(as of December 8, 2017)

Recovering a Riemannian metric from least-area data

Tracey Balehowsky
University of Helsinki

Abstract

In this talk, we address the following question: Given any simple closed curve γ on the boundary of a Riemannian 3-manifold (M, g), suppose the area of the least-area surfaces bounded by γ are known. From this data may we uniquely recover g?

In several settings, we show that the answer is yes. In fact, we prove both global and local uniqueness results given least-area data for a much smaller class of curves on the boundary. We demonstrate uniqueness for g by reformulating parts of the problem as a 2-dimensional inverse problem on an area-minimizing surface. In particular, we relate our least-area information to knowledge of the Dirichlet-to-Neumann map for the stability operator on a minimal surface.

Broadly speaking, the question we address is a dimension 2 version of the classical boundary rigidity problem for simply connected, Riemannian 3-manifolds with boundary, in which one seeks to determine g given the distance between any two points on the boundary. We will also briefly review this problem of boundary rigidity as it relates to aspects of our question of recovering g from knowledge of areas.

This is joint work with S. Alexakis and A. Nachman.

Implementation of enclosure method for p-Laplacian

Tommi Brander
Technical University of Denmark, Denmark

Abstract

Enclosure method of Ikehata is a method of detection the convex hull of an inclusion by using solutions which focus energy on a half-space, and then detecting how far the half-space is from a perturbation in conductivity. The presentation discusses the implementation of the method for the nonlinear p-Laplace equation and the results it gives. Previously, Brander, Kar and Salo have proven that the method should work also in the nonlinear setting. The nonlinearity of the equation makes implementing the forward problem solver nontrivial.

Shearlet-based regularization in sparse dynamic tomography

Tatiana Bubba
University of Helsinki

Abstract

Classical tomographic imaging is soundly understood and widely employed in medicine, nondestructive testing and security applications. However, it still offers many challenges when it comes to dynamic tomography. Indeed, in classical tomography, the target is usually assumed to be stationary during the data acquisition, but this is not a realistic model. Moreover, to ensure a lower X-ray radiation dose, only a sparse collection of measurements per time step is assumed to be available. With such a set up, we deal with a sparse data, dynamic tomography problem, which clearly calls for regularization, due to the loss of information in the data and the ongoing motion. We propose a 3D variational formulation based on 3D shearlets, where the third dimension accounts for the motion in time, to reconstruct a moving 2D object. Results are presented for real measured data and compared against a 2D static model, in the case of fan-beam geometry.

Hierarchical Ensemble Kalman Inversion

Neil Chada
University of Warwick, United Kingdom

Abstract

The use of ensemble methods to solve inverse problems is attractive because it is a derivative-free methodology which is also well-adapted to parallelization. In its basic iterative form the method produces an ensemble of solutions which lie in the linear span of the initial ensemble. Choice of the parameterization of the unknown field is thus a key component of the success of the method. We demonstrate how both geometric ideas and hierarchical ideas can be used to design effective parameterizations for a number of applied inverse problems. In particular we show how hierarchical methods can be used to learn key parameters in continuous fields, such as length-scales, resulting in improved reconstructions.

Subspace Accelerated MCMC on Function Spaces

Tiangang Cui
Monash University, Australia

Abstract

Many inference problems require exploring the posterior distribution of high-dimensional parameters, which in principle can be described as functions. We introduce a family of operator-weighted MCMC samplers that can adapt to the intrinsically low rank and locally complex structure of the posterior distribution while remaining well defined on function space. Posterior sampling in a nonlinear inverse problem and a conditioned diffusion process are used to demonstrate the efficiency of these dimension-independent operator-weighted samplers.

Directional Regularization for CT Reconstruction

Yiqiu Dong
Technical University of Denmark, Denmark

Abstract

In this talk, I will introduce a new high-order anisotropic regularization based on the total generalized variation (TGV), which is very useful for applications with strong directional information. I will show that it has the same essential properties as TGV. With automatic direction estimators, we demonstrate the improvement of using directional TGV compared to standard TGV. Numerical simulations are carried out for X-ray tomography reconstruction.

Convergence of seismic Full Waveform Inversion and extension to Cauchy data

Florian Faucher
INRIA Magique 3D, LMAP, Pau Univ.

Abstract

We study the seismic inverse problem associated with the time-harmonic wave equations for the reconstruction of subsurface media. The reconstruction is conducted using the full waveform inversion (FWI) method and relies on iterative minimization algorithm, which is adapted to large scale situation. In particular, the inverse problem shows a conditional Lipschitz stability when assuming piecewise constant representation of the parameters.

We further study the convergence of the minimization problem and are able to numerically estimate the size of the basin of attraction, depending on the frequency and geometry of the subsurface. From these stability and convergence results, we design a multi-level algorithm with simultaneous progression in frequency and scale. Eventually, we carry out numerical experiments for acoustic and elastic parameters reconstruction assuming no-prior information in the initial models, in two and three dimensions. We also extend the algorithm to Cauchy data, where the stability results allow some promising perspectives.

The aspects of prior-based dimension reduction Kalman filter

Janne Hakkarainen
University of Helsinki

Abstract

The idea in prior-based dimension reduction is to constrain the problem onto a subspace that contains most of the variability allowed by the prior. This idea was extended to Gaussian filtering by Solonen et al, 2016. In this talk we will discuss how this new Kalman filter can be used in various applications like 1) state estimation in chaotic systems, 2) dynamic X-ray tomography, and 3) inverse modeling of greenhouse gases.

[1] Antti Solonen, Tiangang Cui, Janne Hakkarainen, and Youssef Marzouk: On dimension reduction in Gaussian filters, Inverse Problems, Volume 32, Number 4, 2016. arXiv:1508.06452

Huber-penalty as a temporal prior for perfusion MRI

Matti Hanhela
University of Eastern Finland

Abstract

Dynamic magnetic resonance imaging (dMRI) measures temporally varying targets. In dynamic targets, measuring the full k-space (data-space) is not feasible due to the measurement time in MRI, which is limited by the magnetic relaxation rate of the target. For this reason, dMRI is accelerated by measuring only parts of the k-space for each reconstruction, which leads to an underdetermined problem. In dynamic contrast enhanced (DCE) MRI, injected gadolinium contrast agent causes temporal variations in the MRI signal depending on blood flow. In DCE MRI, the signal may have a large drop during the first pass of the contrast agent and the signal then increases smoothly in the regions of interest. The classical total variation (TV) regularization captures fast changes in the signal well, but it exhibits a staircasing effect in smoothly varying signals which causes error. We aim to remedy this with the use of Huber-penalty which behaves smoothly for small changes while allowing large jumps in the signal. The results indicate that the Huber-penalty improves the accuracy of the reconstruction in the regions of interest.

Learning to reconstruct: Deep Learning and image reconstruction

Andreas Hauptmann
University College London, UK

Abstract

The huge recent success of Deep Learning methods in image processing and computer vision has seen an increasing interest in applying similar strategies to tomographic reconstruction problems. Deep Neural Networks are especially popular due to the low latency of a forward pass through a network which leads to prospective highly efficient reconstruction algorithms.

Many applications of Deep Learning for image reconstruction have been concentrated on using a fast and simple direct reconstruction algorithm to obtain low quality and corrupted images and then train a convolutional neural network on removing those artefacts.

Alternatively including the physical forward model into the network has been studied by several groups. However, these improved results in reconstruction quality typically come at the cost of longer computation times which are effectively limited by the repeated simulation of the physical model.

In this talk we give an overview of ongoing research, with the specific focus on the application to experimental and clinical imaging. We present results for both, direct and iterative, approaches and various imaging modalities.

Generalized linearization techniques and smoothened complete electrode model

Nuutti Hyvönen
Aalto University

Abstract

The forward problem of electrical impedance tomography is often linearized with respect to the conductivity and the resulting linear inverse problem is regarded as a subproblem in an iterative algorithm or as a reconstruction method as such. We introduce and numerically test a novel, accurate linearization technique based on the logarithm of the Neumann-to-Dirichlet operator. A smoothened contact conductance model is also proposed for electrode measurements, leading to improved regularity for the complete electrode model.

X-ray tomography in periodic slabs

Joonas Ilmavirta
University of Jyväskylä

Abstract

I will consider X-ray tomography in a product of an interval and a Euclidean space of any dimension. If one assumes compact support or suitable decay, the X-ray transform is injective. Without this assumption there is a non-trivial kernel. I will consider functions which are periodic with respect to all variables in the Euclidean space and characterize the kernel in this case. I will also discuss tensor tomography. For tensor fields there is the usual kernel related to potentials, but in addition there is a kernel similar to the scalar case. The kernel consists of tensor fields of two kinds, and it can be fully characterized. This is based on joint work with Gunther Uhlmann.

Concentration inequalities for the extended Kalman–Bucy filter

Toni Karvonen
Aalto University

Abstract

The extended Kalman–Bucy filter (EKF) estimates the latent state of a system evolving according to a non-linear stochastic differential equation based on indirect and noisy measurements of the state. This talk reviews some recent concentration inequalities for the EKF when the measurements depend linearly on the state and the state process or, alternatively, the filtering error process is contractive. Practicability of the assumptions, that are quite restrictive and difficult to verify, is discussed for a class of simple two-dimensional integrated velocity models.

The talk is based on a recent preprint (2016; arXiv:1606.08251) by Pierre Del Moral, Aline Kurtzmann, and Julian Tugaut, and on ongoing collaboration with Silvère Bonnabel, Eric Moulines, and Simo Särkkä.

Likelihood-Informed Dimension Reduction in Atmospheric Remote Sensing

Otto Lamminpää
Finnish Meteorological Institute, Finland

Abstract

In atmospheric remote sensing, identification of density profiles of atmospheric greenhouse gases is an ill-posed inverse problem. This problem is solved using the Bayesian approach and MCMC-methods, but the solution tends to be computationally demanding. We introduce the Likelihood-Informed Subspace (LIS) methodology to characterize the informative directions of the measurement and reduce the dimensionality of the problem. We also show an application of this method to FTIR measurements conducted at the FMI Arctic Research Centre in Sodankylä, Northern Finland.

Inverse problems for the Einstein-Maxwell equations

Matti Lassas
University of Helsinki

Abstract

We study inverse problems for the Einstein-Maxwell equations. We prove that it is possible to generate gravitational waves from the nonlinear interactions of electromagnetic waves and use the generated waves to do imaging of the space-time. Indeed, we show that by sending electromagnetic waves from a neighborhood of a freely falling observer and taking measurements of the gravitational perturbations in the same neighborhood, one can determine the vacuum space-time structure up to diffeomorphisms in the largest region where these waves can travel to from the observer and return. The results have been done in collaboration with Gunther Uhlmann and Yiran Wang.

Reference:

M. Lassas, G. Uhlmann, Y. Wang: Determination of vacuum space-times from the Einstein-Maxwell equations. Preprint arXiv:1703.10704.

Tensor tomography on Cartan-Hadamard manifolds

Jere Lehtonen
University of Jyväskylä

Abstract

We present results concerning solenoidal injectivity of the geodesic X-ray transform acting on functions and tensor fields on Cartan-Hadamard manifolds, i.e. on complete and simply connected Riemannian manifolds with nonpositive sectional curvature. This is joint work with J. Railo and M. Salo.

Atmospheric turbulence profiling with unknown power spectral density

Jonatan Lehtonen
University of Helsinki

Abstract

Adaptive optics (AO) is a technology in modern ground-based optical telescopes which aims to compensate for the wavefront distortions caused by atmospheric turbulence in real time. A key part of this technology is the severely ill-posed inverse problem of atmospheric tomography, where the turbulence above the telescope is reconstructed from wavefront measurements. Advanced AO systems rely on solid prior information in the form of a vertical turbulence profile and the Kolmogorov/von Kármán models of turbulence statistics. However, these models are known to be inaccurate close to the ground. We propose a novel method which uses AO telemetry to simultaneously recover the turbulence profile and infer a model for turbulence at the ground layer.

Determining the conformal class of anisotropic conductivity in a conformally invariant version of EIT

Tony Liimatainen
University of Helsinki, Finland

Abstract

We consider a conformally invariant version of the anisotropic EIT, where the objective is to determine the conformal class of the conductivity from the Dirichlet-to-Neumann map for the conformal Laplacian. The main result states that a locally conformally real-analytic manifold in dimensions ≥ 3 can be determined in this way, giving a positive answer to a conjecture in Lassas and Uhlmann (2002). We introduce a new coordinate system that replaces harmonic coordinates when determining the conformal class in a neighborhood of the boundary.

This is joint work with Matti Lassas and Mikko Salo.

Characterization of porous materials using full-waveform inversion

Timo Lähivaara
University of Eastern Finland

Abstract

This study aims at developing computational tools to estimate porous material properties. We use discontinuous Galerkin method to solve the forward model that characterizes the propagation of waves in coupled poroviscoelastic-viscoelastic-acoustic media. In this work, the inverse problem is solved in a Bayesian framework or alternatively using deep convolutional neural networks. In the Bayesian framework, we further use the approximation error method, which reduces the overall computational demand. At this stage, results for synthetic models are presented to illustrate the potential of the proposed algorithms for porous material characterization.

Approximating idealised boundary data of Electrical Impedance Tomography by the Shunt Electrode measurements

Nguyet Minh Mach
University of Helsinki

Abstract

Although the most accurate model for current-to-voltage measurements of electrical impedance tomography is the Complete Electrode Model, other models such as the Continuum Model, the Point Electrode Model and the Shunt Electrode Model are still being used in specific situations because of their simplicity to work with mathematically. In this work, we focus on proving the connection between the Shunt Electrode Model and the Continuum Model. Indeed, without any a-priori requirement, we can prove that the current-to-voltage measurements as well as the unique variational solution of the Shunt Electrode Model strongly converge to those of the Continuum Model as the number of electrodes go to infinity and the sizes of electrodes tend to zero.

Convergence of solutions of TV-regularized linear inverse problems

Gwenael Mercier
RICAM, Austrian Academy of Sciences

Abstract

In a recent paper by A. Chambolle et al. [Geometric properties of solutions to the total variation denoising problem. Inverse Problems 33, 2017] it was proven that if the subgradient of the total variation at the true data is not empty, the level-sets of the total-variation denoised solutions converge to the level-sets of the true solution with respect to the Hausdorff distance. This paper explores a new aspect of total variation regularization theory based on the source condition introduced by Burger and Osher [Convergence rates of convex variational regularization. Inverse Problems 20, 2004] to prove convergence rates results with respect to the Bregman distance. We generalize the results of Chambolle et al. to total variation regularization of general linear inverse problems. As applications we consider denoising in bounded and unbounded, convex and non convex domains, deblurring and inversion of the circular Radon transform. In all these examples we can prove Hausdorff convergence of the level-sets of the total variation regularized solutions. This is a joint work with José A. Iglesias and Otmar Scherzer.

On parameter identification of linear stochastic differential equations by Gaussian statistics

Pingping Niu
Fudan University, China

Abstract

Linear stochastic differential equations (SDEs) arise in many contemporary scientific and engineering fields involving dynamical processes. These SDEs are governed by several parameters, for instance the damping coefficient, the volatility or diffusion coefficient and possibly an external forcing. Identification of these parameters allows us a better understanding of the dynamical processes and their hidden statistics. By calculating the Gaussian statistics explicitly for the Ornstein-Uhlenbeck processes with constant parameters and Langevin equations with periodic parameters, we propose a parameter identification approach to recover these parameters by minimizing the difference between the empirical statistics and the theoretical statistics. The proposed approach is further extended to parameter identification of SDEs which are indirectly observed by another random processes.

Obtaining shape and spin distributions of asteroid populations using scarce data

Hari Nortunen
Tampere University of Technology, Finland

Abstract

We have examined asteroid populations in a situation where the brightness measurements are too limited for reconstructing the desired characteristics (shape elongation and spin latitude) of an individual body. In these cases, we may consider the entire population as a distribution, using a CDF of brightness variation estimates as our observable. The CDF can be expressed as a superposition of basis functions. We have an inverse problem, where solving the coefficients of this superposition yields the DF of shape elongation and spin latitude for the population. The solution is accurate on a rough-scale level, and quick to compute. We have created a software package called LEADER to implement this method.

The estimation of the time varying parameters of the General Dynamic Equation for aerosols using the Kalman Filter

Matthew Ozon
University of Eastern Finland, Kuopio, Finland

Abstract

Motivation Aerosols scatter and absorb solar radiation and affect the permeability of the atmosphere to solar energy — the direct effect. In addition, aerosol particles act as seeds for cloud droplets and thus influence the properties of clouds — the indirect effect. The Intergovernmental Panel on Climate Change (IPCC, 2013) recognizes the uncertainty in the radiative forcing caused by aerosols as the main individual factor limiting the scientific understanding of future and past climate changes. Therefore, it is relevant to focus on developing methods that give deeper insights about the evolution of aerosol systems. This work in progress concentrates on two prevailing factors in the mechanics of aerosol systems, 1) the nucleation rate — the creation of new particles from

the ambient vapour— and 2) the growth rate resulting from the condensation of vapour onto the particles.

Method The General Dynamic Equation (GDE) for aerosols is a box model that describes the evolution of the size distribution of particles — histogram of volume — over time. The evolution depends on three mechanisms, 1) the coagulation, which accounts for the particle-particle interactions, 2) the condensation that describes how the vapour makes existing particles grow, and 3) the nucleation that explains the apparently spontaneous generation of new particles of the smallest size — ca. 1.5 nm in diameter. It is possible to take into account other source and sink terms — e.g. washout — but it is beyond the scope of this work. The only measures considered in this work are the size distributions because they are easily measured either in experiments or in field campaign; the nucleation rate and the average growth rate are often determined manually or by fitting some assumed parametric distributions. In order to overcome the manual determination of the parameters and to avoid some assumption on the size distribution shape, we propose a method using the Kalman Filter (KF) in its extended and augmented version. Using as such the GDE and a simple measurement model only leads to the reconstruction of the size distribution. However, if the state space is augmented by adding the nucleation rate and the vapour concentration to the size distribution, then the KF can estimate the non-observed parameters. The both of them evolve smoothly with time, therefore, their evolutions can be described by a second order differential equation with a random source term.

Results In order to prove that the method is well suited for the GDE for aerosol, it is tested on a toy example. A size distribution sequence is simulated for a particle system and it is corrupted with additive and multiplicative noise in order to resemble actual measures. The vapour concentration controls the simulation because it determines the nucleation rate — proportional to the square of the concentration — and the growth rate — proportional to the concentration. From the noisy size distribution we are able to 1) filter the size distribution, 2) estimate the nucleation rate and 3) estimate the vapour concentration — hence the growth rates. Besides, a robust fitting of a second order model of the nucleation vs the vapour concentration is able to accurately compute the nucleation coefficient from the estimated parameters. Those results are encouraging and represent a proof of concept.

Random walks, statistics and boundary value problems

Petteri Piiroinen
University of Helsinki

Abstract

In this talk, we consider few random walks which we can interpret and analyze as statistical models related with well-known boundary value problems. We also consider some parameter estimation problems arising from these random walks.

Taking to the Field: Does the size of sensing skin matter?

Mohammad Pour-Ghaz
North Carolina State University, USA

Abstract

The sensing skin is made of a very thin layer, or layers, of electrical conductive materials that are applied to the surface of a structure in the form of paint or a wallpaper. Sensing skins are engineered so that their electrical conductivity locally changes due to some stimulus of interest such as cracking, mechanical strain, or in contact with certain ions. The spatial distribution of the electrical conductivity is reconstructed using Electrical Resistance Tomography (ERT), enabling

detection of the stimulus [1, 2, 3]. The vision in developing these sensors, is to create practical and low-cost sensors that can be easily installed on the surface of structures, or structural elements, in the form of a "skin" to monitor their integrity, hence the name *sensing skin*.

During the last several years, through extensive laboratory testing, we have shown that sensing skin can successfully localize and quantify damage when applied to small geometries (in the order of several centimeters in each dimension). The maximum size of the sensing skin used, to date, is 23 × 50 cm (1150 cm^2) [2]. This sensing skin size is still too small for practical purposes. We therefore ask, whether the size of sensing skin matters. In other words, does the size of sensing skin affect its resolution in detecting damage?

In this presentation, we discuss our preliminary findings in attempting to answer this question. We discuss the mathematical and computational challenges in taking the sensing skin to the field and discuss the methods we are currently developing in addressing these challenges.

References

[1] M. Hallaji, and M. Pour-Ghaz. A new sensing skin for qualitative damage detection in concrete elements: Rapid difference imaging with electrical resistance tomography. *NDT & E International*, 68: 13–21, 2014.

[2] M. Hallaji, A. Seppänen, and M. Pour-Ghaz. Electrical impedance tomography-based sensing skin for quantitative imaging of damage in concrete. *Smart Materials and Structures*, 23: 085001, 2014.

[3] A. Seppänen, M. Hallaji, and M. Pour-Ghaz. A Functionally Layered Sensing Skin for the Detection of Corrosive Elements and Cracking. *Structural Health Monitoring*, 16:2, 2017.

Synthetic schlieren tomography

Aki Pulkkinen
University of Eastern Finland

Abstract

Synthetic schlieren tomography is an imaging technique to measure ultrasound waves. The technique is based on acousto-optic interaction where propagating sound wave changes refractive index and thus causes propagation of light to change. In the instrumentation, a pulsed light source synchronized with the ultrasound transducer is placed behind an imaged target. The target is imaged with a digital camera while the ultrasound beam propagates through the space between. Apparent changes in the imaged target are seen as the sound waves bend the light, which can be used to determine the ultrasound field. In this talk the physics behind the technique and mathematical approaches for pressure field estimation given the imaged data are presented.

Automated method for choosing regularization parameter: application to X-ray tomography

Zenith Purisha
University of Helsinki

Abstract

Tomographic reconstruction is an ill-posed inverse problem that calls for regularization. One possibility is to require sparsity of the unknown in particular basis or dictionary. It can be achieved by variational regularization, where the penalty term is the sum of the absolute values of the coefficients from a given transformation. In this work, we apply wavelet and shearlet transform. The primal-dual fixed point (PDFP) algorithm showed that the minimizer of the variational regularization functional can be computed iteratively using a soft-thresholding operation. Choosing the soft-thresholding parameter $\mu > 0$ is analogous to the notoriously difficult problem of picking the optimal regularization parameter in Tikhonov regularization. Here, a novel automatic method is introduced for choosing μ , based on a control algorithm driving the sparsity of the reconstruction to an a priori known ratio of nonzero versus zero wavelet/shearlet coefficients in the unknown.

Reconstruction of a piecewise constant conductivity on a polygonal partition via shape optimization in EIT

Matteo Santacesaria
University of Helsinki

Abstract

In Electrical impedance tomography (EIT) one wants to image the conductivity distribution of a body from current and voltage measurements carried out on its boundary. In this talk we present a new iterative reconstruction algorithm that allows the recovery of a piecewise constant conductivity on an unknown triangular partition. This is formulated as a minimization problem for an appropriate cost functional, which is solved using some shape optimization techniques, such as the shape derivative of the functional. We will discuss numerical test cases from simulated data to show the reliability of the method as well as related theoretical issues.

Electrical impedance tomography imaging via the Radon transform

Samuli Siltanen
University of Helsinki

Abstract

In Electrical Impedance Tomography (EIT) one attempts to recover the electric conductivity inside a domain from electric boundary measurements. This is a nonlinear and ill-posed inverse problem. The so-called Complex Geometric Optics (CGO) solutions have proven to be a useful tool for both analysis and practical reconstruction tasks in EIT. A new property of CGO solutions is presented, showing that a one-dimensional Fourier transform in the spectral variable provides a connection to parallel-beam tomography of the conductivity. One of the consequences of this "nonlinear Fourier slice theorem" is a novel capability to recover inclusions within inclusions in EIT. As an important application of the results we discuss the diagnosis of stroke: is it ischemic (blood clot preventing blood flow to a part of the brain) or hemorrhagic (bleeding in the brain).

Grey Box Modeling of Marine Vessels via Bayesian Generalized Additive Models and Gaussian Processes

Antti Solonen
Eniram Oy

Abstract

This talk illustrates some of the applied modeling work we do at Eniram Ltd to understand and predict marine vessel performance. The models are hybrids between completely physical "white box" approaches and "black box" methods that rely only on data. The models involve unknown parameters (e.g. various resistance coefficients) that are inverted from data. To bring more flexibility into the models, we allow some of the coefficients to vary as smooth functions of some input variables, described via Gaussian Processes. This yields a generalized additive modeling approach with which we can "relax" the rigid physical model parameterizations and improve model accuracy. The approach is general, but here we focus on the linear Gaussian case and present numerical examples using marine vessel data collected via the Eniram Vessel Platform.

Correlation integral likelihood: a distance based characterizer and classifier for point clouds

Sebastian Springer
Lappeenranta University of Technology

Abstract

Several characterization and classification problems are discussed here via a point cloud method. We apply a distance based likelihood, recently introduced for the identification of parameters of chaotic systems. For the purpose of identifying high dimensional chaotic systems we employ a surrogate sampling approach of the parameter posterior. A (non-chaotic) pattern classification problem is treated in an analogous manner, with the 2D FitzHugh-Nagumo PDE system as an example. Finally, the approach is modified in order to identify the parameters of both classical and chaotic stochastic differential equation (SDE) systems.

Sequential subspace optimization for nonlinear inverse problems with an application in terahertz tomography

Anne Wald
Saarland University, Germany

Abstract

We introduce a sequential subspace optimization (SESOP) method for the iterative solution of nonlinear inverse problems in Hilbert and Banach spaces, based on the well-known methods for linear problems. The key idea is to use multiple search directions per iteration in an effort to reduce the total number of iterations. The length of the search directions is determined by the nonlinearity and the local character of the forward operator. This choice admits a geometric interpretation after which the method is originally named: The current iterate is projected sequentially onto (intersections of) stripes, which emerge from affine hyperplanes whose respective normal vectors are given by the search directions and contain the solution set of the unperturbed inverse problem. We prove convergence and regularization properties. Furthermore, we extend our methods for complex Hilbert spaces and apply it to solve the inverse problem of terahertz tomography, which

consists in the nondestructive testing of dielectric media. The tested object is illuminated by an electromagnetic Gaussian beam and the goal is the reconstruction of the complex refractive index from measurements of the electric field. Mathematically, we are dealing with a nonlinear parameter identification problem based on the Helmholtz equation with Robin boundary conditions. We conclude with some numerical reconstructions from synthetic data.

Gaussian process regression for forest attribute estimation from airborne laser scanning data

Petri Varvia
University of Eastern Finland

Abstract

In the area based approach (ABA) to forest stand attribute estimation from airborne laser scanning (ALS), the study area is divided into segments. A number of statistical predictors are then formed from the vertical distribution of the measured laser point cloud for each segment, usually supported by additional aerial image derived metrics. The ABA problem is to predict the stand attributes based on these measurement-derived predictors and a set of training data, which consists of a number of segments with field-measured stand attributes. In a nutshell, it is a vector-valued machine learning problem. In the literature, various algorithms have been used for ABA: including linear regression, k-nearest neighbor (kNN), neural networks, and sparse Bayesian estimation.

In this work, we propose a multivariate Gaussian process regression (GPR) for ABA. We hypothesize that GPR can produce prediction accuracy that is competitive with the best existing methods and simultaneously provide feasible estimates of prediction uncertainty. The prediction performance of GPR is tested against a state-of-the-art kNN implementation and the uncertainty quantification capabilities are compared to Bayesian linear estimates.

The preliminary results show that GPR produces roughly 5-10% lower RMSE than kNN for the estimated stand attributes of the minority tree species, and with negligible bias. The performance of the GPR-based uncertainty estimates was found to be roughly equal to the uncertainty quantities produced by Bayesian linear estimation.

Estimating cerival cancer progression with multiple HPV types from prevaccination era screening data

Simopekka Vänskä
THL/University of Helsinki, Finland

Abstract

Genital Human Papillomavirus (HPV) infection of about 12-13 high-risk HPV types have potential to cause for cervical cancer. HPV has high 20-50% prevalence in young women, and multiple-type infections are common. Information on the progression of HPV infection to cancer is needed in optimizing preventing public health interventions. After introduction of HPV vaccination programs during the last ten years, the focus is in optimal cervical cancer screening in HPV vaccinated populations.

We developed a population level compartmental multiple HPV type model with the infection-age-dependent clearance of HPV. The cervical cancer screening findings, retrieved from various Finnish health registers, were used as data in estimating the model parameters for disease progression. In other words, cervical cancer screening was considered not only as an intervention to prevent

cancer, but also as the measurement of the population level disease progression process. Thus, a model for screening was needed as well. To estimate the parameters, the multiple dimensional posteriori functions with alternative model scenarios were computed.

To achieve a computationally effective algorithm in simulating the disease progression, the forward problem, the distribution of multiple-HPV-type disease states in female population was represented as a mixture distribution, allowing negative weights, associating to differently screened subpopulations. To further improve the computational speed, the number of subpopulations was reduced by merging the subpopulations with common screening history. In parameter estimation a simplifying assumption was made: all parameters except clearance of infection were assumed common for different HPV types. Adaptive MCMC were used in sampling the high-dimensional posterior function.

As a conclusion, high quality registry data together with mathematical modeling can provide biological information, despite remaining uncertainties in individual parameter values.

Recovering an unknown source in a fractional diffusion equation

Zhidong Zhang
University of Helsinki

Abstract

We consider a standard inverse problem, which is to determine a source equalling to unity in an unknown domain D of a larger given domain Ω from external boundary measurements. The model for this inverse problem is an anomalous diffusion model which leads to a fractional diffusion equation. The overposed measurements consist of time traces of the solution or its flux values on a set of discrete points on the boundary $\partial\Omega$.

We will show a uniqueness result and examine a reconstruction algorithm. One of the main motives for this work is to examine the dependence of the reconstructions on the parameter α, the exponent of the fractional operator which controls the degree of anomalous behaviour of the process. Some previous inverse problems based on fractional diffusion models have shown considerable differences between classical Brownian diffusion and the anomalous case.

(36 talks in total)