WORKSHOP ON INVERSE PROBLEMS IN SCATTERING AND IMAGING

Saturday, April 13, 2013

Purdue University, West Lafayette, Indiana

Organizers: Jie Shen (Chair), Peijun Li

Check-In and Refreshments   Lawson Building (LWSN) Lobby   8:30 am to 9:00 am

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Morning Session   *Chair: Jie Shen*

Invited Talk 1   LWSN 1142   9:00 am to 9:45 am

An Efficient Algorithm for Generalized Foldy-Lax Formulation with Application to Direct Imaging Method

Hongkai Zhao, University of California, Irvine

Coffee Break   9:45 am to 10:00 am

Invited Talk 2   LWSN 1142   10:00 am to 10:45 am

Fixed-Point Based Proximity Algorithms for Convex Optimization Problems in Signal and Image Processing

Yuesheng Xu, Syracuse University

Coffee Break   10:45 am to 11:00 am

Invited Talk 3   LWSN 1142   11:00 am to 11:45 am

Inverse Transport and Acousto-Optic Imaging

John Schotland, University of Michigan

Lunch Break   11:45 am to 2:00 pm

Afternoon Session   Chair: Plamen Stefanov

Invited Talk 4 LWSN 1142 2:00 pm to 2:45 pm

Stability and Approximation Results for Biomechanical Imaging

Joyce McLaughlin, Rensselaer Polytechnic Institute

Coffee Break 2:45 pm to 3:00 pm

Invited Talk 5 LWSN 1142 3:00 pm to 3:45 pm

Signal and Image Restoration: Solving Ill-Posed Inverse Problems

Rosemary Renaut, Arizona State University

Coffee Break 3:45 pm to 4:00 pm

Contributed Talk 1 LWSN 1142 4:00 pm to 4:20 pm

Reconstruction of Sound Hard Obstacles Using an Eigenvalue Method

Jiguang Sun, Michigan Technological University

Contributed Talk 2 LWSN 1142 4:20 pm to 4:40 pm

Uncertainty Quantification for Lagrangian Data Assimilation

Damon McDougall, University of Texas at Austin

Contributed Talk 3 LWSN 1142 4:40 am to 5:00 pm

Numerical Methods for the Optimal Design of Optical Coatings

Yuliang Wang, Michigan State University

Chair: Peijun Li

INVITED TALKS

An Efficient Algorithm for Generalized Foldy-Lax Formulation with Application to Direct Imaging Method

Hongkai Zhao
Department of Mathematics, University of California, Irvine

We consider the scattering of a time-harmonic plane wave incident on a two scale heterogeneous medium, which consists of scatterers that are much smaller than the wavelength and extended scatterers that are comparable to the wavelength. We use a generalized Foldy-Lax formulation to capture multiple scattering among point scatterers and extended scatterers. Our formulation is given as a coupled system, which combines the original FoldyLax formulation for the point scatterers and the regular boundary integral equation for the extended obstacle scatterers. The existence and uniqueness of the solution for the formulation is established in terms of physical parameters such as the scattering coefficient and the separation distances. Computationally, an efficient physically motivated Gauss-Seidel iterative method is proposed to solve the coupled system. The convergence of the iterative method is also characterized in terms of physical parameters. Numerical tests for the far-field patterns of scattered fields arising from uniformly or randomly distributed point scatterers and single or multiple extended obstacle scatterers are presented. We also apply this formulation to a direct imaging method for extended targets in clutters.

Fixed-Point Based Proximity Algorithms for Convex Optimization Problems in Signal and Image Processing

Yuesheng Xu
Department of Mathematics, Syracuse University

We consider in this talk a class of convex optimization problems in the context of signal and image processing. The computational challenges of these problems are the nonlinearity and non-differentiability of the object function. We characterize the solutions of these problems in terms of fixed-point equations via the proximity operators of the functions that appear in the object function. Efficient algorithms are developed based on the characterization. We introduce the notion of the weakly firmly non-expansive operators to analyze the convergence of the proposed algorithms. Many well-known algorithms are reinterpreted as special cases of the proposed algorithms and new algorithms are shown numerically more efficient than the existing ones.

Inverse Transport and Acousto-Optic Imaging

John C Schotland
Department of Mathematics, University of Michigan, Ann Arbor

A method to reconstruct the optical properties of a highly-scattering medium from acousto-optic measurements is proposed. The method is based on the solution to an inverse problem for the radiative transport equation with internal data.

Stability and Approximation results for Biomechanical Imaging

Joyce McLaughlin
Department of Mathematical Sciences, Rensselaer Polytechnic Institute

Biomechanical Imaging is a promising new medical imaging modality based on coupled physics where the application of two physical concepts to create the data set enables a very rich data set. A significant feature of the data set is that it yields interior data; that is we obtain a movie of the propagation of an elastic wave within the tissue. In this talk we present images to show the promise of this new imaging capability and furthermore present theorems: (1) establishing the error between the true biomechanical property and an approximation often used by experimentalists; and (2) a stability result establishing linear stability for the inverse problem with interior data.

Signal and Image Restoration: Solving Ill-Posed Inverse Problems

Rosemary A. Renaut
School of Mathematical and Statistical Sciences, Arizona State University

The aim of this presentation is to provide an overview of approaches for solving the ill-posed inverse problems associated with signal and image restoration. Spectral decomposition and a Generalized Picard condition analysis highlight the importance of the basis for the solution, which is impacted by regularization choices. Additionally, when introducing regularization the complication of finding appropriate weighting parameters arises. Statistical techniques for finding both the regularization parameters and for filtering the basis are introduced. Total variation regularizers for effective feature extraction are analyzed using the same techniques and verify the significance of appropriately finding the basis and the regularization parameters.

CONTRIBUTED TALKS

Reconstruction of Sound Hard Obstacles Using an Eigenvalue Method

Jiguang Sun
Department of Mathematical Sciences, Michigan Technological University

Recently, a novel eigenvalue method using multiple frequency scattering data was proposed to reconstruct sound soft obstacles and inhomogeneous media. In this talk, we apply the method to reconstruct the support of a sound hard obstacle. Some theoretical justification is provided. In addition, we show that Neumann eigenvalues can be estimated from scattering data. Finally, some numerical examples are presented.

Uncertainty Quantification for Lagrangian Data Assimilation

Damon McDougall
Institute for Computational Engineering and Sciences, University of Texas at Austin

It is of great interest within the scientific community to understand uncertainty. Moreover, understanding uncertainty regarding prediction in weather, climate and ocean models is of utmost importance for the general public. In this talk we will set up the Lagrangian data assimilation problem in a Bayesian framework for a testbed model of ocean gliders in a kinematic travelling wave. We will then solve this Bayesian inverse problem for the entirety of the underlying flow to obtain a probability distribution. Finally, we show the effect on the variance this distribution as we force ocean gliders to cross oceanic transport boundaries and into different flow regimes.

Numerical Methods for the Optimal Design of Optical Coatings

Yuliang Wang
Department of Mathematics, Michigan State University

Optical coatings built from thin-film structures have a wide range of applications in industry and daily life. They have been undergoing active study for more than half a century and various design methods have been invented. New methods are still desirable since they may provide solutions with superior environmental and optical properties than existing ones. We discuss our study on a general issue in design problems and present our approaches which may lead to novel solutions never seen before.
