Finnish-Japanese-Korean Workshop on Inverse Problems / Inverse Days 2011
Abstracts

Arnold, Lilian
University of Würzburg, Germany

Identifiability of conducting objects by electromagnetic measurements in transient eddy current problems

Transient excitation currents generate electromagnetic fields which, in turn, induce electric currents in proximal conductors. In low-frequency applications, the generated electric field can be described by the parabolic-elliptic eddy current equation, an approximation of Maxwell's equations. In this talk, we present a unified variational theory and study existence and uniqueness of solutions of the direct problem. Based on this, we turn to the inverse problem of reconstructing the conductivity from electromagnetic measurements and discuss the identifiability of the conducting domain by the measurement operator.

Auvinen, Harri
University of Helsinki, Finland

An investigation of systematic model error using a quasi-geostrophic weak-constraint 4D-Var system

Even the most sophisticated numerical weather prediction model is not perfect. Although some errors may be entirely random, many will result from systematic misspecification of parameters, or deficiencies in parametrizations. In this work we estimate the covariance structure of systematic error a quasi-geostrophic (QG) model using the Object-Oriented Prediction System (OOPS). Furthermore we demonstrate that a Long-Window Weak-Constraint 4d-Var analysis system is successful in taking model error into account.

Auvinen, Harri
University of Helsinki, Finland

Parallel glottal inverse filtering using MCMC methods

The physiological process of speech production can be divided into two stages: excitation and filtering. The excitation corresponds to the air flow that streams from the lungs and generates oscillations in the vocal folds. The second process, filtering, corresponds to the effects of the vocal tract, that is, the physiological filter that starts at the vocal folds and ends at lips and nostrils, and it is influenced, for example, by the positioning of the tongue and the movement of the lips. The nonlinear inverse problem of glottal inverse filtering (GIF) is to reconstruct both the excitation and the vocal tract filter from recorded voice. In this work we apply Monte Carlo Markov chain (MCMC) -methods to estimate GIF parameters. Furthermore we introduce a concept of parallel glottal inverse filtering using Techila high-performance computing (HPC) environment.

Betcke, Marta
University College London, UK

Image reconstruction from asymmetrically truncated cone beam projections

The mechanical motion of the gantry in conventional cone beam CT scanners becomes a bottle neck of the data acquisition in application with near real time requirements. A possible resolution of this problem, is to replace the moving source detector assembly with static parts, which are electronically activated. An example of such a system is Rapiscan Systems RTT80, real time tomography scanner, featuring a static ring of sources and and axially offset static cylinder of detectors. A consequence of such a design is asymmetrical axial truncation of the collected cone beam projections, resulting, in the sense of integral geometry, in severely incomplete data. In particular, we collect data only a nontrivial fraction of the Tam-Danielsson window, hence the standard cone beam reconstruction techniques do not apply. In this talk we propose a family of multi-sheet rebinning methods for reconstruction from such truncated projections. The proposed methods combine analytical and numerical ideas utilizing linearity of the ray transform to reconstruct data on multi-sheet surfaces, from which the volumetric image is obtained through deconvolution.

Bucataru, Ioan
"Al.I.Cuza" University, Romania

Inverse problems in Finsler geometry: projective and Finsler metrizability

The geometry of a systems of second order ordinary differential equations (SODE)

$$\frac{d^2x^i}{dt^2} + 2G^i\left(x, \frac{dx}{dt}\right) = 0,$$

on some configuration manifold M, is determined by the (differential) properties of functions G^i, and it can be: affine, Riemannian, Finslerian or Lagrangian. In the Finslerian case, functions G^i are 2-homogeneous in $\dot{x} = dx/dt$, and this property allows for a reparameterization of the system. A Finsler function, $F(x, \dot{x})$, is given by a family of Minkovski norms in each tangent space of the manifold.

Within Finsler geometry, one can formulate the following two inverse problems. Find necessary and sufficient conditions for a homogeneous system of SODE such that its solutions coincide with the solutions of the Euler-Lagrange equations for:

PM) a Finsler function F, the solutions coincide as oriented point sets,

FM) the energy F^2 of a Finsler function F, the solutions coincide as parameterized curves.

PM is also known as the Finslerian version of Hilbert's fourth problem. If $G^i = 0$, it reduces to the original Hilbert's fourth problem: "find the metrics with the property that the shortest curve joining two points is the straight line segment between them".

In this talk, I present a reformulation of the above two problems in terms of partial differential operators that acts on semi-basic 1-forms, discuss the relation between the two problems, and provide examples of systems of SODE that satisfy or not PM or FM.

References

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Correia, Teresa
University College London, UK

Split operator method for fluorescence diffuse optical tomography using functional and anatomical priors

Fluorescence diffuse optical tomography (fDOT) is a relatively new optical imaging modality that uses fluorescent markers that accumulate in specific regions, to monitor cellular and subcellular functional activity. Currently, most of the fDOT systems are used for small animal research.

In this talk I will show how nonlinear anisotropic diffusion regularisation that incorporates anatomical prior information can provide images with higher quality than standard regularisation methods. I will also introduce splitting methods that are used to speed up the image reconstruction process. Simulations, experimental phantom and mouse data are used to evaluate the performance of the reconstruction algorithm.

Dahl, Matias
Aalto University, Finland

Electromagnetic mediums with a double light cone structure

If we are given an electromagnetic medium we can compute the speed of a propagating signal. For example, in homogeneous medium we can compute the phase velocity of a plane wave. The corresponding inverse problem is as follows: If we know the behaviour of electromagnetic signal speed in all possible directions, what can we say about the medium?

This problem has a natural formulation on a 4-manifold representing spacetime. Then the Fresnel surface describes propagation speed in an electromagnetic medium. For example, in an isotropic medium the Fresnel surface is a Lorentz light cone. Conversely, A. Favaro and L. Bergamin have proven that isotropic medium is the only medium with this property (in a suitable class of linear mediums). The purpose of this talk is to discuss the analogous question when the Fresnel surface is the union of two Lorentz light cones. We know that uniaxial crystals like calcite is one example. However, we find two additional medium classes with the same property.

Delbary, Fabrice
Technical University of Denmark, Denmark

Reconstruction of conductivities in three dimensions

The inverse problem of recovering an electrical conductivity distribution in a bounded domain by means of the Dirichlet-to Neumann map (or Voltage-to-Current map) was first formulated by Calderón in 1980. Electrical Impedance Tomography (EIT), one of the numerous applications

of this problem, is an emerging imaging technology with applications in medicine or geosciences, among others. In late 1980s, the theoretical foundation of a direct quantitative method for the Calderón problem was formulated (J. Sylvester, G. Uhlmann, R. G. Novikov, A. Nachman). The reconstruction algorithm, making use of ideas from inverse scattering theory, applied to the electrical potential equation reformulated as a Schrödinger equation, has been successfully implemented in the 2D case (S. Siltanen, J. Mueller, D. Isaacson) and in the 3D case for radial symmetric conductivities (J. Bikowski, K. Knudsen, J. Mueller). In this talk, we consider general conductivities in the unit ball and show the feasibility of a 3D implementation of the algorithm. The reconstruction algorithm and its possible simplifications is first introduced. Afterwards, the implementation is presented and then followed by numerical reconstructions.

Durech, Josef
Charles University in Prague, Czech Republic

Inversion of asteroid visual lightcurves and thermal infrared data

I will present a new method that combines asteroid photometry in visible light with thermal infrared (IR) radiometry to derive physical models of asteroids. Traditionally, the thermal properties of asteroids, their size and reflectivity were derived using simple models assuming that the asteroid is spherical. More recently, the convex shapes of asteroids from lightcurve inversion were combined with thermal IR to derive the thermophysical parameters. The new general method uses the same representation as the standard lightcurve inversion but includes both data types at once and optimizes all relevant physical parameters. This way the full physical model (shape, size, spin vector, scattering properties of the surface, surface roughness, thermal inertia) is created. The thermal emission is computed by solving 1D heat diffusion on the surface. The first results, their comparison with real asteroids, and the future development of the method will be presented.

Gaitan, Patricia
IUT d'Aix-en-Provence, France

Inverse problems for coupled parabolic systems by measurements of one component

We present here some recent results obtained for coupled parabolic systems concerning inverse problems of reconstruction of coefficients and controllability results.

We consider systems of parabolic equations with first and zeroth coupling and establish a Carleman estimate by extra data of only one component without data of initial values. We then apply the Carleman estimate to inverse problems of determining several coefficients (one in each equation) by observations in an arbitrary subdomain over a time interval of only one component and data of all the components at a fixed positive time θ over the whole spatial domain. The main results are Lipschitz stability estimates for the inverse problems.

We can also derive from our Carleman estimates approximate controllability results and null controllability results.

Haario, Heikki
Lappeenranta University of Technology, Finland

Inverse problems of weather and climate

Hamilton, Sarah
Colorado State University, USA

A direct nonlinear D-bar reconstruction algorithm for complex admittivities in the 2-D EIT problem

Electrical Impedance Tomography (EIT) is a fairly new, portable, relatively inexpensive, real-time imaging system that requires no ionizing radiation. Electrodes are placed at the surface of a body and low frequency and amplitude current is applied on the electrodes. The currents penetrate the body to varying depths before returning to the electrodes where the voltage value on each electrode is measured. By applying a basis of current patterns, one can obtain enough information to create a picture of the complex admittivity distribution (conductivity along with permittivity) in the plane of the electrodes. Previous direct solvers have focused on the inverse conductivity problem and have not reconstructed the permittivity component. Reconstructing permittivity may allow doctors to solve problems that were very difficult with a conductivity-only approach such as detecting tissue necrosis in transplant organs and distinguishing between a pneumothrorax and hyperinflation. In 2000, Elisa Francini presented a nearly constructive proof that was the first approach using D-bar methods to solve the full nonlinear problem for complex once-differentiable admittivities. In this talk I will describe the additions we have made to turn her proof into a direct D-bar reconstruction algorithm that solves the full nonlinear admittivity problem in 2-D. I will present reconstructions for simulated data.

Hauptmann, Andreas
TU München, Germany

A total variation method for x-ray tomography based on a discontinuous Galerkin approximation

Total variation regularization can improve the quality of x-ray tomographic reconstructions. It is known that the minimization of the total variation produces piecewise constant solutions, since it allows jumps in the reconstructions and thereby recovers sharp edges, but it is difficult to handle due to non-linearity and because the objective to be minimized is not classically differentiable. Therefore several methods have been proposed for solving a regularization of the total variation, e.g. by smoothing the non-differentiable part. Instead of smoothing we propose an algorithm based on a variational formulation of the total variation functional and a discretization with respect to a basis of piecewise constant functions. The main interest is to get useful images from sparsely sampled projection data. The results show, that the proposed method produces nicely piecewise constant reconstructions from noisy sparse data sets. The project is a joint work with Keijo Hämäläinen, Aki Kallonen, Esa Niemi and Samuli Siltanen from University of Helsinki.

Hyvönen, Nuutti
Aalto University, Finland

Electrical impedance tomography with two electrodes

Ikehata, Masaru
Gunma University, Japan

The enclosure method in inverse obstacle scattering

Isozaki, Hiroshi
University of Tsukuba, Japan

Introduction to the generalized arithmetic surface

Kaasalainen, Mikko
Tampere University of Technology, Finland

Simple solutions in $\mathbb{R}^2$ as useful analogies of inverse problems of generalized projections in $\mathbb{R}^3$

Kako, Takashi
University of Electro-Communications, Japan

Designing the vocal tract shape of vowels based on resonance poles

Kalke, Martti
University of Helsinki, Finland

Adaptive constrained least squares reconstruction for sparse imaging

A novel reconstruction technique, called WIRT, for sparse tomographic imaging is introduced. This method applies a varying constrained least square filter with regularization method based on total variation. The WIRT algorithm is selectively applying regularization in the frequency domain where the frequency component values are more difficult to estimate because of insufficient imaging geometry and noise. Based on the qualitative and quantitative comparison against state-of-the-art methods, the WIRT method appears to be superior reconstruction algorithm in sparse imaging scene, specially when noise is present. Since the WIRT reconstruction is implemented in the frequency domain, the likelihood and a priory information can be partly separated. This separation enables computationally more effective iteration procedure than conventional iterative reconstruction methods.

Kang, Hyeonbae
Inha University, Korea

Generalized polarization tensors, imaging, and other applications

The notion of Generalized Polarization Tensors (GPT) appear naturally in various areas such as asymptotics of electric potentials at infinity, low frequency asymptotics of waves and effective properties of dilute composites. In this talk we will discuss some general properties of GPTs and then review some recent applications to imaging.

Kim, Kyoungsun
Inha University, Korea

A gradient estimate for solutions to parabolic equations with discontinuous coefficients

Li-Vogelius and Li-Nirenberg gave a gradient estimate for solutions of strongly elliptic equations and systems of divergence forms with piecewise smooth coefficients, respectively. The discontinuities of the coefficients are assumed to be given by manifolds of codimension 1, which we called them *manifolds of discontinuities*. Their gradient estimate is independent of the distances between manifolds of discontinuities. In this talk, we gave a parabolic version of their results. That is, we gave a gradient estimate for parabolic equations of divergence forms with piecewise smooth coefficients. The coefficients are assumed to be independent of time and their discontinuities are likewise the previous elliptic equations. As an applications of this estimate, we also gave a pointwise gradient estimate for the fundamental solution of a parabolic operator with piecewise smooth coefficients. The both gradient estimates are independent of the distances between manifolds of discontinuities. This is a joint work with Jishan Fan, Sei Nagayasu and Gen Nakamura.

Kolehmainen, Ville
University of Eastern Finland, Finland

Approximate marginalization of uninteresting distributed parameters in inverse problems

Kurylev, Yaroslav
University College London, UK

Electro-magneto-encephalography for the three-shell model

In this talk (joined with A. S. Fokas) we consider the problem of the identification of a continuously distributed neuronal current inside the brain within the framework of the three-shell model. It is shown that, under the condition of the L^2 minimality of the current, it is uniquely determined by from paired electroencephalography and magnetoencephalography.

Kwon, Kiwoon
Dongguk University, Korea

Remarks on nonuniqueness of inverse problems with anisotropic anomaly and cloaking

Unique determination of inverse problems including electrical impedance tomography (EIT) and inverse scattering problem attracted many mathematical researchers in these area, resulting in many kinds of uniqueness results. However, nonuniqueness examples are also shown for anisotropic conductivities in EIT. This nonuniqueness results are extended to classify nonuniqueness conductivity classes for given Dirichlet-to-Neumann map. Recently, based on these nonuniqueness classification results, cloaking devices is theoretically suggested and implemented in simple settings. We add the author's nonuniqueness result for EIT and inverse scattering problem with anisotropic anomaly and analyze the meaning of the nonuniqueness result with respect to cloaking.

Laakso, Teemu
Tampere University of Technology, Finland

Inverse Poincaré problem

The phase space of an integrable Hamiltonian system H_0 is foliated by invariant tori. The fundamental problem of dynamics, according to Poincaré, is to find out what happens to these tori in a perturbed system $H = H_0 + \varepsilon H_1$. The Kolmogorov-Arnold-Moser theory gives an answer, and paints a qualitative picture which applies to near-integrable Hamiltonians in general.

In the inverse Poincaré problem, a near-integrable system H is given, and an underlying integrable Hamiltonian H_0 is sought. We discuss how to solve the inverse problem by torus construction, i.e., by numerically (re)constructing invariant tori for H.

Lasanen, Sari
University of Oulu, Finland

Uncertainties of noise distributions in statistical inverse theory

Consider the equation $Y = L(X) + \varepsilon$, where X represents the unknown, L represents the direct theory and ε represents random noise. The probability distribution of noise ε is not always exactly known. In statistical inverse theory, it is possible to model the uncertainties of the noise distribution with hierarchical models. We discuss the simple case of zero mean Gaussian noise, whose covariance structure is known up to a multiplicative constant. The posterior distribution of the unknown given Y turns out to be very simple in certain infinite-dimensional cases.

Lassas, Matti
University of Helsinki, Finland

Schrödinger's hat and the cloaked wave amplifiers via transformation optics

The advent of transformation optics and metamaterials has made possible devices producing extreme effects on wave propagation. Here we give theoretical designs for devices, Schrodinger hats, acting as invisible concentrators of waves. These exist for any wave phenomenon modeled by either the Helmholtz or Schrodinger equations, e.g., polarized waves in electromagnetism, pressure waves in acoustics and matter waves in quantum mechanics, and occupy one part of a parameter space continuum of wave-manipulating structures which also contains standard transformation optics based cloaks, resonant cloaks and cloaked sensors. For electromagnetic, acoustic, and quantum mechanical Schrodinger hats, the resulting centralized wave is a localized excitation. We discuss also the possible solid state implementations. The presented results are done in collaboration with A. Greenleaf, Y. Kurylev, U. Leonhardt, and G. Uhlmann.

Laukkanen, Anne-Maria
University of Tampere, Finland

Phonation related vocal fold loading as a challenge for imaging and quantification

Voice disorders form a major occupational, communicative and economic problem. There is evidence that these disorders are to a large extent caused by phonation related excessive loading posed on the vocal fold tissue. Estimations of the amount of loading have been made based on various acoustic parameters of the human voice and experiments with excised larynges and vocal fold models. True quantification of biomechanical loading (e.g. measurement of impact or shear stress) is difficult or impossible in humans. Effects of loading have been studied by visual inspection of the vocal fold surface or by registering subjective sensations. Methods for reliable quantification of vocal loading and its effects on the tissue would be highly needed but

very difficult to obtain e.g. due to the problems related to invasiveness and risks for subjects. Noninvasive possibilities might be found from electrical impedance tomography and optical near infrared tomography. Both methods however offer difficult challenges e.g. due to the fact that the structure of the larynx is complicated: vocal folds are small in size (in the fundamental frequency range of speech the length is ca 1.5-2 cm, thickness < 1 cm) and located inside many layers of tissue, whose material properties differ from each other and are not even well known. Furthermore, the vocal folds vibrate at a high speed (in conversational speech ca 100 Hz in males, 200 Hz in females, and in loud speech 200-500 Hz). Inverse mathematical methods may offer a way of improving the noninvasive imaging of the vocal folds and, thus, also the noninvasive estimation of the loading stresses and their effects on tissue (changes in blood flow, quantity and quality of fluid in tissue and temperature of the tissue). Such methodological improvements could increase knowledge of the biomechanics and consequences of vocal loading and help in developing dosimetric methods to estimate the individual risk of getting a voice disorder. That in turn would have a great influence in preventing serious voice problems with vocal fold lesions.

Lee, Chang-Ock
KAIST, Korea

Absolute conductivity reconstruction in magnetic resonance electrical impedance tomography (MREIT)

Magnetic resonance electrical impedance tomography (MREIT) is a conductivity imaging modality providing high-spatial resolution. During the injection of currents using several pairs of surface electrodes, we extract a component of the magnetic flux density, so called B_z, induced by the injected current using an MR scanner. Using the non-linear relation between B_z data and conductivity, there have been numerous theories and experimental results for imaging reconstruction. In the stage of *in-vivo* animal or human experiments, conductivity value estimation or absolute conductivity reconstruction become one of important research issues for the diagnosis. In this talk, we discuss several issues for conductivity reconstruction for the conductivity value estimation and absolute conductivity imaging in MREIT.

Lee, Hyundae
Inha University, Korea

Analysis of the anomalous localized resonance

We give a mathematical justification of the anomalous localized resonance (ALR). We consider the conductivity problem with a source term in a structure with a layer of metamaterial. Using layer potentials and symmetrization techniques, we give a necessary and sufficient condition on the source term for the ALR to take place. This condition is written in terms of the Newton potential of the source term. In the case of concentric disks, we obtain such a condition even more explicitly. Using the condition, we are able to show that for any source supported outside the anomalous resonance region the ALR does not take place, and for the dipole or quadrapole sources inside the anomalous resonance region the ALR take place as the loss parameter of the metamaterial structure goes to zero. Moreover, we provide a weak condition for general source terms under which the ALR takes place.

This is a joint work with Habib Ammari, Giulio Ciraolo, Hyeonbae Kang and Graeme W. Milton.

Lee, June-Yub
Ewha Womans University, Korea

Non-uniform fast Fourier transformation (NUFFT) and magnetic resonance imaging (MRI) technique

A MRI hardware is able to acquire the Fourier transform of proton density of a specimen at selected points in the frequency domain. In most clinical systems, the device is designed to acquire Fourier sampling signal on a uniform Cartesian mesh, from which a standard FFT can be used for image reconstruction. However, nonuniform data sampling techniques are much better suited for fast data acquisition, motion correction, and functional MRI and a fast MRI reconstruction method usually requires some form of Non-Uniform Fast Fourier Transformation (NUFFT). We have developed a simple version of the type 1, type 2, and type 3 nonuniform FFT and also constructed a fast algorithm for the discrete sinc and sinc^2-transforms. The type 3 NUFFT allows the evaluation of MRI signal in the presence of a field inhomogeneity and the Fast sinc and sinc^2-transformation also accelerate fairly broad class of signal and image processing algorithms including MR reconstruction algorithm.

Lehtikangas, Ossi
University of Eastern Finland, Finland

Modeling boundary measurements of scattered light using the corrected diffusion approximation

Non-invasive boundary measurements of light scattered by tissues are important for biomedical applications. For example, in diffuse optical tomography, one seeks to reconstruct the optical properties within tissues from light transport measurements at the surface of the domain. In order to reconstruct a tomographic image, a mathematical model for light propagation inside the object is needed. The conventionally used model, the diffusion approximation to the radiative transport equation, does not model light propagation accurately close to the boundaries where the measurements are taken.

In this work, we implement the corrected diffusion approximation [1] in two spatial dimensions. In the approach, an additive correction term is computed for the diffusion approximation at the boundary based on asymptotic analysis of the radiative transport equation. Expansions in plane wave solutions are used to compute boundary condition coefficients of the diffusion approximation and the boundary correction term. Finite element method is used to solve the diffusion approximation. We show that the corrected diffusion approximation models boundary measurements substantially better than the conventional diffusion approximation in comparison to numerical solutions of the radiative transport equation.

This is a joint work with Tanja Tarvainen and Arnold D. Kim.

References

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Lim, Mikyoung
KAIST, Korea

Enhancement of near-cloaking using multilayer structures

In this talk, we discuss a method of constructing very effective near-cloaking structures for the conductivity and the scattering problem. These new structures are, before using the transformation optics, layered structures and are designed such that their first Generalized Polarization Tensors or scattering coefficients vanish. Any target inside the cloaking region has near-zero boundary or scattering cross section measurements. We show analytically and numerically that this new multilayer structures significantly enhance the cloaking effect for the conductivity and the Helmholtz equations. We also numerically show that this new construction is quite robust with respect to random fluctuations of the material parameters around their theoretical values.

Liu, Shitao
University of Helsinki, Finland

On recovering sound speed and an initial condition for the wave equation

We consider a problem of recovering the sound speed and an initial condition for wave equations which is motivated from the thermoacoustic imaging model. We will also show the connection between such a problem and the classical inverse hyperbolic problem with a single measurement.

Nakamura, Gen
Hokkaido University, Japan

Reconstruction schemes for diffusion equations

In this talk reconstruction schemes for active thermography and time resolved diffusive optical tomography to identify unknown inclusions and their physical properties are given. The measured data are Neumann to Dirichlet map and Robin to Neumann map, respectively. By defining some indicator functions via the measured data with some inputs, the identifications are done by looking at the behavior of the indicator functions. The underlying analysis is the shory time asymptotic of fundamental solution of diffusion equations with discontinuous coefficients.

Nakata, Susumu
Ritsumeikan University, Japan

Inclusion detection in electrical impedance tomography using localized boundary measurements and its stabilization

The objective of this study is to develop an algorithm for detecting electrical inclusions in a body using boundary data given on a portion of the surface. In our method, the positions of the inclusions are estimated from localized Dirichlet-to-Neumann map based on the idea of the hyperbolic geometry. The algorithm is equipped with a stabilizer which moderates the ill-posedness specific to the electrical impedance tomography. Our numerical experiments of inclusion detection in a three-dimensional body show that the algorithm gives a good estimation of the positions of the inclusions and the stabilizer effectively removes the influence of measurement errors.

Neumayer, Markus
Graz University of Technology, Austria

Accelerated Bayesian inversion and calibration for electrical tomography

The Bayesian inversion of measurement data for the solution of inverse problems forms an attractive though computational expensive approach to gain statistical knowledge about the quantity of interest given the measured data and the model.

This talk covers the issue of accelerating Markov chain Monte Carlo (MCMC) methods by the use of fast computational techniques as well as approximation techniques. Further the issue of model errors and calibration is discussed. Examples are demonstrated for the inverse problem of Electrical Capacitance tomography (ECT). A forward map framework maintaining Green's functions is presented taking computational advantage of the self adjoint boundary value problem. The framework features several advantageous computational techniques including fast Jacobian and transpose of Jacobian operations as well as exact low-rank updates using the Woodbury identity. Low-rank updates allow the efficient implementation of a Gibbs sampler enabling the generation of independent output samples with the same frequency similar to nonlinear deterministic methods. Different approximation techniques are presented which allow an acceleration of the solution process in combination with the Delayed acceptance version of the Metropolis Hastings algorithm (DAMH).

The second part of the talk covers the issue of model errors and the effective use of calibration measurements to correct the forward map. Calibration strategies are reviewed in the Bayesian sense where the calibration variables are consequently treated as additional unknowns. Finally a stochastic forward map approach is investigated, which allows the incorporation of knowledge about the error of the forward map to quantify the error of the computer model.

Oksanen, Lauri
University of Helsinki, Finland

Solving an inverse obstacle problem for the wave equation by using the boundary control method

We consider boundary measurements for the wave equation on a bounded domain $M \subset \mathbb{R}^2$ or on a compact Riemannian surface, and introduce a method to locate a discontinuity in the wave speed. Assuming that the wave speed consist of an inclusion in a known smooth background, the method can determine the distance from any boundary point to the inclusion. In the case of a known constant background wave speed, the method reconstructs a set contained in the convex hull of the inclusion and containing the inclusion. Even if the background wave speed is unknown, the method can reconstruct the distance from each boundary point to the inclusion assuming that the Riemannian metric tensor determined by the wave speed gives simple geometry in M. Computationally the method consists of solving a sequence of linear equations. We present some numerical results.

Orispää, Mikko
Sodankylä Geophysical Observatory, Finland

Linear inverse problem solver utilizing GPUs

We introduce a method and R[1] package RLIPS for solving linear stochastic linear inverse problems utilizing the computational power of the Graphics Processing Units present in personal computers. RLIPS is is written using R, C99 and OpenCL[2]. With OpenCL it is relatively easy to program parallel computation applications that put the hundreds of computational cores

[1] R is free software environment for statistical computing and graphics, see www.r-project.org
[2] Open Computing Language, see http://www.khronos.org/

found in modern GPUs into an effective use. The development of RLIPS is part of the EISCAT 3D project.

Piiroinen, Petteri
University of Helsinki, Finland

Fractional Brownian motion and statistical inversion

We study the problem of estimating the *Hurst parameter* from a finite and discrete sample of fractional Brownian motion. We formulate the problem as a statistical inverse problem and we describe the *a posteriori* distribution of the Hurst parameter.

We show the *Strong Law of Large Numbers (SLLN)* for the quadratic form appearing in the *a posteriori* distribution. With the help of this SLLN we show the *almost sure asymptotic normality* for the *a posteriori* distribution.

This is joint work with Lassi Päivärinta.

Poisson, Olivier
Universite de Provence, France

Inverse problem for time-dependent singular heat conductivities

We consider the inverse boundary value problem arising from the equation of heat conduction. The conductivity depends on time and is spatially discontinuous.

We define an ansatz and show it is near the exact solution of the parabolic equation. Then we obtain the asymptotic behaviour of an indicator function depending on a large parameter. This gives us a reconstruction method for the conductivity.

Seiskari, Otto
Aalto University, Finland

Locating multiple inclusions from sweep data of electrical impedance tomography

Sweep data of EIT is a recent concept associated with a special two-electrode measurement configuration. In this talk, a method for locating small inclusions of different conductivities in an otherwise homogeneous disk-shaped object from noisy sweep data is presented. The positions of the inclusion are tracked by the poles of a complex Laurent-Pade approximant that reproduces the sweep data. This approach is based on a recent paper by Martin Hanke, where a similar algorithm is devised for a related novel EIT measurement, the backscatter data. As a new result, it is shown how certain information about the sizes and conductivities of the inclusions can be extracted from sweep data. The performance of the method is demonstrated by numerical experiments.

Seo, Jin Keun
Yonsei University, Korea

Electrical tissue property imaging

Cross-sectional imaging of conductivity and permittivity distributions inside the human body has been actively investigated in impedance imaging areas including electrical impedance tomography (EIT), magnetic induction tomography (MIT) and microwave tomography (MT). Since the conductivity and permittivity values exhibit frequency-dependent changes, it is worthwhile to perform spectroscopic impedance imaging from almost dc to hundreds of MHz. To probe the human body, we may inject current in EIT or apply electromagnetic field in MIT and MT. In all of these methods, measured data are available on the boundary or exterior of the body unless we invasively place sensors inside the body. Image reconstruction problems using external measurement are ill-posed. Noting that an MRI scanner can noninvasively measure magnetic fields inside the human body in a form of cross-sectional image, impedance imaging methods using MRI have been lately proposed. Magnetic resonance electrical impedance tomography (MREIT) performs conductivity imaging at dc or below 1∼kHz by externally injecting current into the human body, and MR electrical property imaging (MREPT) produces both conductivity and permittivity images at the Larmor frequency of 126 MHz using a 3∼T MRI scanner based on B1-mapping techniques. Since measured data inside the imaging object are available in MREIT and MREPT, we may formulate well-posed image reconstruction problems. In this talk, we present the latest techniques in EIT, MREIT, and MREPT and provide images of electrical tissue properties which change with frequency.

Seppänen, Aku
University of Eastern Finland, Finland

Electrical impedance tomography imaging of larynx

Electrical impedance tomography (EIT) is an imaging modality based on non-invasive electrical measurements. In biomedical applications of EIT, an array of electrodes is attached on skin of a person. Weak alternating currents are injected through chosen electrodes and the resulting potentials are measured on several electrodes. This procedure is repeated using various current injection patterns. Based on the collected current and potential data, the internal three-dimensional (3D) conductivity distribution is reconstructed. The biomedical applications of EIT include e.g. monitoring of ventilation and diagnosing breast cancer. With the aid of EIT, it might also be possible to get information on human larynx: EIT could perhaps serve as a tool for imaging the vocal foldÕs movement during speech production, and for estimating the physiological changes in the vocal fold tissue caused by vocal loading. This information could be utilized for detecting and quantifying vocal loading (i.e. getting estimates of stresses acting upon the tissue) and measuring the consequences of vocal loading (i.e. changes in the tissue). In this paper, the feasibility of EIT for imaging of the larynx is studied. Especially, the computational challenges associated with the complex internal structure of larynx are considered.

This is joint work with A. Nissinen, V. Kolehmainen, S. Siltanen and A-M Laukkanen.

Simon, Martin
University of Mainz, Germany

Multilevel MCMC reconstruction of heterogeneous microstructure

In this talk we consider current-to-voltage maps arising in the complete electrode model of impedance tomography. A probabilistic representation in terms of reflected diffusion processes and their boundary local times is presented. Furthermore, we discuss the numerical computation of current-to-voltage maps by a Monte Carlo method derived from this representation. Finally,

we demonstrate the applicability of our approach within a multilevel Bayesian MCMC algorithm for the reconstruction of heterogeneous microstructure.

Tanuma, Kazumi
Gunma University, Japan

Perturbation of phase velocity of Rayleigh waves in anisotropic elastic media with orthorhombic principal part

We present a first-order perturbation formula for the phase velocity of Rayleigh waves that propagate along the free surface of a homogeneous anisotropic elastic half-space, the elasticity tensor of which has a principal part that is orthorhombic. The remaining (perturbative) part of the elasticity tensor can be arbitrarily anisotropic. The perturbation formula is given to the shift of phase velocity of Rayleigh waves from its corresponding value for the comparative orthorhombic medium. As an application of the perturbation formula, we examine the possibility of determination of the initial stress by boundary measurement of phase velocities of Rayleigh waves. Our present theory will be applicable, for instance, to directional fiber-reinforced composite materials (modeled as transversely-isotropic homogeneous elastic media with strong anisotropy) when the wave-length of the propagating wave is much longer than the fiber diameter. This is a joint work with C.-S. Man and W. Du (University of Kentucky, USA).

Toivanen, Jussi
University of Eastern Finland, Finland

Thermal tomographic imaging of uninsulated targets

In thermal tomography, the thermal properties of a target are estimated as spatially distributed parameters based on surface measurements of heat transfer. The estimated distributions can be used to detect air bubbles, cracks and other manufacturing defects that alter thermal properties. Therefore, thermal tomography can be used for non- destructive testing of targets that withstand moderate temperature changes.

In the measurement setup, the target is sequentially heated at different surface heating locations and the induced temperature evolutions are measured at multiple surface measurement locations. The estimation of thermal properties as distributed parameters from these measurements is an ill-posed inverse boundary value problem.

In [V. Kolehmainen et al., Int. J. of Heat and Mass Transfer, 50 (2007) 5150-5160], it was demonstrated with simulations that thermal tomographic imaging of thermally insulated targets is feasible. In this presentation, we discuss thermal tomography and the extension of computational methods to imaging of uninsulated targets.

This is a joint work with V. Kolehmainen, T. Tarvainen, H.R.B. Orlande and J.P. Kaipio.

Viikinkoski, Matti
Tampere University of Technology, Finland

Asteroid shape reconstruction from multiple data sources

We present a new parametric representation for surfaces, capable of modelling non-starlike shapes. As examples of our approach, we present new models of Kleopatra (from photometry, adaptive optics and interferometry) and Hermione.

Yamaguchi, Takao
University of Tsukuba, Japan

Collapsing manifolds and inverse spectral problems

In this talk, we consider the inverse spectral problem in the moduli space of closed Riemannian manifolds with uniformly bounded sectional curvatures and diameters. This is recent joint work with Yaroslav Kurylev and Matti Lassas.

Yamamoto, Masahiro
University of Tokyo, Japan

Recent uniqueness results by partial Cauchy data for 2-dimensional stationary equations

We discuss the general two-dimensional elliptic equation and the isotropic Lame system. I will survey recent uniqueness results in recovering coefficients by partial Cauchy data on arbitrary subboundary.

Yoon, Jeong-Rock
Clemson University, USA

Sensitivity analysis for magnetic resonance elastography

Magenetric resonance elastography (MRE) is a hybrid imaging technique to quantify the stiffness of soft tissue, which is targeting early stage cancer detection. The MRE data acquired can be thought of a solution of Helmholtz equation with physical parameters such as frequency, stiffness contrast, and size of inclusion. In this talk, we investigate the dependence of solution with respect to the given parameters and try to answer the smallest inclusion that can be detected by MRE technique. It has been believed among experimentalists that the smallest detectable size is 5mm in diameter, and our mathematical analysis shows it is matching to their expectation.

Åkerblom, Markku
Tampere University of Technology, Finland.

A quantitative method for analysis of single tree LIDAR-measurements

We present a new quantitative method for analysing single trees from LIDAR measurements. The measurements produce point clouds which are samples of the tree surface and the problem is to reconstruct the surface from the samples. Our method produces a cylinder model of the surface which can be used to compute for example the total volume and the branch size distribution of the tree. The cylinder model also contains information about the specific tree structure.

The presented method is based on a topological approach, which starts by defining spherical neighbourhoods of the sample points in order to create a cover for the point cloud. The cover is used together with geometrical characterization to break down the sample point cloud into parts each of which present a part of the tree that can be approximated as a cylinder. Least-squares fitting is used to find a suitable cylinder for each part separately.

This is joint work with Pasi Raumonen and Mikko Kaasalainen.