Michigan Center for Industrial and Applied Mathematics (MCIAM)

Computational Wave Propagation Workshop Schedule

Friday, April 15

0820-0900: Continental Breakfast

Session Chair: Gang Bao
0900-0950: William Symes

0950-1010: break 1

Session Chair: Jianliang Qian
1010-1100: Hongkai Zhao
1100-1150: Maarten de Hoop

1200-1400: lunch (Riverside)

Session Chair: John Schotland
1400-1450: Liliana Borcea
1450-1540: Guillaume Bal

1540-1600: break 2

Session Chair: David Dobson
1600-1650: Plamen Stefanov
1650-1715: Songting Luo
1715-1740: Russel Richins

1800-1900: Cash bar (Big Ten C)
1900-2100: Dinner (Big Ten C)

Saturday, April 16

0820-0900: Continental Breakfast

Session Chair: William Symes
0900-0950: David Colton

0950-1010: break 3

Session Chair: Liliana Borcea
1010-1100: David Dobson
1100-1150: John Schotland

1200-1400: lunch (Corniche)

Session Chair: Jianliang Qian
1400-1450: Shingyu Leung
1450-1540: Peijun Li

All sessions in Michigamme Room at the Kellogg Center.

Sponsors

The major funding is provided by the **National Science Foundation**.

Some partial support is provided by the department of Mathematics and **MCIAM**.

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Workshop Description

The Michigan Center for Industrial and Applied Mathematics (MCIAM) at the Michigan State University is pleased to announce a two-day workshop on April 19-20, 2010, on "Inverse Problems: Theory, computation, and applications."

One of the main objectives of the MCIAM center is to expose local, national and international industry to skills and tools that modern applied mathematics can bring to bear on multiscale problems. Problems of interests are non-linear and span many temporal and spatial scales, making these problems challenging from both analytical and numerical perspectives. While modeling has been used as a tool to bridge a wide range of scales, it is the combination of modeling with simulation and analysis that has led to a range of successful tools for exploring these problems; yet there are many problems that remain well beyond the existing capabilities.

This fourth MCIAM workshop is a followup workshop to the 2010 IMA PI graduate summer school. It will focus on Compuational Wave Propagations and Applications in Inverse Problems. A main goal of the workshop is to bring together researchers in various fields that involve analysis and computation of inverse problems. The workshop aims to offer a comfortable and spirited gathering at a small scale to promote exchange of ideas between colleagues in computation, analysis, and modeling of wave propagation and inverse problems along with applications, and to explore future research directions.

Organizing Committee:

Gang Bao,	Department of Mathematics, MSU
Leo Kempel,	College of Engineering, MSU
Jianliang Qian,	Department of Mathematics, MSU (Workshop Chair)

Invited Speakers:

Guillaume Bal,	Applied Physics and Applied Mathematics, Columbia University
Liliana Borcea,	Computational and Applied Mathematics, Rice University
Jin Cheng,	School of Mathematics, Fudan University
David Colton,	Department of Mathematical Sciences, University of Delaware
David Dobson,	Department of Mathematics, University of Utah
Maarten de Hoop,	Department of Mathematics, Purdue University
Gregory A. Kriegsmann,	Department of Mathematical Sciences, New Jersey Inst. Tech.
Shingyu Leung,	Dept. Mathematics, Hong Kong University of Science and Technology
Peijun Li,	Department of Mathematics, Purdue University
Fadil Santosa,	IMA and School of Mathematics, University of Minnesota
John Schotland,	Department of Mathematics, University of Michigan
Hart Smith,	Department of Mathematics, University of Washington
Plamen Stefanov,	Department of Mathematics, Purdue University
William W. Symes,	Computational and Applied Mathematics, Rice University
Gunther Uhlmann,	Department of Mathematics, UC Irvine and University of Washington
Hongkai Zhao,	Department of Mathematics, UC Irvine
Jianxin Zhu,	Department of Mathematics, Zhejiang University
Songting Luo,	Department of Mathematics, Michigan State University
Russel Richins,	Department of Mathematics, Michigan State University

Imaging in Random Media

Guillaume Bal

Dept. of Applied Physics and Applied Mathematics, Columbia University

Abstract not available yet.

Wave propagation in time dependent, randomly layered media

Liliana Borcea, Noah Harding Professor

Computational and Applied Mathematics, Rice University

I will describe the cumulative scattering effects on wave front propagation in time dependent randomly layered media. It is well known that the wave front has a deterministic characterization in time independent media, aside from a small random shift in the travel time. That is, the pulse shape is stable, but faded and smeared as described mathematically by a convolution kernel determined by the second order statistics of the random fluctuations of the wave speed. I will describe the extension of the pulse stabilization results to time dependent randomly layered media.

Transmission Eigenvalues in Inverse Scattering Theory

David Colton, Unidel Professor

Department of Mathematical Sciences, University of Delaware

The transmission eigenvalue problem is a new class of eigenvalue problems that has recently appeared in inverse scattering theory for inhomogeneous media. Such eigenvalues provide information about material properties of the scattering object and can be determined from scattering data, hence can play an important role in a variety of problems in target identification. The transmission eigenvalue problem is non-selfadjoint which make its mathematical investigation challenging and interesting.

In this lecture we will describe how the transmission eigenvalue problem arises in scattering theory, how transmission eigenvalues can be computed from scattering data, what is known mathematically about these eigenvalues and what kind of information can they provide on the index of refraction of the inhomogeneous medium. For the sake of simplicity, most of our mathematical exposition will be done for the case of scattering for isotropic media and at the end of the lecture we will discuss how these results can be used in non-destructive testing of anisotropic materials such as airplane canopies. We end our lecture with a list of open problems important to inverse scattering theory and new future research directions.

Computation of solutions to the wave equation with coefficients of limited smoothness: A multi-scale approach

Maarten de Hoop

Department of Mathematics, Purdue University

Abstract not available yet.

Numerical modeling and analysis of structures admitting surface plasmons

David Dobson

Department of Mathematics, University of Utah

Surface plasmons are electromagnetic fields, highly localized near metal-dielectric interfaces, and associated with surface electron density oscillations. These typically appear at optical frequencies, with wavelengths much smaller than the diffraction limit in the surrounding dielectric. Interest is growing for developing applications in photonics, sensors, and biotechnology. Numerical modeling and analysis of structures admitting surface plasmons is challenging, due to the poor regularity of solutions and the high sensitivity of the fields to perturbations in problem parameters. These difficulties are magnified in the context of optimal design, where the goal is to determine the geometry of a plasmonic structure through the solution of an optimization problem. This talk will provide a brief overview of the topic, and present some specific solution strategies aimed at developing a general approach to optimal design.

The backward phase flow and FBI-transform-based Eulerian Gaussian beams

Shingyu Leung

Department of Mathematics, Hong Kong University of Science and Technology

In this talk, we present the backward phase flow method to implement the FourierBrosIagolnitzer (FBI)-transform-based Eulerian Gaussian beam method for solving the Schrdinger equation in the semi-classical regime. We aim at two crucial computational issues of the Eulerian Gaussian beam method: how to carry out long-time beam propagation and how to compute beam ingredients rapidly in phase space. By virtue of the FBI transform, we address the first issue by introducing the reinitialization strategy into the Eulerian Gaussian beam framework. Essentially we reinitialize beam propagation by applying the FBI transform to wavefields at intermediate time steps when the beams become too wide. To address the second issue, inspired by the original phase flow method, we propose the backward phase flow method which allows us to compute beam ingredients rapidly.

Mathematical Analysis of the Scattering Problems by Unbounded Rough Surfaces

Peijun Li

Department of Mathematics, Purdue University

This talk is concerned with the mathematical analysis of the solution for the wave propagation from the scattering by an infinite or unbounded rough surfaces. An unbounded rough surface is referred to as a surface which is a non-local perturbation of an infinite plane surface such that the whole surface lies within a finite distance of the original plane. The unbounded rough surface scattering problems arise from various applications such as modeling acoustic or electromagnetic wave propagation over ground or sea surfaces, optical scattering from the surface of materials in diffractive, near-field, or nano-optics, detection of underground or underwater mines or oil.

The talk consists of two part. The first part is to consider a time-harmonic electromagnetic field generated by either a magnetic dipole of an electric dipole incident on an infinite rough surface. The scattering problem is modeled as a boundary value problem governed by the Maxwell equations with transparent boundary conditions proposed on plane surfaces with the inhomogeneity in between. The existence and uniqueness of the weak solution will be addressed using a variational approach. The perfectly matched layer (PML) method is investigated to truncate the unbounded domain in the direction away from the rough surfaces. The truncated PML problem will be shown to attain a unique solution, which converges exponentially to the original scattering problem. The second part is focused on the case when the scattering surface is a sufficiently small and smooth deformation of a plane surface. Under this assumption, the problem will be equivalently formulated into a set of two-point boundary value problems in the frequency domain. The analytical solution will be deduced by using a boundary perturbation method combined with the transformed field expansion approach.

Factored singularities for traveltime and amplitude

Songting Luo

Department of Mathematics, Michigan State University

In the geometrical-optics approximation for the Helmholtz equation with a point source, traveltimes and amplitudes have upwind singularities at the source point. We use a factorization approach to resolve the source singularity, then apply a third-order WENO based Lax-Friedrichs scheme to compute the traveltime and amplitude with high accuracy. We construct the asymptotic wave fields using computed traveltimes and amplitudes in the WKBJ form. 2-D and 3-D examples demonstrate that the constructed WKBJ Green functions are in good agreement with direct solutions of the Helmholtz equation before caustics appear. (joint work with J. Qian and H. Zhao)

A Numerical Minimization Scheme for the Complex Helmholtz Equation

Russel Richins

Department of Mathematics, Michigan State University

We use the work of Milton, Seppecher, and Bouchitt e on variational principles for waves in lossy media to formulate a finite element method for solving the complex Helmholtz equation that is based entirely on minimization. In particular, this method results in a finite element matrix that is symmetric positive-definite and therefore simple iterative descent methods and preconditioning can be used to solve the resulting system of equations. We also derive an error bound for the method and illustrate the method with numerical experiments.

Recovery of a source term or a speed with one measurement and applications

Plamen Stefanov

Department of Mathematics, Purdue University

We study the problem of recovery of a source term or a sound speed with one measurement. The method is based on Carleman estimates and microlocal analysis. We will discuss application to thermoacoustic tomography: recovery of the speed if the source is known. This is a joint work with Gunther Uhlmann.

Wave Upscaling without Scales

William W. Symes, Noah Harding Professor

Computational and Applied Mathematics, Rice University

Galerkin approximate solutions of two elliptic systems with the same right-hand side have errors that mutually dominate each other, provided that the approximating subspaces contain exact solutions to problems with the same right-hand sides for their respective systems. This "transfer of approximation" property was first formulated by Berlyand and Owhadi in a more specialized setting. It provides a very general framework for numerical homogenization, that is, construction of optimal-order finite element approximations for linear elliptic boundary value problems with bounded and measurable coefficients, relying neither for formulation nor proof of convergence on assumed scale separation or ergodic properties of coefficients. The construction extends to hyperbolic problems provided that the data is smooth in time. In its original form, the transfer construction of optimal order approximation has severe practical drawbacks: it produces bases with global support, hence dense stiffness matrices, and at the cost of many solutions of problems as difficult in principle as the original. In this talk, I suggest a domain decomposition method for approximation of causal solutions to hyperbolic problems using their finite-speed-of-propagation property, which localizes the basis construction, dramatically reducing the computational complexity of numerical homogenization based on transfer of approximation.

Inverse Problems in Quantum Imaging

John C Schotland

University of Michigan

I will review recent work on inverse scattering problems that arise in imaging with entangled photons. Experiments involving entanglement via post-detection selection or due to illumination with down converted photons will be analyzed.

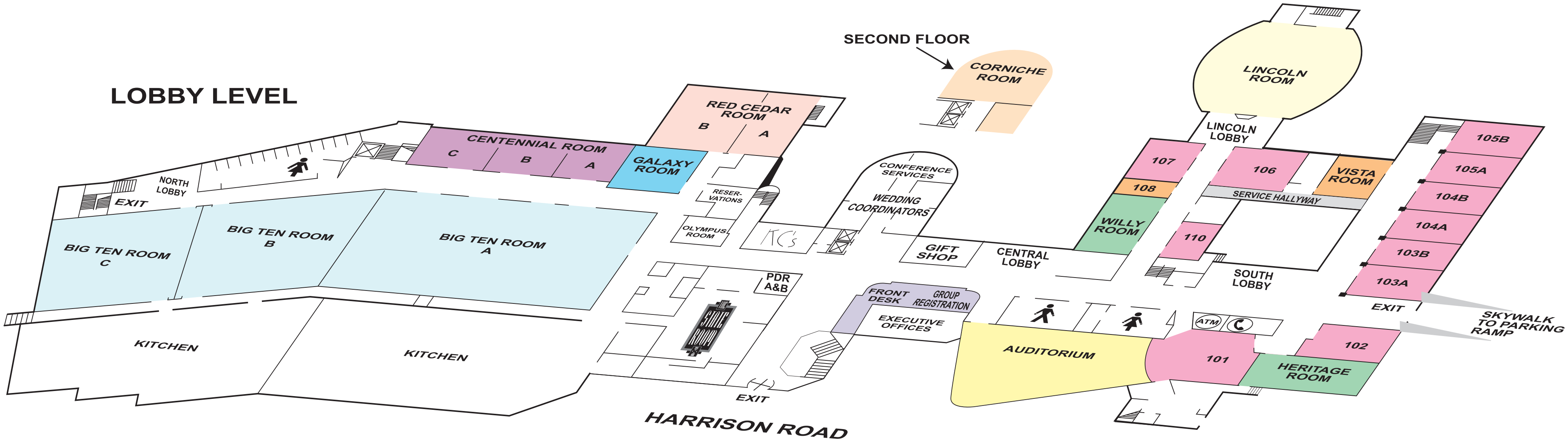
A new approximation for effective Hamiltonians for homogenization of a class of Hamilton-Jacobi equations

Hongkai Zhao

University of California at Irvine

We propose a new formulation to compute effective Hamiltonians for homogenization of a class of Hamilton-Jacobi equations. Our formulation utilizes a special property for viscosity supersolutions of Hamilton-Jacobi equations. The key idea is how to link the effective Hamiltonian to a suitable effective equation. The main advantage of our formulation is that only one auxiliary equation needs to be solved in order to compute the effective Hamiltonian $\bar{H}(p)$ for all p. Error estimates and stability are proved and numerical examples are presented to show very encouraging results.

LOBBY LEVEL



GARDEN LEVEL