International Conference on Inverse Problems

April 25 - 29, 2010

Wuhan University, Wuhan

Objective

Inverse Problems has become a very active, interdisciplinary and well-established research area over the past two decades. It has found wide applications in engineering, industry, medicine, as well as life and earth sciences. The aim of this conference is to bring together computational and applied mathematicians from around the world to present and discuss recent developments in inverse problems and their applications. This conference will encourage international collaboration and interactive activities on inverse problems and provide an opportunity for young researchers to learn the current state-of-the-art in the field and present their recent research results.

Organizing Committee

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List of Invited Speakers

H. T. Banks,	North Carolina State University, USA
Gang Bao,	Michigan State University, USA
Tony F. Chan,	National Science Foundation, USA
Jin Cheng,	Fudan University, China
Heinz W. Engl,	RICAM, Austrian Academy of Sciences, Austria
Victor Isakov,	Wichita State University, USA
Kazufumi Ito,	North Carolina State University, USA
Sergey I. Kabanikhin,	Sobolev Institute of Mathematics, Russia
Hyeonbae Kang,	Inha University, Korea
Rainer Kress,	University of Goettingen, Germany
Philipp Kuegler,	RICAM, Austrian Academy of Sciences, Austria
Karl Kunisch,	University of Graz, Austria
Tatsien Li,	Fudan University, China
Jijun Liu,	Southeast University, China
Peter Monk,	University of Delaware, USA
Roland Potthast,	University of Reading, UK
William Rundell,	Texas A&M University, USA
Gunther Uhlmann,	University of Washington, USA
Gengsheng Wang,	Wuhan University, China
Jenn-Nan Wang,	National Taiwan University, Taiwan
Yuesheng Xu,	Syracuse University, USA and Sun Yat-sen University, China
Masahiro Yamamoto,	University of Tokyo, Japan
Bo Zhang,	Chinese Academy of Sciences, China
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06:05 - 07:30pm	Dinner

2 Invited talks

Generalized Sensitivities and Optimal Experimental Design

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Abstract

We consider the problem of estimating a modeling parameter θ using a weighted least squares criterion $J_d(y, \theta) = \sum_{i=1}^{n} \frac{1}{\sigma(t_i)^2}(y_i - f(t_i, \theta))^2$ for given data $\{y_i\}$ by introducing an abstract framework involving generalized measurement procedures characterized by probability measures. We take an *optimal design* perspective, the general premise (illustrated via examples) being that in any data collected, the information content with respect to estimating θ may vary considerably from one time measurement to another, and in this regard some measurements may be much more informative than others. We propose mathematical tools which can be used to collect data in an *almost optimal* way, by specifying the duration and distribution of time sampling in the measurements to be taken, consequently improving the accuracy (i.e., reducing the uncertainty in estimates) of the parameters to be estimated. We recall the concepts of *traditional* and *generalized sensitivity functions* and use these to develop a strategy to determine the "optimal" final time T for an experiment; this is based on the time evolution of the sensitivity functions and of the condition number of the Fisher information matrix. We illustrate the role of the sensitivity functions as tools in optimal design of experiments, in particular in finding "best" sampling distributions. Numerical examples are presented throughout to motivate and illustrate the ideas. This represents joint efforts with F. Kappel, S. Dediu and S. Ernstberger.

Inverse Scattering by Near-Field Imaging

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Abstract

Recent progress on inverse scattering problems for Maxwell's equations with near-field and far-field boundary measurements will be presented. Our approaches could be applied to both single and multiple frequency cases. Various analytic aspects of the approaches will be discussed. Numerical results on the inverse problems will be presented, which are accurate, data driven, and with super-resolution for near-field measurements. Related on-going work on inverse problems involving uncertainties will also be highlighted.

A General Framework for a Class of First Order Primal-Dual Algorithms for Separable Convex Minimization with Applications to Image Processing

Tony Chan
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Abstract

We generalize a recently proposed primal-dual hybrid gradient (PDHG) algorithm proposed by Zhu and Chan, draw connections to similar methods and discuss convergence of several special cases and modifications. In particular, we point out a convergence result for a modified version of PDHG that has a similarly good empirical convergence rate for total variation (TV) minimization problems. Its convergence follows from interpreting it as an inexact Uzawa method. We also prove a convergence result for PDHG applied to TV denoising with some restrictions on the PDHG step size parameters. It is shown how to interpret this special case as a projected averaged gradient method applied to the dual functional. We discuss the range of parameters for which the inexact Uzawa method and the projected averaged gradient method can be shown to converge. We also present some numerical comparisons of these algorithms applied to TV denoising, TV deblurring and constrained l1 minimization problems. (Joint work with Ernie Esser and Xiaoqun Zhang, Math Dept, UCLA).

Unique Continuation on a Line for Helmholtz Equation

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Abstract

In this talk, local unique continuation on a line for the solution to Helmholtz equation is presented. The conditional stability estimation is proved by using complex extension method which is proposed in Cheng and Yamamoto. Since the fundamental solution of Helmholtz equation has a logarithmic singularity which behaviors more or less like a Laplacian equation, the result obtained here can be viewed as a natural extension of the previous results. Numerical results for Laplacian and Helmholtz equations confirm the theoretical prediction of the Hölder type estimation provided that the line does not attain the boundary of the domain.

Inverse Problems in Systems Biology

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Abstract

Systems biology, a relatively young biological discipline, claims to consider cells and organism as entities in a holistic way emphasizing at the same time the interplay of components from the molecular to the systemic level. One of its major goals is to reach an understanding of the properties of cells or organisms emerging as consequence of the interaction of large numbers of molecules, which organize themselves into highly intricate reaction networks that span various levels of complexity. There is widespread scepticism if or to which extent these goals are reachable. But any progress in this field depends on "inverse problems technology".

Inverse problems arise in at least two levels:

- parameter estimation from measurements.
- qualitative inverse problems that aim at the identification or reverse engineering of bifurcation patterns and of other types of desired qualitative behaviour.

In both cases, sparsity plays a major role: metabolic or genetic networks are typically sparse, and one wants to design desired qualitative behaviour with as few changes to the system as possible.

We describe regularization techniques for both types of problems and exemplify their effect by qualitative inverse problems in connection with the cell division cycle and the circadian rhythm, respectively.

The Increasing Stability in the Continuation and Inverse Problems for the Helmholtz Type Equations

Victor Isakov
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Abstract

We consider the Cauchy problem for the Helmholtz equation (with variable coefficients) in a domain D with the data on $\Gamma \subset \partial D$ and demonstrate increasing stability with growing frequency when Ω is inside a convex hull of Γ. Proofs use energy estimates for hyperbolic equations and Carleman type estimates. When the convexity condition is violated, the stability of all solutions is deteriorating. However for some cases we show both analytically and numerically that disregard any geometric (or pseudo-convexity) assumptions there is an increasing subspace of all solutions of the Helmholtz equation where the continuation problem is Lipschitz stable.

In addition, we show increasing stability of recovery of potential in the Schrödinger equation from its Dirichlet-to-Neumann map.

Nonsmooth Tikhonov Regularization and Semismmoth Newton Method

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Abstract

Applications and analysis of the semismooth Newton method for non-smooth equations associated with nonsmooth Tikhonov functionals are presented. The semismmooth Newton method is a generalized Newton method for a class of the Lipschitz but not C^1 equations in Banach spaces. For the Tikhonov regularization the nonsmooth equation is reduced from the necessary optimality condition for minimizing the cost functional involving L^1, and TV (total variation) norms and/or subject to the point-wise constraint of the solution and its gradient. The L^1 norm is used to obtain the spike and impulsive solutions and TV norm is used to capture the edge and the discontinuity in the image. A robust algorithm based on the primal and dual active set method and the semismooth Newton is developed and analyzed.

Numerical Methods of Solving Inverse Hyperbolic Problems

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Abstract

The problems of determining coefficients of hyperbolic equations and systems from some additional information on their solutions are of great practical significances. We consider dynamical type of inverse problem in which the additional information is given by the trace of the direct problem solution on a (usually time-like) surface of the domain. This kind of inverse problems were originally formulated and investigated by M.M. Lavrentiev and V.G. Romanov (1966). The technique developed by V.G. Romanov for proving local theorems of unique solvability for dynamic inverse problems and also theorems of uniqueness and conditional stability "on the whole" was applied in the elaboration of numerical methods for solving a wide range of inverse problems of acoustics, siesmics, electrodynamics.

A majority of the papers and books devoted to the study of dynamic inverse problems deal with one of the following basic methods:

- method of Volterra operator equations;
- linearization and Newton-Kantorovich method;
- Landweber iterations (LI) and optimization;
- Gelfand-Levitan-Krein and boundary control methods;
- method of finite-difference scheme inversion.

The first group of methods, namely, Volterra operator equations, Newton-Kantorovich, Landweber iteration and optimization methods produce the iterative algorithms where one should solve the corresponding direct (forward) problem and adjoint (or linear inverse) problem on every step of the iterative process. On the contrary, the Gelfand-Levitan method, the method of boundary control, the finite-difference scheme inversion and sometimes linearization method do not use the multiple direct problem solution and allow one to find the solution in a specific point of the medium. Therefore we will refer to these methods as the "direct" methods.

In the present talk we will discuss theoretical and numerical background of the direct and iterative methods. We formulate and prove theorems of convergence, conditional stability and other properties of the mentioned above methods.

We will consider the following direct methods:
- finite-difference scheme inversion,
- linearization,
- method of Gelfand-Levitan-Krein,
- boundary control method,
- singular value decomposition method.

We intend to estimate the convergence rate of several numerical algorithms used extensively for solving inverse problems for hyperbolic equations, be they in partial differential, integral-differential, operator, finite-difference or variational form.

Our attention is focused on inverse problems for hyperbolic equations (IPHE) for the following reasons. First, the great majority of IPHE can be reduced to Volterra operator equations, thus creating a possibility to extend the theoretical results and numerical methods from the Volterra equations theory to IPHE. In particular, the Picard and Caratheodory successive approximations (PSA and CSA, respectively) developed for Volterra equations are applicable to IPHE. Second, a great number of numerical methods, such as finite-difference scheme inversion, linearization and Newton-Kantorovich type methods, regularization method and optimization methods, the dynamical version of the Gelfand-Levitan methods and many others, were elaborated for and tested on IPHE. A fair amount of experimental results has been accumulated, thereby inducing researchers to systematize and generalize the compiled material. Finally, it is well known that in some important cases the direct problems for elliptic and parabolic equations reduce to those for hyperbolic ones. Therefore, the technique worked out for IPHE may also be useful in studying inverse problems for elliptic or parabolic equations.

We formulate inverse problems in the form of operator equation $Aq = f$ and in variation form

$$J(q) = < Aq - f, Aq - f > \quad \to \min .$$

In direct methods we construct the solution without solving the corresponding direct (forward) problem. We describe linearization: $A'(q_0)q_1 = f_1$, finite-difference scheme inversion, Gelfand-Levitan and boundary control methods, and SVD algorithms.

In iterative methods it is necessary to solve direct problem and corresponding conjugate or inverse problem. We consider Landweber iteration

$$q_{n+1} = q_n - \alpha[A'(q_n)]^*(Aq_n - f),$$

gradient methods

$$q_{n+1} = q_n - \alpha_n J'(q_n), \quad J'(q) = 2[A'(q)]^*(Aq - f),$$

Newton-Kantorovich method

$$q_{n+1} = q_n - [A'(q_n)]^{-1}(Aq_n - f).$$

We analyze the convergence and the rate of convergence of direct and iterative methods using the simplest examples of inverse problems of acoustics, electrodynamics and heat transfer.

The work was supported by RFBR grant No 09-01-00746-a.

References

[1] S. I. Kabanikhin, Inverse and Ill-Posed Problems, Siberian Science Publishers, Novosibirsk, 2009, 456 pp.
[2] S. I. Kabanikhin, Definitions and examples of inverse and ill-posed problems, Journal of Inverse and Ill-Posed Problems, 2008, 16(4), pp. 317-357.

[3] S. I. Kabanikhin, A. D. Satybaev, M. A. Shishlenin, Direct Methods of Solving Inverse Hyperbolic Problems, 2004, VSP/BRILL, the Netherlands, 179 pp.

Imaging Finer Details of Shape and the Material Property of Inclusions Using Higher Order Polarization Tensors

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Abstract

It is well-known that using the polarization tensor we can recover the "equivalent ellipse (ellipsoid)" of the inclusions. The equivalent ellipse is an ellipse which represents the overall property of the inclusion. In this talk we will discuss on possibility of using higher order polarization tensors to recover finer details of the shape of the inclusion and to separate the material property, such as conductivity and stiffness, from the volume.

This talk is based on joint works with H. Ammari, E. Kim, J.-Y. Lee, M. Lim, and H. Zribi.

Huygens' Principle and Iterative Methods in Inverse Obstacle Scattering

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Abstract

The inverse problem we consider is to determine the shape of an obstacle from the knowledge of the far field pattern for scattering of time-harmonic plane waves. In the case of scattering from a sound-soft obstacle, we will interpret Huygens' principle as a system of two integral equations, named data and field equation, for the unknown boundary of the scatterer and the induced surface flux. Reflecting the ill-posedness of the inverse obstacle scattering problem these integral equations are ill-posed. They are linear with respect to the unknown flux and nonlinear with respect to the unknown boundary and offer, in principle, three immediate possibilities for their iterative solution via linearization and regularization.

We will first discuss the mathematical foundations of these algorithms including results on injectivity and dense range for the linearized operators and then describe the main ideas of their numerical implementation. Further, we will illuminate various relations between these three solution methods and exhibit connections and differences to the traditional regularized Newton type iterations as applied to the boundary to far field map. Numerical results in 3D are presented.

This is joint work with Olha Ivanyshyn, Göttingen, Germany, and Pedro Serranho, Coimbra, Portugal.

References

[1] D. Colton, R. Kress, Inverse Acoustic and Electromagnetic Scattering Theory, 2nd Edition, Springer, Berlin 1998.
[2] O. Ivanyshyn, R. Kress, P. Serranho, *Huygens' principle and iterative methods in inverse obstacle scattering*, Advances in Computational Mathematics, DOI 10.1007/s10444-009-9135-6.

Applications of Sparsity Enforcing Regularization in Systems Biology

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Abstract

One postulate of systems biology is that diseases arise from disease-perturbed biological networks. In the pursuit of understanding diseases by a combination of experimental and computational techniques also mathematical models of biochemical reaction networks find their applications. Focusing on ODE type models we give examples of how such models are built or analyzed by means of sparsity promoting regularization methods. For solving underdetermined systems of nonlinear equations we present an algorithm that aims at sparse corrections of the initial guess. It is applied to an inverse bifurcation analysis of a model for intrinsic signaling pathways of apoptosis.

Semi-smooth Newton Methods for L^1 Data Fitting with Automatic Choice of Regularization Parameters and Noise Calabriation

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Abstract

Inverse problems with L^1 fidelity terms are investigated. Using convex analysis techniques the non-differentiable problem is reformulated as smooth optimization problem with pointwise constraints. This can be efficiently solved using semismooth Newton methods. In order to achieve superlinear convergence, the dual problem requires additional regularization, which is based on the structure of the problem. Regularization in the primal problem is chosen according to a balancing principle derived from the model function approach, which does not rely on knowledge of the noise level in the data.

This is joint work with C. Clason and B. Jin.

A Constructive Method to Controllability and Observability for Quasilinear Hyperbolic Systems

Tatsien Li
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Abstract

In this talk a simple constructive method is presented to get the exact boundary controllability, the exact boundary controllability of nodal profile and the exact boundary observability for 1-D quasilinear hyperbolic systems.

Inverse Scattering Problems for Complex Obstacles

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Abstract

For given incident wave, the scattered wave outside an obstacle is governed by the Helmholtz equation in frequency domain. The inverse scattering problems aim to detect the obstacle property such as boundary shape and type from some information about the scattered wave. Such kind of inverse problems have been studied thoroughly using optimization techniques from the numerical points of view. In this talk, we will introduce some recent works for inverse scattering problems by complex obstacles. By complex obstacle, we mean that the obstacle may be of different acoustic wave property on the different part of the boundary, or the obstacle is a crack. We will present the reconstruction behavior of singular source method and show the effect of boundary impedance and boundary curvature.

The Interior Transmission Problem in Acoustics

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Abstract

As a result of studies of the far field pattern of the scattered wave for time harmonic acoustic waves, a new class of interior problem arises termed the "Interior Transmission Problem" (ITP). The ITP is not a standard elliptic problem, and a study of the solvability of this problem gives rise to a non- standard eigenvalue problem for the ITP. The proof of existence and properties of these eigenvalues is not straightforward. I shall survey the ITP and its properties in several applications, and describe numerical schemes for computing transmission eigenvalues. Remarkably, transmission eigenvalues can be observed from far field data, and the resulting eigenvalues can be used to estimate properties of the scatterer. The interior transmission problem has similarities with problems involving negative index of refraction, so it may be that the study of interior transmission eigenvalues is also relevant there.

The Point Source Method - Techniques and Applications

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Abstract

We will provide a survey about the point source method for the reconstruction of acoustic, electromagnetic or fluid dynamical fields from remote measurements. The method is based on an application of Green's theorem or related formulas for different applications to represent fields by surface integrals. An approximation of the fundamental solutions, which are typically involved in the representation, by a superposition of incident fields leads to a reconstruction formula to calculate the fields from remote measurements. The method can be used for various application areas. It provides a very effective tool which is employed in probing methods for object reconstruction. We will discuss further applications for source splitting and source identification.

Rational Approximation Methods for Inverse Source Problems

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Abstract

The basis of most imaging methods is to detect hidden obstacles or inclusions within a body when one can only make measurements on an exterior surface. Such is the ubiquity of these problems, the underlying model can lead to a partial differential equation of any of the major types, but here we focus on the case of steady-state electrostatic or thermal imaging and consider boundary value problems for Laplace's equation. Our inclusions are interior forces with compact support and our data consists of a single measurement of (say) voltage/current or temperature/heat flux on the external boundary. We propose an algorithm that under certain assumptions allows for the determination of the support set of these forces by solving a simpler "equivalent point source" problem.

Cloaking and Transformation Optics

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Abstract

We describe recent theoretical and experimental progress on making objects invisible to detection by electromagnetic waves, acoustic waves and matter waves. For the case of electromagnetic waves, Maxwell's equations have transformation laws that allow for design of electromagnetic materials that steer light around a hidden region, returning it to its original path on the far side. Not only would observers be unaware of the contents of the hidden region, they would not even be aware that something was being hidden. The object, which would have no shadow, is said to be cloaked. We recount some of the history of the subject and discuss some of the mathematical issues involved.

An Approach to the Optimal Time for a Time Optimal Control Problem of an Internally Controlled Heat Equation

Gengsheng Wang, Guojie Zheng
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Abstract

In this paper, we study the optimal time for a time optimal control problem $(\mathcal{P})$, where the state system is an internally controlled heat equation. By projecting the original problem via the finite element method, we obtain another time optimal control problem $(\mathcal{P}_{hl})$ governed by a linear system of ordinary differential equations. Here, h and l are the mesh sizes of the finite element spaces of the state space and the control space respectively. The purpose of this study is to find the relationship between the optimal times for the original and projected problems. We prove that the optimal time for the problem $(\mathcal{P}_{hl})$ converges to the optimal time for the problem $(\mathcal{P})$ when h and l are approaching zero. More significantly, we obtain error estimates between the optimal times in terms of h and l from the following two cases: (i) the state system of $(\mathcal{P})$ is the globally controlled heat equation; (ii) the state system of $(\mathcal{P})$ is an internally controlled one-dimensional heat equation. Also, we derive

that the projected internally controlled one-dimensional heat equation (via the finite element method) is exactly controllable.

Quantitative Uniqueness Estimates for the Stokes and Lame Systems

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Abstract

In this talk, I would like to discuss quantitative uniqueness estimates for the Stokes and Lame systems with singular and Lipschitz coefficients, respectively. Due to insufficient smoothness of the coefficients, both systems can not be decoupled. We will prove our results by the Carleman method. Our quantitative uniqueness results imply the strong unique continuation property. For the Lame system with Lipschitz coefficients, the result is optimal.

Fast Algorithms for Inverting the Regularized Kernel Matrix in Machine Learning

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Abstract

Many kernel based machine learning methods require to invert the regularized kernel matrix. Normally, such a kernel matrix is a full matrix of large size. Especially, for high dimensional data, it is difficult to invert the regularized kernel matrix. This is a bottleneck problem of the implementation of the kernel based machine learning methods. To efficiently invert the regularized matrix, we approximate the kernel matrix by a multilevel circulant matrix and then apply the super-fast Fourier transform to the regularized multilevel circulant matrix to find its inverse. Theoretical results and numerical examples will be presented in the talk.

Parabolic Carleman Estimates and the Applications to Inverse Source Problems for Equations of Fluid Dynamics

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Abstract

First we derive a Carleman estimate for a parabolic equation by a direct method. Next we will apply the Carleman estimate to inverse problems of determining source terms in the Navier-Stokes equations and related equations and we establish conditional stability estimates.

Uniqueness in the Inverse Obstacle Scattering in a Piecewise Homogeneous Medium

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Abstract

In this talk, we are concerned with the inverse scattering problem by an impenetrable obstacle embedded in a piecewise homogeneous medium. We will establish a uniqueness result in determining both the penetrable interface between the layered media and the impenetrable obstacle with its physical property from a knowledge of the far field pattern for incident plane waves. This we do by establishing both a new mixed reciprocity relation and a priori estimates of the solution on some part of the interface for the direct problem, employing the integral equation method.

Unique Continuation Property (UCP) of Some PDEs: from the Deterministic Situation to its Stochastic Counterpart

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Abstract

In this talk, I will recall some classical results/tools on the UCP of deterministic PDEs, and explain why the study of the global UCP, even when the local UCP is not clear or even negative, is possible and necessary. Further, I will analyze the difficulty and new phenomenon appeared in the study of UCP for stochastic PDEs, and especially, why the problem in the stochastic setting has to be considered globally in some sense. Finally, I will present some new UCP results for stochastic PDEs and comment a list of open problems.

3 Contributed talks

The Linearized Traveltime Tomography in Transversal Isotropic Elastic Media

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Abstract

The standard method of seismic data processing is to introduce the velocity model as the superposition of two components: the smooth macro velocity model that doesn't practically change the wave propagation direction and the high contrast component that has no influence on traveltimes but changes propagation directions (reflecting and scattering objects). The presence of elastic anisotropy produces extra demands to macrovelocity model. That is why our study is concerned with the macrovelocity model recovering in the anisotropic media. We consider tomography problem in transversal isotropic media (TI media).

Before solving tomography problem it is necessary to find out the possibility of the different anisotropic parameters recovering. That is why our study is devoted to the analyses: we consider qP traveltimes in TI media and study what parameters can be recovered and which way of the TI media parameterization is the optimal one for the tomography.

Let's search the observed elastic TI media parameters m as a sum of two components $m = m_0 + dm$, where m_0 are the parameters of the undisturbed "containing" media expected to be known, and dm are their small disturbances to be recovered using observed qP-wave traveltimes. These assumptions lead to linearized statement of the tomography problem that can be formally represented by equation:

$$B < dm >= d\tau, \tag{1.1}$$

where $d\tau$ are time residuals between computed traveltimes in "containing" media (with known parameters m_0) and real observed traveltimes for every pair source-receiver, B is linear integral tomography operator.

In practice the equation (1.1) is solved numerically and instead of linear integral operator B its matrix approximation B is used. The heart of the problem is the solution of a linear system of equations. Matrix B inherits the properties of the initial operator B. B is compact operator so matrix B is ill-conditioned (has very large condition number). SVD was performed on the matrix B for the different parameterization. To understand what parameters can be resolved it is necessary to find out the structure of stable decisions spaces. These spaces are linear shells of the highest right singular vectors. If the order of the data error is know the error in solution can be controlled by the number of involved right singular vectors .

We have find out that optimal parameterization for linearized inverse kinematic problem is Schoenberg's parameterization. Only two of three parameters can be practically defined: p wave velocity along the axis of symmetry direction and ellipticity parameter.

Subdifferential Inverse Problems for Magnetohydrodynamics

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Abstract

The magnetohydrodynamic (MHD) equations in the bounded domain $\Omega \subset \mathbb{R}^d$ with the boundary Γ are considered.

$$\partial u/\partial t - \nu\Delta u + (u\nabla)u = -\nabla p + S \cdot \mathrm{rot}\, B \times B,\ x \in \Omega,\ t > 0, \tag{1}$$

$$\partial B/\partial t + \operatorname{rot} E = 0,\ \operatorname{rot} B = 1/\nu_m(E + u \times B + E_c),\ \ \operatorname{div} u = 0,\ \ \operatorname{div} B = 0. \tag{2}$$

Here u, B, E and $E_c = \sum_{i=1}^{m} \alpha_i(t)E_i$ are vector fields of velocity, magnetic induction, electric intensity and external electromotive intensity respectively; p is the flow pressure, $\nu = 1/Re$. $\nu_m = 1/R_m$, $S = M^2/Re\,R_m$, where Re,Re_m and M are the Reynolds number, Reynolds magnetic number and Hartmann number.

To the equations (1)-(2) we add the initial and the boundary value conditions

$$u|_{t=0} = u^0(x),\ B|_{t=0} = B^0(x),\ x \in \Omega,\ \ u|_\Gamma = 0,\ B \cdot n|_\Gamma = 0,\ n \times E|_\Gamma = 0, \tag{3}$$

where n is the unit outward normal to the boundary.

The following inverse problem is considered. Find the functions $\alpha_i = \alpha_i(t)$, $i = 1, ..., m$ and the solution $\{u, B\}$ of (1)-(3) satisfying the additional conditions

$$\alpha_i(t) \geq 0,\ \int_\Omega \operatorname{rot} B \cdot E_i\, dx \geq q_i(t),\ \ \alpha_i(t)(\int_\Omega \operatorname{rot} B \cdot E_i\, dx - q_i) = 0. \tag{4}$$

The functions $q_i(t)$, $E_i(x)$ are given.

To study the Problem (1)–(4) the theory of solvability of an evolution inequality in a Hilbert space for the operators with the quadratic nonlinearity is created. Obtained results is used for the study of MHD flows. For the 3 - dimensional flows the global in time existence of the weak solutions to the variational inequalities is proved. For the two-dimensional flows existence and uniqueness of the strong solutions are proved. Then the inverse problem is considered. On the base of estimates of the solution for subdifferential problem for the MHD system the solvability is proven on the condition that the norm of E_c is minimal.

A New Phase Space Method for Recovering Index of Refraction from Travel Times

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Abstract

We develop a new phase space method for reconstructing the index of refraction of a medium from travel time measurements. The method is based on the so-called Stefanov-Uhlmann identity which links two Riemannian metrics with their travel time information. We design a numerical algorithm to solve the resulting inverse problem. The new algorithm is a hybrid approach that combines both Lagrangian and Eulerian formulations. In particular the Lagrangian formulation in phase space can take into account multiple arrival times naturally, while the Eulerian formulation for the index of refraction allows us to compute the solution in physical space. Numerical examples including isotropic metrics and the Marmousi synthetic model are shown to validate the new method.

Asymptotic Behaviour of the Energy for Electromagnetic Systems in the Presence of Small Inhomogeneities

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Abstract

For such solution, of the time-harmonic case, we give a rigorous derivation of the asymptotic expansions in the interesting situation when a finite number of inhomogeneities of small diameter are embedded in the entire space. Then, we analyze the behavior of the electromagnetic energy caused by the presence of these inhomogeneities. In case of general time dependent, we show that the local electromagnetic energy, trapped in the total collection of these well separated inhomogeneities, decays toward zero as the shape parameter decreases to zero or as time increases.

References

[1] H. Ammari, E. Iakovleva, D. Lesselier, G. Perrusson, *MUSIC-type electromagnetic imaging of a collection of small three-dimensional inclusions*, SIAM Sci. Comput., 29 (2007), pp. 674-709.
[2] H. Ammari, M. S. Vogelius, D. Volkov, *Asymptoticc formulas for perturbations in the electromagnetic fields due to the presence of inhomogeinities of small diameter II. The full Maxwell equations*, J. Math. Pures Appl., 80 (2001), pp. 769-814.
[3] B. Ducomet, *Decay of Electromagnetic Energy in a Perturbed Half-Space*, Computers Math. Applic., 29 (1995), No. 3, pp. 13-21.
[4] M. Schiffer, G. Szegö, *Virtual mass and polarization*, Trans. Amer. Math. Soc., 67 (1949), pp. 130-205.
[5] M. Vogelius and D. Volkov, *Asymptotic formulas for perturbations in the electromagnetic fields due to the presence of inhomogeneities*, Math. Model. Numer. Anal., 34 (2000), pp. 723-748.

Posterior Covariances of the Optimal Solution Errors in Variational Data Assimilation

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Abstract

The problem of variational data assimilation for a nonlinear evolution model is formulated as an optimal control problem to find unknown model parameters such as initial and/or boundary conditions, right-hand sides (forcing), and distributed coefficients. A necessary optimality condition reduces the problem to the optimality system (see, e.g., [1]) which includes input errors (background and observation errors); hence the error in the optimal solution. The error in the optimal solution can be derived through the errors in the input data using the Hessian of the cost functional of an auxiliary data assimilation problem. For a deterministic case it was done in [2]. In [3], a similar result was obtained for the continuous operator formulation, where a nonlinear evolution problem with an unknown initial condition was considered, when errors in the input data are random

and subjected to the normal distribution. In [4], we presented an extension of the results reported in [3] for the case of other model parameters (boundary conditions, coefficients, etc.) and show that in a nonlinear case the a posteriori covariance operator of the optimal solution error can be approximated by the inverse Hessian of the auxiliary data assimilation problem based on the tangent linear model constraints. Here we investigate cases of highly non-linear dynamics, when the inverse Hessian does not properly approximate the analysis error covariance matrix, the latest being computed by the fully non-linear ensemble method with a significant ensemble size. A modification of this method that allows us to obtain sensible approximation of the covariance with a much smaller ensemble size is presented. Numerical examples are presented for a nonlinear convection-diffusion problem and Burgers equation.

References

[1]F. -X. Le Dimet, O. Talagrand, *Variational algorithms for analysis and assimilation of meteorological observations: theoretical aspects*, Tellus, 1986, v. 38A, pp. 97-110.
[2] F. -X. Le Dimet, V. Shutyaev, *On deterministic error analysis in variational data assimilation*, Nonlinear Processes in Geophysics, 12 (2005), pp. 481-490.
[3] I. Gejadze, F. -X. Le Dimet, V. Shutyaev , *On analysis error covariances in variational data assimilation*, SIAM J. Sci. Computing, 30 (2008), no. 4, pp. 1847-1874.
[4] I. Gejadze, F. -X. Le Dimet, V. P. Shutyaev, *On optimal solution error covariances in variational data assimilation problems*, J. Comp. Phys., 2009, doi:10.1016/j.jcp.2009.11.028.

Simultaneous Identification of Electric Permittivity and Magnetic Permeability

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Abstract

In this paper we will investigate the simultaneous reconstruction of the electric permittivity and magnetic permeability. The two physical parameters are allowed to be highly discontinuous in the concerned physical domain. The ill-posed inverse problem is formulated into an output least-squares nonlinear minimization with BV-regularization. The regularizing effect and mathematical properties of the regularized system are justified and analysed. A fully discrete Nedelec's edge element method is applied to approximate the regularized nonlinear optimization system, and its convergence is demonstrated. This is a joint work with Daijun Jiang and Jun Zou.

Identification of a Time-varying Point Source: Application to Rivers Water Pollution

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Abstract

We are interested in the inverse source problem that consists of the localization of a sought point source S and the recovery of the history of its time-dependent intensity function λ which are both unknown and involved in the following system of two coupled $1D$ advection-diffusion-reaction equations:

$$\begin{array}{lll} L[u](x,t) = \lambda(t)\delta(x-S) & \text{for} & 0<x<\ell,\ \ 0<t<T, \\ L[v](x,t) = Ru(x,t) & \text{for} & 0<x<\ell,\ \ 0<t<T, \\ u(x,0) = v(x,0) = 0 & \text{for} & 0<x<\ell, \\ u(0,t) = v(0,t) = 0 \text{and} \quad u(\ell,t) = v(\ell,t) = 0 & \text{for} & 0<t<T, \end{array} \tag{1}$$

where $L[w](x,t) =: \partial_t w(x,t) - D\partial_{xx} w(x,t) + V\partial_x w(x,t) + Rw(x,t)$.

A motivation of our study is an environmental application where the aim is to identify pollution sources in rivers. Therefore, the system (1) corresponds to the coupled $u = [BOD]$ (Biological Oxygen Demand) concentration and $v = [OD]$ (Oxygen Deficit) concentration model, see [3,4,5]. The inverse source problem with which we are concerned here consists of the determination of the elements (S, λ) defining the sought pollution source using some records of the OD concentration. In [2], we treated the identification of (S, λ) where only the first equation in (1) is considered. That corresponds to the identification of the sought pollution source using some records of the BOD concentration.

In [1], assuming that the time-dependent intensity function λ vanishes before reaching the final control time T, we proved the identifiability of the sought point source using the records of the state v in (1) at two interior observation points. Note that the two observation points should frame the source region and at least one of them should be strategic. We established an identification method that uses the records of v to identify the source position S as the root of a continuous and strictly monotonic function. Whereas the source intensity function λ is recovered using a recursive formula without any need of an iterative process. Some numerical experiments on a variant of the surface water pollution $BOD - OD$ coupled model are presented and compared to those obtained in [2].

References

[1] A. Hamdi, *Identification of a time-varying point source in a system of two coupled linear diffusion-advection-reaction equations: application to surface water pollution*, Inverse Problems, Vol. 25, No 11, 115009, 2009.
[2] A. Hamdi, *The recovery of a time-dependent point source in a linear transport equation: application to surface water pollution*, Inverse Problems, Vol. 25, No 7, 075006, 2009.
[3] C. Linfield et al, The enhanced stream water quality models QUAL2E and QUAL2E-UNCAS: Documentation and user manuel, EPA: 600/3-87/007, May 1987.
[4] Okubo, Diffusion and Ecological Problems: Mathematical Models, Springer-Verlag, New York, 1980.
[5] J. S. F. Roldao, J. H. P. Soares, L. C. Wrobel, T. R. Buge, N. L. C. Dias, *Pollutant Transport Studies in the Paraiba Do Sul River Brazil*, Water Pollution, pp. 167-180, 1991.

Uniqueness in Inverse Scattering of Elastic Waves by Polygonal Periodic Structures

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Abstract

This talk is concerned with the inverse scattering of a time-harmonic elastic wave by an unbounded periodic structure of $\mathbb{R}^2$. Such structures are also called diffraction gratings and have many important applications in diffractive optics, radar imaging and non-destructive testing.

We assume that a periodic surface divides the three-dimensional space into two non-locally perturbed half-spaces filled with homogeneous and isotropic elastic media. Moreover, we suppose that this surface is periodic in x_1-direction and invariant in x_3-direction, and that all elastic waves are propagating perpendicular to the x_3-axis in the upper half-space. This special geometry implies that the problem can be treated as a problem of plane elasticity. Furthermore, the diffraction grating is supposed to have an impenetrable surface on which normal stress and tangential displacement (or normal displacement and tangential stress) vanish. This gives rise to the so-called the third (or fourth) kind of boundary conditions for the Navier equation. The direct problem is to predict the displacement distribution given the incident elastic waves and grating profile, whereas the inverse problem is to determine the grating profile from a knowledge of incident waves and the near-field measurements on a straight line above the grating.

In general, global uniqueness for the inverse problem is impossible by taking the measurements from a fixed number of incident pressure or shear waves, which can be seen from the scattering by flat gratings. We investigate the global uniqueness by several incident waves within an admissible class of grating profiles $\mathcal{A}$, which consists of the non-flat graphs given by piecewise linear functions. Based on the reflection principle for the Navier equation developed by Elschner J. and Yamamoto M. [2009] and a novel idea established by Bao G., Zhang H. and Zou J., we deduce that the total field remains rotation-invariant and only consists of the compressional (or shear) part for the incident pressure (or shear) wave. The rotational invariance together with the form of incident wave leads to explicit representations of the total field as well as special geometrical structures of the grating profile. This enable us to classify all the grating profiles of $\mathcal{A}$ that can not be identified by one incident elastic wave and thus to prove global uniqueness with a mimimal number of incident elastic waves in the resonance case. Compared to the case where Rayleigh frequencies are exluded, the resonace case gives rise to more classes of unidentifiable gratig profiles, which provide non-uniqueness examples for appropriately chosen wave number and incident angles.

This is a joint work with Johannes Elschner.

Efficient Reconstruction of 2D Images and 3D Surfaces

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Abstract

The goal of this talk is to introduce several effective techniques for solving inverse problems arising from 2D image and 3D surface reconstruction. Both computational and theoretical issues will be discussed.

The first part of the talk is concerned with the recovery of 2D images, e.g., denoising and deblurring. We first consider implicit methods that involve solving linear systems at each iteration. An adaptive Huber regularization functional is used to select the most reasonable model and a global convergence result for lagged diffusivity is proved. Two mechanisms—multilevel continuation and multigrid preconditioning—are proposed to improve efficiency for large-scale problems. Next, explicit methods involving the construction of an artificial time-dependent differential equation model followed by forward Euler discretization are analyzed. A rapid, adaptive scheme is then proposed, and additional hybrid algorithms are designed to improve the quality of such processes. We also devise methods for more challenging cases, such as recapturing texture from a noisy input and deblurring an image in the presence of significant noise.

It is well-known that extending image processing methods to 3D triangular surface meshes is far from trivial or automatic. In the second part of the talk we discuss techniques for faithfully reconstructing such surface models with different features. Some models contain a lot of small yet visually meaningful details, and typically require very fine meshes to represent them well; others consist of large flat regions, long sharp edges (creases) and distinct corners, and the meshes required for their representation can often be much coarser. All of these models may be sampled very irregularly. For models of the first class, we methodically develop a fast multiscale anisotropic Laplacian (MSAL) smoothing algorithm. To reconstruct a piecewise smooth CAD-like model in the second class, we design an efficient hybrid algorithm based on specific vertex classification, which combines K-means clustering and geometric *a priori* information. Hence, we have a set of algorithms that efficiently handle smoothing and regularization of meshes large and small in a variety of situations.

Parameter Choice Rules for Sparse Reconstruction

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Abstract

Recently, minimization problems involving so-called sparsity constraints, e.g. l^1 regularization, have received much attention. However, the crucial problem of choosing an appropriate regularization parameter remains largely unexplored. In this talk we shall discuss some rules for choosing regularization parameters in l^1 regularization. Firstly, we revisit classical Morozov's discrepancy principle. Theoretical properties of the discrepancy equation, e.g. existence, uniqueness, error estimates and bounds, are investigated. Its efficient numerical realization is also briefly discussed. Secondly, we adapt some heuristic rules, e.g. balancing principle and generalized cross validation, and numerically evaluate their utility.

Numerical Identification of Small Imperfections Using Dynamical Methods

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Abstract

The imaging of small imperfections has been studied, in various contexts, using static boundary measurements (see the monograph [1] and references therein) and transient wave boundary measurements (see [2], [3] and [4]). In the *limited-view case,* where measurements are available on only a part of the object's boundary, the theory is posed in [5] and numerical computations were performed in [6]. These computations were able to validate the general algorithmic approach that is based on the exact controllability of the wave equation [7] and geometric control theory [8]. This study proposes an extension of the numerical work to the case of the photoacoustic equations, where energy absorption of an optical pulse causes thermo-elastic expansion of the tissue, which in turn leads to propagation of a pressure wave. This pressure wave can then be measured by transducers distributed on the boundary of an organ.

Let Ω be a bounded, smooth subdomain of $\mathbb{R}^d$, $d = 2, 3$, with for simplicity, a smooth boundary $\partial\Omega$. We suppose that Ω contains a finite number m of imperfections, each of the form $z_j + \alpha B_j$, where $B_j \subset \mathbb{R}^d$ is a bounded, smooth domain containing the origin. This gives a collection of imperfections of the form $B_\alpha = \cup_{j=1}^m (z_j + \alpha B_j)$. The points $z_j \in \Omega$, $j = 1, ..., m$ that define the locations of the imperfections are assumed to satisfy some separation conditions. Let γ_0 denote the conductivity of the background medium which, for simplicity, we shall assume is constant. Let γ_j be the constant conductivity of the j-th imperfection, $z_j + \alpha B_j$. We define the piecewise constant conductivity

$$\gamma_\alpha(x) = \begin{cases} \gamma_0, & \text{if } x \in \Omega \backslash \bar{B}_\alpha \\ \gamma_j, & \text{if } x \in z_j + \alpha B_j. \end{cases}$$

Consider the initial boundary value problem for the wave equation, in the *presence* of the imperfections,

$$\begin{cases} \dfrac{\partial^2 u_\alpha}{\partial t^2} - \nabla \cdot (\gamma_\alpha \nabla u_\alpha) = 0 & \text{in } \Omega \times (0, T), \\ u_\alpha = f & \text{on } \partial\Omega \times (0, T), \\ u_\alpha|_{t=0} = u^0 \,, \left.\dfrac{\partial u_\alpha}{\partial t}\right|_{t=0} = u^1 & \text{in } \Omega. \end{cases} \tag{1}$$

If we suppose that the measurements are only done on a part of the boundary, then the detection of the absorbers from these partial measurements hold only under an extra assumption on T and the support of the control. Geometric control theory can be used to construct an appropriate probe function in this limited-view data case.

This problem is solved numerically by a finite-element discretization in space, using P_1 conforming elements, and a Newmark method in time. The control problem is solved using a bi-grid implementation of the HUM algorithm [9]. The actual identification is performed by a Fourier method in the pure conductivity case and by an arrival-time algorithm in the photoacoustic case. We will present some new numerical results for both cases.

References

[1] H. Ammari, An Introduction to Mathematics of Emerging Biomedical Imaging, Math and Applications, Volume 62, Springer-Verlag, Berlin, 2008.
[2] H. Ammari, E. Bossy, V. Jugnon, and H. Kang, *Mathematical modelling in photo-acoustic imaging*, SIAM Review (2010), to appear.
[3] H. Ammari, Y. Capdeboscq, H. Kang, and A. Kozhemyak, *Mathematical models and reconstruction methods in magneto-acoustic imaging*, Euro. J. Appl. Math., 20 (2009), pp. 303–317.
[4] H. Ammari, P. Garapon, L. Guadarrama Bustos, H. Kang, *Transient anomaly imaging by the acoustic radiation force*, J. Diff. equat. (2010), to appear.
[5] H. Ammari, *An inverse initial boundary value problem for the wave equation in the presence of imperfections of small volume*, SIAM J. Control Optim., 41 (2002), pp. 1194-1211.
[6] M. Asch, M. Darbas, J.-B. Duval, *Numerical solution of an inverse initial boundary value problem for the wave equation in the presence of conductivity imperfections of small volume*, ESAIM Control Optim. Calc. Var., (2010), to appear.
[7] J.-L. Lions, *Contrôabilité exacte, Perturbations et Stabilisation de Systèmes Distribués, Tome 1, Contrôabilité exacte*, Masson, Paris, 1988.
[8] C. Bardos, G. Lebeau, J. Rauch, *Sharp sufficient conditions for the observation, control and stabilization of waves from the boundary*, SIAM J. Control Optim., 30 (1992), pp. 1024-1065.
[9] M. Asch and G. Lebeau, *Geometrical aspects of exact boundary controllability for the wave equation - A numerical study*, ESAIM: control, Optimization and Calculus of Variations, 3 (1998), pp. 163-212.

Two Techniques to Make Linear Sampling Methods More Efficient and Effective

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Abstract

In this presentation, we will discuss in detail about two techniques to make linear sampling methods efficient and effective. First, we introduce the inverse obstacle scattering problems, to which the methods will apply. Existing theoretical results and numerical methods are reviewed. Among them, we will focus on linear sampling methods (LSM), which essentially exploits the blow-up behavior of the indicator functioin around the boundaries of the obstacles on some sampling mesh. Two techniques are presented to enhance the LSM, i.e., Multilevel and strengthened ideas. For the Multilevel LSM, it is proved that it possesses asymptotic optimal computational complexity, while for the strengthened LSM, a practical guide is developed for the choice of cut-off values with resort to any known obstacle component as well as a by-product, namely the fact that interior eigenvalue problems do not exist when there are noise in data. Some conclusions are made in the end. This is a joint work with Hongyu Liu and Jun Zou.

Identification of Acoustic Coefficient of a Wave Equation Using Extra Boundary Measurements

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Abstract

In this paper we apply the adjoint-based optimization technique to estimate the acoustic coefficients of a wave equation. Various types of acoustic coefficients, constant, time-dependent and space-dependent acoustic coefficients are investigated in this paper. The forward problem is numerically solved by some efficient and accurate finite difference methods while the adjoint, for the purpose of comparison, is generated by both continuous and discrete methods. Several numerical examples are conducted to demonstrate the effectiveness and accuracy of the proposed methods.

Keywords: Acoustic wave equation, Parameter identification, Finite difference scheme, Inverse problem, Auto differentiation

Inverse Problem for a Structural Acoustic Interaction

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Abstract

In this work, we consider an inverse problem of determining a source term for a structural acoustic partial differentia equation (PDE) model, comprised of a two or three-dimensional interior acoustic wave equation coupled to a Kirchoff plate equation, with the coupling being accomplished across a boundary interface. For this PDE system, we obtain the uniqueness and stability estimate for the source term from a single measurement of boundary values of the "structure". The proof of uniqueness is based on Carleman estimate. Then, by means of an observability inequality and a compactness/uniqueness argument, we can get the stability result. Finally, an operator theoretic approach gives us the regularity needed for the initial conditions in order to get the desired stability estimate.

Model Function Approach in the Modified L-curve Method for the Choice of Regularization Parameter

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Abstract

In this talk we propose a model function approach in the modified L-curve method for the choice of a regularization parameter. The idea is to replace the residual norm and the regularized solution norm with an approximated model function. With such an approach, the computational cost of minimum procedure can be dramatically saved. We present numerical tests to support the reliability of the approach. Finally, the model function approach in modified L-curve method is applied to pool boiling data to reconstruct unknown heat fluxes at the boiling surface.

Optimal Control for the Elliptic System with General Constraint

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Abstract

The optimal control problems governed by partial differential equations with state and/or control constraints received a significant amount of attention recently. The most existing works focus on the unilaterally or bilaterally constrained problems. In this talk, we will discuss the optimal control for the elliptic system with the polygonal type state constraint or point-wise Euclidean norm control constraint. An efficient semi-smooth Newton algorithm is proposed and numerical feasibility of this method is shown.

Some Regularization Methods for the Numerical Analytic Continuation

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Abstract

The problem of analytic continuation of ananalytic function, in general, is an ill-posed problem and it is frequently encountered in many practical applications. The main earlier works for this topic focus on the conditional stability and some rather complicated computational techniques. However, it seems there are few applications of the modern theory of regularization methods which have been developed intensively in the last few decades. This paper is devoted to some new regularization methods for solving the numerical analytic continuation of ananalytic function $f(z) = f(x + iy)$ on a strip domain $\Omega^+ = \{z = x + iy | x \in R, 0 < y < y_0\}$, where the data is given approximately only on the line $y = 0$. Some numerical examples are also provided.

An Adaptive Method for Recovering Sparse Solutions to Inverse Problems with Applications in System Biology

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Abstract

The approximation of sparse solutions has become an important task in inverse problems settings over the last few years. This is due to the fact, that many types of functions and signals arising in nature can be described by a small number of signifi- cant degrees of freedom.

In this talk we present an algorithm for cheaply determining sparse solutions of inverse problems. The method is based on an adaptive discretization scheme, introduced by Ben Ameur, Chavent, and Jaffre for estimating a distributed hydraulic transmissivity. Adaptivity is introduced through refinement and coarsening indicators which allow to efficiently add or remove degrees of freedom. In this talk we discuss a generalization of these ideas, which leads to an algorithm providing sparse solutions.

We applied this algorithm to a recent sparse problem in systems biology, namely the reconstruction of gene networks out of microarray data sets. This is in general a highly underdetermined and ill-posed problem. In a first simplified approach, we model it as a linear inverse problem. Taking into account realistic measurement

scenarios we arrive at a nonlinear problem. We show numerical results and compare them with other wellknown sparse approximation algorithms.

Quantum Mechanical Inverse Scattering Problem at Fixed Energy: a Constructive Method

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Abstract

The inverse scattering problem of the three-dimensional Schrödinger equation is considered at fixed scattering energy with spherically symmetric potentials. Theorems of Loeffel [1], Ramm [2] and Horvath [3] predict the existence of a unique potential of the class $L_{1,1}$ from the knowledge of an *infinite* set of phase shifts (that are deductable from scattering experiments). Therefore a constructive scheme for recovering the scattering potential from a *finite* set of phase shifts at a fixed energy is of interest. Such a scheme is suggested by Cox and Thompson [4] and their method is revisited here. A condition is given [5] for the construction of potentials belonging to the class $L_{1,1}$ which are the physically meaningful ones. An uniqueness theorem is obtained [5] in the special case of one given phase shift by applying the previous condition. An unknown property of the Bessel functions is discovered [5] in the course of the proof. It is shown that if only one phase shift is specified for the inversion procedure the unique potential obtained by the Cox-Thompson scheme yields the one specified phase shift while the others are small in a certain sense. As the one-phase-shift case occurs frequently in the applications (e.g. at low energies the s-wave dominates the scattering event) some physical examples are given.

References

[1] J. J. Loeffel, Ann. Inst. Henri Poincare, 8 (1968), pp. 339-447.
[2] A. G. Ramm, Commun. Math. Phys., 207 (1999), pp. 231-247.
[3] M. Horváth, Trans. Amer. Math. Soc., 358 (2006), pp. 5161-5177.
[4] J. R. Cox and K. W. Thompson, J. Math. Phys., 11 (1970), pp. 805-815.
[5] T. Pálmai and B. Apagyi, J. Math. Phys., 51 (2010), 022114.

Fast Acoustic Imaging for a 3D Penetrable Object Immersed in a Shallow Water Waveguide

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Abstract

The paper is concerned with the inverse problem for reconstructing a 3D penetrable object in a shallow water waveguide from the far-field data of the scattered fields with many acoustic point source incidences. An indicator sampling method is analyzed and presented for fast imaging the size, shape and location of such a penetrable object. The method has the advantages that a priori knowledge is avoided for the geometrical and material properties of the penetrable obstacle and the much complicated iterative techniques are avoided during the inversion. Numerical examples are given of successful shape reconstructions for several 3D penetrable obstacles

having a variety of shapes. In particular, numerical results show that the proposed method is able to produce a good reconstruction of the size, shape and location of the penetrable target even for the case where the incident and observation points are restricted to some limited apertures.

On Optimal Reconstruction of Constitutive Relations

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Abstract

In this investigation we develop a computational framework for optimal reconstruction of isotropic constitutive relationships between thermodynamic variables based on measurements obtained in a spatially-extended system. In other words, assuming the constitutive relation in the following general form

$$\begin{bmatrix} \text{thermodynamic} \\ \text{flux} \end{bmatrix} = k(\text{state variables}) \begin{bmatrix} \text{thermodynamic} \\ \text{“force”} \end{bmatrix}, \tag{1}$$

our approach allows us to reconstruct the dependence of the transport coefficient k on the state variables consistent with the assumed governing equation(s). Constitutive relations in the form (1) arise in many areas of nonequilibriumthermodynamics and continuum mechanics. To fix attention, but without loss of generality, in the present investigation we focus on a heat conduction problem in which the heat flux q represents the thermodynamic flux, whereas the temperature gradient ∇T is the thermodynamic “force”, so that relation (1) takes the specific form

$$q(x) = k(T)\nabla T, \quad x \in \Omega, \tag{2}$$

where $\Omega \in \mathbb{R}^n, n = 1, 2, 3$ is the spatial domain on which the problem is formulated. We note that problems in which the transport coefficient k is a function of the space variable x, rather than the state variable T, i.e., $k = k(x)$, have received a lot of attention in the literature, and are now relatively well understood. The originality of our contribution consists in that, in contrast to such “parameter estimation” problems, we address estimation of state-dependent, and therefore nonlinear, constitutive relations. We demonstrate that, as a matter of fact, the mathematical structure of this new problem is quite different from the structure of the parameter estimation problem. Combining constitutive relation (2) with the conservation of energy, we obtain a partial differential equation (PDE) describing the distribution of the temperature T in the domain Ω corresponding to the distribution of heat sources $g : \Omega \to \mathbb{R}$ and suitable boundary conditions (for example, of the Dirichlet type)

$$-\nabla \cdot [k(T)\nabla T] = g \quad \text{in } \Omega, \tag{3a}$$
$$T = T_b \quad \text{on } \partial\Omega, \tag{3b}$$

where T_b denotes the boundary temperature. We note that, for all values of T, we should have $k(T) > 0$ which follows from the second principle of thermodynamics, but is also required for the mathematical well-posedness of elliptic boundary value problem (3). The specific inverse problem we address in this investigation is formulated as follows. Given a set of “measurements” $\{\tilde{T}_i\}_{i=1}^M$ of the state variable (temperature) T at a number of points $\{x_i\}_{i=1}^M$ in the domain Ω, we seek to reconstruct the constitutive relation $k(T)$ such that solutions of problem (3) obtained with this reconstructed function will fit best the available measurements. An approach commonly used to solve such inverse problems consists in reformulating them as minimization problems. This is done by defining the cost functional $\jmath : \mathbb{R} \to \mathbb{R}$ as

$$\jmath(k) \triangleq \frac{1}{2} \sum_{i=1}^{M} [\tilde{T}_i - T(x_i; k)]^2, \tag{4}$$

where the dependence of the temperature field $T(\cdot;k)$ on the form of the constitutive relation $k = k(T)$ is given by governing equation (3). The key ingredient of the minimization algorithm is computation of the cost functional gradient $\nabla_k \jmath(k)$. We emphasize that, since $k = k(T)$ is a continuous variable, the gradient $\nabla_k \jmath(k)$ represents in fact an infinite dimensional sensitivity of $\jmath(k)$ to perturbations of $k(T)$. In our presentation we will show that this gradient can be determined based on suitably defined *adjoint variables* and this derivation can be significantly simplified using the Kirchhoff transformation. These adjoint variables (Lagrange multipliers) are obtained from the solution of the corresponding *adjoint system* which is at the heart of the proposed reconstruction algorithm. Since in general inverse problems often tend to be ill-posed, care must be taken to perform suitable regularization. In our presentation we will review foundations of this approach together with its computational implementation. We will also present a number of computational examples and will discuss extensions of this methods to more complicated problems.

Scenario of Seismic Monitoring of Productive Reservoirs

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Introduction. For over decade 4D or time-lapsing seismic has been effectively applied in reservoir monitoring during the production life of a series of oil deposits (Clifford et al., 2003). The usual way to do this is implementation of 3D seismic survey over a producing reservoir. The main objective of this monitoring is to locate reservoir floodfront and to control flood movement pathways.

Mostly reported successful 4D seismic applications, however, are in offshore field areas where near surface related noise is low and repeatability of seismic signal is rather high. It is necessary to stress that both of these items, especially repeatability, are of crucial importance for seismic monitoring. In order to provide the same quality of collected data for land 4D seismic monitoring the reasonable way seems to be in use of acquisition system fixed within a network of boreholes - it provides data with extremely low level of noise and very high range of repeatability. Its main disadvantage is possibility to use only few sources/geophones placed rather sparsely. Therefore one should study sensitivity of any particular borehole based acquisition system very carefully before to implement it. In order to perform this study, known as survey design, we use Singular Value Decomposition.

Statement of the problem. The essence of seismic monitoring is to follow perturbation of elastic parameters via inversion of successive data set collected over the same reservoir. Initial distribution $\vec{m}_0$ of these properties usually is supposed to be known while its perturbation $\delta\vec{m}$ as a rule can be treated as small enough in order to justify linearization procedure. Therefore seismic monitoring results in resolution of linear operator equation:

$$DB(\vec{m}_0) < \delta\vec{m} >= \vec{u}^{obs}_{curr} - \vec{u}^{obs}_{prev} \quad (1)$$

where $B(\vec{m}_0)$ is nonlinear forward map which transforms model $\vec{m}$ to data $\vec{u}^{obs}$, $DB(\vec{m}_0)$ its Frechet derivative, $\delta\vec{m}$ perturbation of the model happened between two successive observations - previous and current.

Derivative DB is a compact operator (Khaidukov et al., 1997) and, so, has no bounded inverse. In order to resolve equation (1) numerically one needs to apply some regularization procedure. In this specific situation r-solution is used (Kostin and Tcheveda, 1995). It is based on truncated SVD for operator DB and consists in resolution of finite-difference version of (1)

$$Q_r(DB(\vec{m}_0))P_r < \delta\vec{m} >= Q_r(\vec{u}^{obs}_{curr} - \vec{u}^{obs}_{prev}) \quad (2)$$

with Q_r and P_r being orthogonal projectors onto subspaces spanned r left and right singular vectors respectively, corresponding to the largest r singular values.

Singular Value Decomposition and r-pseudoinverse of DB. As was mentioned above for seismic monitoring borehole based acquisition system is chosen for implementation. It is made from array of sources placed within producing oil wells (borehole pump acts like a seismic source), while receivers are within non-producing wells.

Singular values computed for this acquisition system is computed and used for analysis of stabilty and resolution ability of the method.

Numerical results of synthetic data inversion are presented and discussed.

Acknowledgement. This research was partially supported by RFBR grants 08-05-00265.

Reference:

[1] P. J. Clifford, R. Trythall, R. S. Parr, T. P. Moulds, T. Cook, P.M. Allan, P. Sutcliffe, Integration of 4D seismic data into the management of oil reservoirs with horizontal well between fluid contacts, *Society of Petroleum Engineers*, SPE No. 83956. Offshore Europe 2003, Aberdeen.

[2] V. Khaidukov, V. Kostinand, V. Tcheverda, The r-solution and its application in linearized waveform inversion for a layered background. In IMA Volume *"Inverse Problems of Wave Propagation"*, eds. G. Chavent, W. Symes, 1997, Springer, New York, pp. 277-294.

[3] V. Kostin, V. Tcheverda, *r-pseudoinverse for compact operators in Hilbert spaces: existence and stability*, J. Inverse and Ill-posed problems., 1995, **3**(2), pp. 131-148.

Travel-time Inversion for 3D Media without of Ray Tracing: Simultaneous Determination of Velocity and Hypocenters

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Abstract

The paper deals with the problem of simultaneous recovery of a velocity model and hypocenters coordinate by first arrivals recorded by seismic network for local earthquakes. It is the classical problem and a lot of efforts are paid to its resolution, especially for last ten years. But, nevertheless, it is still far away from its completion, especially for 3D statements. In comparison with classical tomographic statement necessity to recover source positions introduces additional troubles and increases level of uncertainty. It should be noted that a posteriori estimation of uncertainty is rather memory and time consuming procedure as it claims repeating data inversion and it is the vulnerability of currently used approaches. We propose to perform inversion iteratively by LSQR - based procedures. Now it is common knowledge that these procedures are regularizing ones with number of iterations being regularization parameter. This approach opens a possibility to iterative computation of a posteriori estimation of desired parameters together with inversion procedure itself and, so, does not claim any additional efforts to do this.

First arrivals are treated as an image of some non-linear operator $t = B(\vec{h}, c)$ with a composite domain treated as superposition of two different subsets - finite dimensional set of hypocenters Cartesian coordinate $\vec{h}$ and functional space of wave propagation velocity c. Solution of this equation is searched by means of Newton iterative techniques consisting in resolution of linear operator equations $\gamma \equiv t - B(\vec{h}_k, c_k) = H < \vec{h}_{k+1} - \vec{h}_k > + A < c_{k+1} - c_k >$. These equations are resolved with the help of Pavlis - Booker approach by their splitting on two "independent" linear equations (see paper Pavlis G.L., Booker J.R. "The mixed discrete-continuous inverse problem: Application to the simultaneous determination of earthquake hypocenters and velocity structure" in J. Geophys. Res.,1980. 85, 4801–4810.):

$$\begin{bmatrix} U_1^T \\ U_0^T \end{bmatrix} \gamma = \begin{bmatrix} U_1^T \\ 0 \end{bmatrix} < \vec{h}_{k+1} - \vec{h}_k > + \begin{bmatrix} U_1^T \\ U_0^T \end{bmatrix} A < c_{k+1} - c_k >$$

where U is matrix made of left singular vectors of H while U_1 represents first r of them with r being reasonably chosen rank of H. In order to resolve this equation we start with c_{k+1} recovery from equation $U_0^T \gamma = U_0^T A < c_{k+1} - c_k >$. Its solution is searched by means of LSQR and claims repeated computations of A and A^T . We decline ray tracing procedures to do this but apply finite-difference techniques to numerical resolution of eikonal equation instead. Thus we avoid troublesome procedure of numerical solution of boundary value problem (two-point) ray tracing. Moreover on this way happens to be possible to avoid storage of matrix representation of operator A , but just compute its action and action of A^T by numerical resolution of two Cauchy problems for the same linear system of partial differential equations (linearized eikonal equation). On this way computer cost of the problem is essentially reduced but still claims parallel implementation, especially for 3D heterogeneous media. This approach is tested on synthetic data and applied to inversion of aftershocks data of Chuya 2003 year earthquake (Altai region, Russia). Real data are recorded in Altai region (south of Western Siberia) by temporary and stationary seismic networks of Geophysical Survey of SB RAS.

Keywords: eikonal equation, travel-time inversion, Newton method, iterative regularization, Singular Value Decomposition.

Numerical Study to the Inverse Source Problem with Convection -Diffusion Equation

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Abstract

In this work, a stochastic method named as quantum-behaved particle swarm optimization (QPSO) is used to solve the inverse source problem associated with transient convection-diffusion equation. This equation is intended to model the process of water pollution. The boundary and initial condition of the concentration are assumed to be known, and then identification of the source term becomes a function specification problem. The finite difference method is used as a numerical method for the convection-diffusion equation. The least square method is used to model the inverse problem, which transforms to an optimization problem. Considering the sensitivity to the measurement noise, the Tikhonov regularization method is used to stable the inverse solution. The numerical experiments demonstrate the efficiency and validity of the quantum-behaved particle swarm optimization. Finally, comparison with a deterministic method known as conjugate gradient method (CGM) is also presented in this paper.

Tikhonov Regularization with Sparsity Constraints: Convergence Rates and Exact Recovery

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Abstract

In this talk we consider linear inverse problems with a bounded linear operator $A : \mathcal{H}_1 \to \mathcal{H}_2$ between two separable Hilbert spaces $\mathcal{H}_1$ and $\mathcal{H}_2$,

$$Af = g. \tag{1}$$

We are given a noisy observation $g^\varepsilon \in \mathcal{H}_2$ with $\|g - g^\varepsilon\|_{\mathcal{H}_2} \leq \varepsilon$ and try to reconstruct the solution f of (1) from the knowledge of g^ε.

Moreover, we assume that the operator equation (1) has a solution $f^\dagger$ that can be expressed sparsely in an orthonormal basis $\Psi := \{\psi_i\}_{i\in\mathbb{N}}$ of $\mathcal{H}_1$. In [1], the authors introduce the Tikhonov regularization with sparsity

constraints to obtain a sparse approximate solution $f^{\alpha,\varepsilon}$. They define $f^{\alpha,\varepsilon}$ as the minimizer of the functional

$$\frac{1}{2}\|Af - g^\varepsilon\|^2_{\mathcal{H}_2} + \alpha \sum_{i \in \mathbb{N}} | < f, \psi_i > |, \tag{2}$$

with regularization parameter $\alpha > 0$. In contrast to the classical Tikhonov functional with quadratic penalty this functional promotes sparsity since small coefficients are penalized stronger.

Stability and convergence rates for the functional (2) have been deduced in [4,5]. For a suitable a priori parameter choice rule $\alpha = \alpha(\varepsilon)$ it has been shown that the Tikhonov functional (2) yields a regularization method. If an additional source condition is fulfilled, then the convergence can be obtained with a linear rate.

This talk deals with stability results for the regularization method consisting in the minimization of (2) and it goes beyond the question of convergence rates. We will deduce an a prior parameter choice rule which ensures that the unknown support of the sparse solution $f^\dagger$ is recovered exactly, i.e.

$$\text{support}((< f^{\alpha,\varepsilon}, \psi_i >)_{i\in\mathbb{N}}) = \text{support}((< f^\dagger, \psi_i >)_{i\in\mathbb{N}}).$$

The results which will be presented are a generalization of [3, 8].

The practicability of the deduced parameter choice rule will be demonstrated with an examples from digital holography of particles. Here, the data g are given as sums of characteristic functions convolved with a Fresnel kernel. The measurement of particle size and location amounts to an inverse convolution problem [2, 7].

References:

[1] I. Daubechies, M. Defrise, C. De Mol, *An iterative thresholding algorithm for linear inverse problems with a sparsity constraint*, Communications in Pure and Applied Mathematics, 57(11), pp. 1413-1457, 2004.
[2] L. Denis, D. A. Lorenz, E. Thiébaut, C. Fournier, D. Trede, *Inline hologram reconstruction with sparsity constraint*, Optics Letters, 34(22), pp. 3475-3477, 2009.
[3] J. -J. Fuchs, *Recovery of exact sparse representations in the presence of bounded noise*, IEEE Transactions on Information Theory, 51(10), pp. 3601-3608, 2005.
[4] M. Grasmair, M. Haltmeier, O. Scherzer, *Sparse regularization with l^q penalty term*, Inverse Problems, 24(5): 055020 (13pp), 2008.
[5] D. A. Lorenz, *Convergence rates and source conditions for Tikhonov regularization with sparsity constraints*, Journal of Inverse and Ill-Posed Problems, 16(5), pp. 463-478, 2008.
[6] D. A. Lorenz, S. Schiffler, D. Trede, *Beyond convergence rates: Exact inversion of ill-posed problems with sparsity constraints*, Preprint, 2009.
[7] F. Soulez, L. Denis, C. Fournier, E.Thiébaut, C. Goepfert, *Inverse problem approach for particle digital holography: accurate location based on local optimisation*, Journal of the Optical Society of America A, 24(4): 1164-1171, 2007.
[8] J. A. Tropp, *Just relax: Convex programming methods for identifying sparse signals in noise*, IEEE Transactions on Information Theory, 52(3), pp. 1030-1051, 2006.

On Inverse Scattering for Nonsymmetric Operators

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Abstract

We consider a nonsymmetric operator A_P in $\{L^2(0,\infty)\}^2$. defined by differential expression

$$(A_P u)(x) = Bu'(x) + P(x)u(x), \quad 0 < x < \infty$$

where

$$B = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, P(x) = \begin{pmatrix} p_{11}(x) & p_{12}(x) \\ p_{21}(x) & p_{22}(x) \end{pmatrix},$$

with the domain

$$D = \{u(x) = \begin{pmatrix} u_1(x) \\ u_2(x) \end{pmatrix} \in \{H^1(R_+)\}^2;\ u_1(0) = hu_2(0)\}.$$

An inverse problem of reconstruction of complex-valued coefficients $p_{ij}(x)$ from the scattering data of operator A_P is investigated.

Inverse Problems for Some System of Viscoelasticity via Carleman Estimate

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Abstract

The viscoelastic properties of a human body are very important information for a diagonosis of diseases. In recent years, a non-invasive method to measure these properties, which is called elastography, is developed. In this talk, we will consider a Kelvin-Voigt model, one of the models of viscoelasticity and formulate the inverse problem for this model to determine the viscoelasticity coefficients from the data on subboundary. We will give the uniqueness and conditional stability of this inverse problem under several times measurements. The Carleman estimate which is necessary to prove the stability estimate will be also given.

Error Estimates of Finite Element Methods for Parameter Identifications in Elliptic and Parabolic Systems

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Abstract

This work is concerned with the finite element solutions for parameter identifications in second order elliptic and parabolic systems. The L2- and energy-norm error estimates of the finite element solutions are established in terms of the mesh size, time step size, regularization parameter and noise level. (This is a joint work with Jun Zou.)

A FE-based Algorithm for the Inverse Natural Convection Problem

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Abstract

In this talk, several numerical algorithms for solving inverse natural convection problems are revisited and studied. Our aim is to identify the unknown strength of a time-varying heat source via a set of coupled nonlinear partial differential equations obtained by the so-called finite element consistent splitting scheme. Viewed as an optimization problem, the solutions are obtained by means of the conjugate gradient method. A second order consistent splitting scheme in time involving the direct problem, the adjoint problem, the sensitivity problem and a system of sensitivity functions is used in order to enhance the numerical accuracy of obtaining the unknown heat source function. A spatial discretisation of all field equations is implemented using mixed and equal-order finite element methods. Numerical experiments validate the proposed optimization algorithms that are good an agreement with the existing results.

A Posteriori Error Estimates of Finite Element Methods for Heat Flux Reconstructions

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Abstract

We derive a posteriori error estimates of the finite element methods for heat flux reconstructions using the residual approach. For the stationary inverse problem, we obtain both upper bound and lower bound. It is revealed for the first time that the upper bound depends explicitly on the regularization parameter. Numerical experiments are presented to show the applicability and effectiveness of the error estimator.

For the time dependent inverse problem, we obtain a posteriori error estimates in a simple form which can help guiding the mesh adaptivity in both space and time.

This is a joint work with Jingzhi Li and Jun Zou.

An Adaptive Greedy Technique for Inverse Boundary Determination Problem

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Abstract

The purpose of this paper is to propose a new numerical method for the inverse boundary determination problem of the Laplace equation. The method of fundamental solutions is used for determining an unknown portion of the boundary from the Cauchy data specified on a part of the boundary. Since the resultant matrix equation is badly ill-conditioned, the adaptive greedy technique is employed to choose the source points. Meanwhile, the Tikhonov regularization method is used to solve ill-conditional matrix equation, while the regularization parameter in the Tikhonov regularization method is provided by the L-curve criterion. The numerical results show that our proposed method is effective and stable for high noisy data.

Reconstrcting Electromagnetic Obstacles by the Enclosure Method

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Abstract

We study an inverse boundary value problem for Maxwell's equation. Let $\Omega \subset \mathbb{R}^3$ be a bounded domain with smooth boundary, filled with isotropic electromagnetic medium, characterized by three parameters: the permittivity $\varepsilon(x)$, conductivity $\sigma(x)$ and permeability $\mu(x)$. A perfect magnetic conducting obstacle is a subset D of Ω, with smooth boundary, such that the electric-magnetic field **(E,H)** satisfies the following **BVP** for Maxwell's equation

$$\begin{cases} \nabla \wedge \mathbf{E} = i\omega\mu\mathbf{H}, \quad \nabla \wedge \mathbf{H} = -i\omega\Big(\varepsilon + i\frac{\sigma}{\omega}\Big)\mathbf{E} \ \text{ in } \ \Omega \setminus \o D, \\ \nu \wedge \mathbf{E}|_{\partial\Omega} = f, \\ \nu \wedge \mathbf{E}|_{\partial\Omega} = 0 \end{cases} \tag{0.1}$$

where ν is the unit outer normal vector to the boundary $\partial\Omega \cup \partial D$. Define the impedance map by taking the tangential component of the electric field $\nu \wedge \mathbf{E}|_{\partial\Omega}$ to the tangential component of the magnetic field $\nu \wedge \mathbf{H}|_{\partial\Omega}$. Then our purpose is to retrieve information of the shape of D from the impedance map.

The enclosure method was first introduced by Ikehata [1, 2] to identify obstacles, cavities and inclusions embedded in conductive or acoustic medium. Geometrically, using the property of so called complex geometric optics (CGO) solutions that decay on one side and grow on the other side of a hyperplane, one can enclose obstacles by those hyperplanes.

In [3], the Maxewell's operator was reduced into a matrix Schrödinger operator and vector CGO solutions were constructed to recover electromagnetic parameters. To address the inverse problem of determining an electromagnetic obstacle, we observe that solutions of a non-dissipative Maxwell's equation ($\sigma = 0$) share similar asymptotical behavior to those of Helmholtz equations. Therefore, with CGO solutions at hand, the enclosure method is applicable.

References

[1] M. Ikehata, *The enclosure method and its applications*, Int. Soc. Anal. Comput., 9 (2001), pp. 87-103.
[2] M. Ikehata, *How to draw a picture of an unkown inclusion from boundary measurements. Two mathematical inversion algorithms*, J. Inv. Ill-Posed Prob., 7 (1999), pp. 255-271.
[3] P. Ola, E. Somersalo, *Electromagnetic inverse problems and generalized sommerfeld potentials*, SIAM. J. Appl. Math., 56 (1996), no. 4, pp. 1129-1145.

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5 Direction Information

Directions for International Conference on Inverse Problems

All participants are arranged to stay at the conference hotel:
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On April 25, 2010, Sunday, from 9:00am-9:00pm:

Find some conference staff with signs for "**International Conference on Inverse Problems**", you will be guided to either the airport taxis or the airport shuttle buses.

Taxis:
You may directly take a taxi from the airport to **FengYi Hotel** (丰颐大酒店), it takes about 45-60 minutes (approx. CNY110).

Airport shuttle buses:
The airport shuttle bus runs once every 30 minutes, from 9:00am to the last flight of each day. You should get off the shuttle bus at **Fujiapo Station** (付家坡站), **Wuchang** (it costs CNY30). Then you may take a taxi from **Fujiapo Station** (付家坡站) to **FengYi Hotel** (丰颐大酒店) (approx. CNY15).

2. **From Railway Stations to FengYi Hotel**

You may take a taxi from the **Wuchang Railway Station**, **Hankou Railway Station** or **Wuhan Railway Station** to **Fengyi Hotel** (丰颐大酒店). It takes about 15, 45 and 30 minutes respectively (approx. CNY18, 40 and 35 resp.)

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5. **The map of FengYi Hotel**


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