analysis of edge elements was started by Peter Monk in his 1994 NMPDE paper. In this talk, we will first give a brief overview of this area, then present our recent works obtained for the lowest-order rectangular, triangular and tetrahedral edge elements. We also show their applications to metamaterial Maxwell's equations.

25. Li, Peijun
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   - Inverse Random Source Scattering Problems
   - This talk concerns the source scattering problems for acoustic wave propagation, which is governed by the two- or three-dimensional stochastic Helmholtz equation. As a source, the electric current density is assumed to be a random function driven by an additive colored noise. Given the random source, the direct problem is to determine the radiated random wave field. The inverse problem is to reconstruct statistical properties of the source from the boundary measurement of the radiated random wave field. In this work, we consider both the direct and inverse problems. We show that the direct problem has a unique mild solution via a constructive proof. Using the mild solution, we derive effective Fredholm integral equations for the inverse problem. A regularized Kaczmarz method is developed by adopting multi-frequency scattering data to overcome the challenges of solving the ill-posed and large scale integral equations. Numerical experiments will be shown to demonstrate the efficiency of the proposed method. The framework and methodology developed here are expected to be applicable to a wide range of stochastic inverse source problems.

26. Li, Xiaoshang
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- Inverse Problems in Unbounded Domains with Impedance Boundary Condition
- The inverse boundary value problems consist of recovering the coefficients of partial differential equations in a domain from measurements of the solutions on its boundary. In this talk we study such problems for Schrödinger equations with impedance boundary conditions in some unbounded domains. We show the unique determination results when the measurements are made on only part of the boundaries.

27. Liu, Jijun

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- On Spectral Computations for Transmission Eigenvalue Problems
- The transmission eigenvalue problem, except for its critical role in inverse scattering problems, is of its own special interest due to the fact that the corresponding differential operator is neither elliptic nor self-adjoint. In this talk, we provide the spectral analysis and propose a novel iterative algorithm for the computation of a few positive real eigenvalues and the corresponding eigenfunctions of the transmission eigenvalue problem.

28. Liu, Xiaodong

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- A Fast and Robust Sampling Method for Shape Reconstruction in Inverse Acoustic Scattering Problems
- A sampling method by using far field measurements is proposed for shape reconstruction in inverse acoustic scattering problems. The key ingredient of this method is a novel indicator function. Only inner products are involved in the computation, which makes the method very easy and simple to implement. With the help of the factorization of the far field operator, we establish an inf-criterion for characterization of underlying scatters. This result is then used to give a lower bound of the proposed indicator function for sampling points inside the scatters. While for the sampling points outside the scatters, we show that the indicator function decays as the sampling point goes away from the boundary of the scatters. We also show that the proposed method is extremely stable with respect to errors in the data. Some numerical experiments are presented to demonstrate the feasibility and effectiveness of our method.

29. Luostari, Teemu

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- Remote sensing of forests in Bayesian framework
- Collecting 3D remote sensing data of forests and urban environments has been increasing over the years. The 3D data is generally collected using Airborne Laser Scanning (ALS) due to its efficiency and accuracy. The analysis of ALS data can be divided in two categories: area based methods and individual tree detection. In the former approach, plot-level statistics (such as biomass, mean tree heights and volume of the plot) are predicted directly from the ALS data using regression-type methods, while in the latter approach, the plot-level statistics are derived from the individual tree information inferred from the ALS data. Thus, the individual tree detection amounts to estimation of the heights, crown radii and positions of trees. In our approach, a set of canopy height models (CHM) are fitted to the ALS data for this aim. However, interpretation of ALS data is often challenging and correct positioning and height estimation of trees can be difficult. Therefore, we develop new computational methods for interpreting the ALS data more accurately in remote sensing of forests. We focus on the tree detection within the Bayesian inversion framework wherein we can utilize prior information on tree shapes in the estimation. In this study we investigate how 3D point cloud density affects our maximum a posteriori (MAP) estimate.

30. Marcinek, Pawel

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- Analysis and Simulations of Debonding of Bonded Rods Caused by Mechanical Stresses, Humidity and Thermal Effects
- There is a considerable industrial interest in developing light-materials, such as metals with low density (magnesium, aluminum) or polymer materials in new parts and components to make them stronger and more fuel economic. Light materials require a special bonding technology, especially for joining dissimilar materials. It is observed that the bonding strength decreases in time due to mechanical stresses, thermal and humidity effects. Therefore, there is a need for mathematical models to gain deeper understanding of the deterioration process of adhesives and to qualitatively predict it. In this lecture we present the model for the process of debonding of two rods that are glued together. We discuss the physical and mathematical details of the model, mention the proof of existence of weak solution and then present extensive numerical simulations of the model behavior and compare to experimental data.

31. Meng, Shixu
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    - Spectral analysis of the interior transmission eigenvalue for Maxwell's equations
    - We consider the transmission eigenvalue problem for Maxwell's equations corresponding to non-magnetic inhomogeneities with contrast in electric permittivity that has fixed sign (only) in a neighborhood of the boundary. Following the analysis made by Robbiano in the scalar case we study this problem in the framework of semiclassical analysis and relate the transmission eigenvalues to the spectrum of a Hilbert-Schmidt operator. Under the additional assumption that the contrast is constant in a neighborhood of the boundary, we prove that the set of transmission eigenvalues is discrete, infinite and without finite accumulation points. A notion of generalized eigenfunctions is introduced and a denseness result is obtained in an appropriate solution space.
32. Mu, Lin
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    - Weak Galerkin Finite Element Methods and Applications
    - Weak Galerkin FEMs are new numerical methods that were first introduced by Wang and Ye for solving general second order elliptic PDEs. The differential operators are replaced by their weak discrete derivatives, which endows high flexibility. This new method is a discontinuous finite element algorithm, which is parameter free, symmetric, symmetric, and absolutely stable. Furthermore, through the Schur-complement technique, an effective implementation of the WG is developed. Several numerical applications will be discussed.
33. Muniz, Wagner
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    - A high order collocation scheme for EM scattering from buried objects
    - In this talk we will discuss the problem of electromagnetic scattering from penetrable obstacles buried in an N-layered background. Under a standardly modified Lippmann-Schwinger equation, the problem is approximated by a high order discontinuous Galerkin collocation scheme where, under Duffy?s transformation, we give an analytical treatment for the singularity in triangular elements. The layered background Green?s function is computed by special quadratures for the hard to evaluate Sommerfeld integrals.
34. Nigam, Nilima
    - nigam@math.sfu.ca
    - A Bayesian approach to eigenvalue optimization (Authors: Sebastian Dominguez, Nilima Nigam and Bobak Shahriari.)

- A celebrated conjecture by Polyá and Szegö asserts that amongst all n-sided polygons of a given area, the regular n-gon is the global optimizer of the first Dirichlet eigenvalue of the Laplacian. This conjecture has been shown to hold for triangles and quadrilaterals, but is open for pentagons. In this talk, we present a novel framework for shape optimization for eigenvalues. The method combines finite element computations in a validated numerics setting, with a Bayesian optimization approach. We illustrate this approach for the specific case of the Polyá-Szegö conjecture on triangles and quadrilaterals, for which the result is known, and for pentagons, where the conjecture is open.

35. Ong, Benjamin
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    - An Incremental SVD Algorithm for Distributed Data
    - We present an incremental, hierarchical approach for computing the SVD of a distributed matrix. The proposed algorithm is proven to recover the singular values and vectors of the input matrix A if it's rank is known. Further, the hierarchical algorithm can be used to recover the d largest singular values and left singular vectors with bounded error. It is also shown that the proposed method is stable with respect to roundoff errors or corruption of the original matrix entries. (Benjamin Ong and Mark Iwen (MSU))
36. Qu, Fenglong
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    - Uniqueness results and the factorization method in the inverse scattering problem for an inhomogeneous cavity
    - In this talk I will give some uniqueness results for the refractive index and the transmission coefficient of an inhomogeneous cavity based on some estimates for the corresponding interior transmission problems and some $L_P(1 < P < 2)$ estimates for the direct scattering problem. We will also introduce the factorization method for the inhomogeneous cavity.
37. Ren, Kui
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    - Mathematical Modeling of Semiconductor-Electrolyte Solar Cells
    - This talk is about the mathematical modeling of charge transport processes inside semiconductor-electrolyte solar cells. We propose a macroscopic mathematical model for the complete description of the transport dynamics in the cells, and compare it to various simplified models in the literature. We then develop some efficient computational algorithms for the numerical solutions of the model. If time permits, we will also discuss some parameter identification problems related to the mathematical model. Simulation results under various model parameters will be presented.
38. Rossi, Louis
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    - Achieving high order accuracy with smoothed particle hydrodynamic methods
    - Smooth particle hydrodynamic methods approximate fluid flow mass and velocity as a moving collection of interacting particles. Originally developed for astrophysical simulations, these methods have proven to be robust, naturally adaptive mesh-free methods for challenging fluid flow problems. Unfortunately, many implementations are limited to low orders of accuracy, and a systematic means of analyzing and addressing these issues remains elusive. This paper will provide an overview of the state of the art in boosting the accuracy of these methods and provide simple examples of improved rates of convergence.
39. Sayas, Francisco
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- Hybridizable Discontinuous Galerkin Methods for Elastodynamics
- In this talk I will present some preliminary results on the use of an Hybridizable Discontinuous Galerkin method for the simulation of elastic waves. I will show how the Lehrenfeld-Schoberl or Qiu-Shi choice of spaces and stabilization parameters for an HDG scheme applied to quasi-static elasticity also apply for time-harmonic elastic waves, providing a superconvergent method. I will next discuss a conservation of energy property that holds in the transient case when the elasticity equations are semidiscretized in space with the same HDG strategy.

  This work is a collaboration with Allan Hungria (University of Delaware) and Daniele Prada (Indiana University Purdue University at Indianapolis)

40. Selgas, Virginia

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- A time domain Linear Sampling Method for a waveguide
- We consider the problem of locating and imaging an obstacle in an infinite tubular waveguide from time domain measurements of the scattered field for point sources and receivers placed on a pair of surfaces located inside the waveguide. To deal with this problem, previous researchers have considered the usage of the frequency domain Linear Sampling Method (LSM) for detecting sound-hard obstacles in infinite sound-hard tubular pipes (cf. [2]). The assumption of a sound-hard pipe is in accordance with the application we have in mind, which is that of acoustic techniques to inspect underground pipes such as sewers. However, unlike [2, 5], we deal with this inverse problem using the scattering data measured in the time domain, without transforming the data to the frequency domain. More precisely, we first show new time domain estimates for the forward problem, as well as analyze the operators arising in the inversion scheme (in particular, retarded single layer potentials defined on surfaces of scatterers located inside the waveguide). This allows us to justify that the TD-LSM presented in [3] behaves as in the frequency domain version for the problem at hand. We also implement the inversion algorithm and apply it to investigate some academic experiments, most of which are the time domain counterparts of the frequency domain examples in [2]. In particular, in all the experiments we use synthetic data computed with a time domain boundary integral equation for a sound-soft bounded obstacle in a two dimensional waveguide (cf. [4]). We finally show how the reconstructions built with our inversion technique improve by choosing the regularizing pulse function not to be a standard one (as in [6]) but an ad hoc pulse designed to avoid the cut-off frequencies (as proposed in [1]).

  References

  [1] V. Baroniana, L. Bourgeois, A. Recoquillay, Imaging an acoustic waveguide from surface data in the time domain, submitted.

  [2] L. Bourgeois, E. Lunéville, The linear sampling method in a waveguide: a modal formulation, Inverse Problems 24 (2008), 15-18.

  [3] Q. Chen, H. Haddar, A. Lechleiter, P. Monk, A sampling method for inverse scattering in the time domain, Inverse Problems 26 (2010), 085001.

  [4] M. Hassell, F.J. Sayas, Convolution quadrature for wave simulations, Lecture notes SEMA/SIMAI 2014.

  [5] P. Monk, V. Selgas, Sampling type methods for an inverse waveguide problem, Inverse Problems and Imaging 6 (2012), no.4, 709-747.

  [6] P. Monk, V. Selgas, An inverse acoustic waveguide problem in the time domain, Inverse Problems, in press.

41. Wang, Junping

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- Primal-Dual Weak Galerkin Finite Element Methods

- In this talk, the speaker will introduce a primal-dual finite element technique for problems where the trial and test spaces are different. The primal-dual method enhances the primal (original) equation by its dual with homogeneous data. The two equations are linked together by using appropriately defined stabilizers commonly used in weak Galerkin finite element methods. The primal-dual technique will be discussed for three model problems: (1) second order elliptic equation in nondivergence form, (2) stationary linear convection equations, and (3) elliptic Cauchy problem which is generally ill-posed. The work on primal-dual weak Galerkin was jointly conducted with Dr. Chunmei Wang of Texas State University.

  Weak Galerkin (WG) is a finite element method for PDEs where the differential operators (e.g., gradient, divergence, curl, Laplacian etc.) in the weak forms are approximated by discrete generalized distributions. The WG discretization procedure often involves the solution of inexpensive problems defined locally on each element. The solution from the local problems can be regarded as a reconstruction of the corresponding differential operators. The fundamental difference between the weak Galerkin finite element method and other existing methods is the use of weak functions and weak derivatives (i.e., locally reconstructed differential operators) in the design of numerical schemes based on existing weak forms for the underlying PDEs. Weak Galerkin is a natural extension of the classical Galerkin finite element method with advantages in many aspects. Due to its great structural flexibility, the weak Galerkin finite element method is well suited to most partial differential equations by providing the needed stability and accuracy in approximation.

  The talk will start with the second order elliptic equation, for which WG shall be applied and explained in detail. In particular, the concept of weak gradient will be introduced and discussed for its role in the design of weak Galerkin finite element schemes. The speaker will then introduce a general notion of weak differential operators, such as weak Hessian, weak divergence, and weak curl etc. These weak differential operators shall serve as building blocks for WG finite element methods for other class of partial differential equations, such as the Stokes equation, the biharmonic equation, the Maxwell equations in electron magnetics theory, div-curl systems, and PDEs in non-divergence form. The speaker will then discuss the primal-dual technique for the three model problems. The talk should be accessible to graduate students with adequate training in computational methods.

42. Yang, Jiaqing

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    - An approximate factorization method for inverse medium scattering with unknown buried objects
    - This talk is concerned with the inverse problem of scattering of time-harmonic acoustic waves by an inhomogeneous medium with different kinds of unknown buried objects inside. By constructing a sequence of operators which are small perturbation of the far-field operator in a suitable way, we prove that each operator in this sequence has a factorization satisfying the Range Identity. We then develop an approximate factorization method for recovering the support of the inhomogeneous medium from the far-field data. Finally, numerical examples are provided to illustrate the practicability of the inversion algorithm.

43. Yang, Yang

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    - Discontinuous Galerkin methods for Chemotaxis models
    - In this talk, we will focus on local discontinuous Galerkin methods for Chemotaxis model, which might yield blow-up solutions. We first give the error estimates based on two different finite element spaces, and then proceed to the positivity-preserving technique to obtain positive numerical approximations. Finally, we will numerically demonstrate how to find the blow-up time.

44. Zhang, Haiwen

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- A novel integral equation for scattering by locally rough surfaces and application to the inverse problem: the Neumann case
- This talk is concerned with the direct and inverse acoustic or electromagnetic scattering problems by a locally perturbed, perfectly reflecting, infinite plane (which is called a locally rough surface) with Neumann boundary condition. We propose a novel integral equation formulation for the direct scattering problem which is defined on a bounded curve (consisting of a bounded part of the infinite plane containing the local perturbation and the lower part of a circle) with two corners. This novel integral equation can be solved efficiently by using the RCIP method introduced previously by Johan Helsing and is capable of dealing with large wave number cases. For the inverse problem, we propose a Newton iteration method to reconstruct the local perturbation of the plane from multiple frequency far-field data, based on the novel integral equation formulation. Numerical examples are carried out to demonstrate that our reconstruction method is stable and accurate even for the case of multiple-scale profiles.

45. Zhang, Ruming

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    - The reconstruction of obstacles in a periodic waveguide
    - In this talk, we will introduce a numerical method to reconstruct a penetrable obstacle embedded in a periodic waveguide. The numerical solution of the direct scattering problem is solved by a doubling recursive method. The inverse problem is reformulated as an optimization problem with a regularization term. Then, we develop a quasi-Newton method to solve this optimization problem with the help of a finite element method. In the numerical procedure, the stiffness matrix, mass matrix and right hand side are assembled at the beginning only once. At each iteration, only minor changes are made to the mass matrix and right hand side. This finite element method can greatly improve the efficiency of the numerical program. The effectiveness of the program is shown by numerical examples.

46. Zheng, Chunxiong

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    - Optimal error estimates for Gaussian beam approximations to the Schrodinger equation
    - Gaussian beams are local asymptotic solutions to the linear wave equations in the high-frequency regime. Each Gaussian beam is concentrated around a specific ray path determined by the underlying Hamiltonian system. Expressed as some superposition of Gaussian beams, Gaussian beam approximation is expected to be a high-frequency asymptotic solution which remains globally valid even around caustics. We derive optimal first order error estimates for first-order Gaussian beam approximations to the Schrodinger equation equipped with a WKB initial data. Our error estimates are valid for any spatial dimension and unaffected by the presence of caustics.

47. Zheng, Weiying

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    - Perfectly matched layer method for electromagnetic scattering problems in layered media
    - In this talk, we study the perfectly matched layer (PML) method for electromagnetic scattering problems in a two-layer medium. Since the background materials in the upper and lower half spaces are different, the dyadic Green's function becomes very complicated. The exponential convergence of the PML method depends on elaborative analysis for the Green's function. We established the stability and the exponential convergence of the approximate solution.

48. Zou, Jun

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    - Adaptive finite element methods for some linear and nonlinear inverse problems

- In this talk we shall review some recently developed adaptive finite element methods for solving several linear and nonlinear inverse problems, including flux reconstructions, Robin inverse problems and electrical impedance tomography. We will present many interesting numerical experiments and demonstrate the convergence of these adaptive finite elements. This is a joint work with Bangti Jin (UCL) and Yifeng Xu (Shanghai Normal University), and it was substantially supported by Hong Kong RGC grants (projects 14306814 and 405513).