Abstracts

A regularization method based on an augmented Lagrangian approach for parameter identification problems.

Thursday 13.12
14:00-14:30
Hall B-200

Juan Pablo Agnelli
National University of Córdoba

We propose and analyse a solution method for parameter identification problems modelled by ill-posed nonlinear operator equations, where the parameter function to be identified is known to be a piecewise constant function.

A level-set approach is used to represent the unknown parameter, and a corresponding Tikhonov functional is defined. Additionally, a suitable constraint is enforced, resulting that our Tikhonov functional is to be minimized over a set of piecewise constant level-set functions. Thus, the original parameter identification problem is rewritten in the form of a constrained optimization problem, which is solved using an augmented Lagrangian type method.

We prove existence of zero duality gaps and existence of generalized Lagrangian multipliers. Moreover, we prove convergence and stability of the parameter identification method, i.e. the solution method is a regularization method.

Additionally, a primal-dual algorithm is proposed to compute approximate solutions of the original inverse problem, and its convergence is proved. Numerical examples applied to a 2D diffuse optical tomography benchmark problem demonstrate the viability of the proposed approach.

Joint work with A. De Cesaro and A. Leitão.

Nonnegativity Constraints for Hierarchical Bayesian Inverse Problems

Thursday 13.12
10:00-10:30
Hall B-200

Johnathan M. Bardsley
University of Montana/DTU

A nonnegativity constraint is standard for imaging problems in which the vector of unknown parameters consists of light intensities. In many such applications, we expect that some of the unknown intensities will be zero, suggesting that the posterior density function should have positive mass at the boundary of the nonnegative orthant. The standard approach for implementing a nonnegativity constraint is to multiply an unconstrained posterior density function by an indicator function on the nonnegative orthant. However, the resulting constrained posterior will have zero mass at the boundary of the nonnegative orthant. In this talk, we explore an alternative approach, in which we implicitly define the constrained posterior through a nonnegativity constrained, stochastic optimization problem. The resulting constrained posterior has positive mass at the boundary, as desired. We then show how to embed this constrained posterior within a hierarchical model and implement both a Gibbs sampler and a marginalization-based MCMC method with better convergence properties.

Inverse problems with one measurement

Wednesday 12.12
11:00-11:30
Hall A-301

Eemeli Blåsten

Inverse scattering and boundary value problems were traditionally solved by an infinite number of measurements, as done by Sylvester and Uhlmann. It is also well known that a single measurement is not always enough. However under quite general conditions it is possible to find useful information about the unknown from a single measurement. Such conditions include for example the scatterer having a polyhedral shape. This topic also has wide-ranging implications: to invisibility, the interior transmission problem, non-scattering sources and the inverse source problem.

Boundary determination with hybrid imaging

Thursday 13.12
14:00-14:30
Hall A-301

Tommi Brander
Norwegian University of Science and Technology

When electrical impedance tomography is enhanced with suitable other imaging modalities, one receives power or current density data, $\sigma |\nabla u|^q$, $q = 1$ or $q = 2$, in addition to Dirichlet and Neumann data on the boundary of the domain. We combine all three types of data to reconstruct conductivity on the entire boundary from a single almost arbitrary measurement. The reconstruction is elementary and we provide formulae for the conductivity in terms of the data. The theoretical results also hold for p-Laplace equation and even variable exponent $p(\cdot)$-Laplace equation, and with arbitrary variable power $q(x) \geq 0$ in the power density. We illustrate the linear and physically relevant scenarios with numerical examples with noise and with uncertain placement of electrodes.

Based on joint work with Torbjørn Ringholm (NTNU).

Inverse problems for a fractional conductivity equation

Tuesday 11.12
14:00-14:30
Hall A-301

Giovanni Covi
University of Jyväskylä

I will show global uniqueness in two inverse problems for a fractional conductivity equation: an unknown conductivity in a bounded domain is uniquely determined by measurements of solutions taken in arbitrary open, possibly disjoint subsets of the exterior. The results are based on a reduction from the fractional conductivity equation to the fractional Schrödinger equation, and as such represent extensions of previous works. Moreover, I will show a simple application in which the fractional conductivity equation is put into relation with a long jump random walk with weights.

Proximal Alternating Linearized Minimization for dynamic CT in the foot and ankle

Wednesday 12.12
11:30-12:00
Hall B-200

Nargiza Djurabekova
University College London

Due to the lack of a precise bio-mechanical model of foot and ankle, the interaction of this 28 bones structure is not yet fully understood. The ability to resolve joint dynamics could be instrumental to the ankle replacement surgery leading to increased success rates which are currently at half that of a fusion procedure.

The Proximal Alternating Linearized Minimization or PALM has been developed as a broadly applicable algorithm for nonconvex and nonsmooth optimization problems. We apply this algorithm to the aforementioned dynamic foot and ankle problem to reconstruct the spatio-temporal image with the help of the optical flow constraint. This is a joint work with Marta Betcke.

Structure preserving preconditioning for frame-based image deblurring

Wednesday 12.12
10:00-10:30
Hall B-200

Marco Donatelli
University of Insubria, Como

Regularizing preconditioners for accelerating the convergence of iterative regularization methods for inverse problems have been extensively investigated in the literature. For inverse problems, a correct choice of the preconditioner is crucial for accelerating the convergence of iterative methods without to spoil the quality of the computed approximation. Classical regularizing preconditioners for image deblurring are usually based on the circular convolution, which is equivalent to impose periodic boundary conditions.

We show that a preconditioner preserving the same structure of the convolution operator can be more effective than the circulant approach both for the quality of the restoration and the robustness of the regularization parameter, in particular when the choice of appropriate boundary conditions is crucial. We explore the use of a structure preserving preconditioner for a modification of the linearized Bregman iteration applied to the image deblurring problem with a ℓ_1-norm regularization term in the wavelet domain.

Unfortunately, the theoretical results proved for the circulant preconditioning can not be easily carry on to the structured preconditioning, but a large number of numerical experiments shows the effectiveness of our preconditioning strategy.

First steps towards the numerical quantification of source conditions.

Thursday 13.12
11:00-11:30
Hall B-200

Daniel Gerth
Technische Universität Chemnitz

We consider linear ill-posed problems of the form $Ax = y$ with possibly noisy data y and exact solution $x^\dagger$. A classical assumption in the theory of inverse problems are source conditions of the type $x^\dagger \in \text{range}((A^*A)^\mu)$ for some $\mu > 0$. This allows to bound the worst-case error between approximate solutions and $x^\dagger$ as the noise goes to zero, and it yields rules for an appropriate choice of the regularization parameter. In the real-world situation where a fixed operator A and a datum y are given, a good approximation to μ is only available in specific cases, while in general μ is unknown, rendering in particular a-priori parameter choice rules unfeasible. In this talk, we make a first attempt of breaking the disconnection between theory and practice. Based on the Kurdyka-Łojasiewicz inequality and the Landweber method, we develop an algorithm that allows to approximate μ as long as the noise in the data is not too large. We show several numerical examples, including the X-ray tomography datasets of the FIPS. In particular the lotus root slice yields results suggesting that it fulfils a source condition with $\mu \approx 0.22$.

We also show that there is a simple lower bound for the reconstruction error, which can be computed without any knowledge of a source condition. We again provide numerous numerical examples and explain how the lower bound allows us to better interpret the results of the approximation of μ. It is notable that, if a source condition holds, the lower bound is of the same order as the upper bound.

Transmission Eigenvalues for a Conductive Boundary

Wednesday 12.12
9:00-9:30
Hall B-200

Isaac Harris
Purdue University

In this talk, we will investigate the inverse acoustic scattering problem associated with an inhomogeneous media with a conductive boundary. We consider the corresponding interior transmission eigenvalue problem. This is a new class of eigenvalue problem that is not elliptic, not self-adjoint, and non-linear, which gives the possibility of complex eigenvalues. We investigate the convergence of the eigenvalues as the conductivity parameter tends to zero as well as prove existence and discreteness for the case of an absorbing media.

Networks for diffusion and flow in imaging

Tuesday 11.12
14:00-14:30
Hall B-200

Andreas Hauptmann
University College London

A multitude of imaging and vision tasks have seen recently a major transformation by deep learning methods and in particular by the application of convolutional neural networks (CNN). These methods achieve impressive results, even for application where it is not apparent that convolutions are suited to capture the underlying physics.

In this work we develop a network architecture based on nonlinear diffusion processes. By design, we obtain a nonlinear network architecture that is well suited for diffusion related problems in imaging. Furthermore, the performed updates are explicit, by which we obtain better interpretability and generalisability compared to classical CNN architectures.

The network performance is tested on the forward and inverse problem of nonlinear diffusion with the Perona-Malik filter performed on the STL-10 image dataset. We obtain superior results to the established U-Net architecture, with a fraction of parameters and necessary training data.

This is joint work with Simon Arridge.

Estimation of optical parameters and their reliability in quantitative photoacoustic tomography

Thursday 13.12
15:00-15:30
Hall A-301

Niko Hänninen
University of Eastern Finland

In quantitative photoacoustic tomography (QPAT), the aim is to estimate optical parameters inside a domain from initial pressure distribution induced by externally introduced light pulse. In this talk, the inverse problem of QPAT is approached in a Bayesian framework. In addition to reconstructing the optical parameters, evaluating the credibility of the estimates based on a local Gaussian approximation of the posterior distribution is studied. Furthermore, the Bayesian approximation error modelling is utilized in compensating the modelling errors caused by a coarse discretization of the forward model. Numerical simulations in two-dimensional domain are carried out to investigate the reconstruction method and the credibility estimates. This is a joint work with Aki Pulkkinen and Tanja Tarvainen.

Functions of constant X-ray transform

Tuesday 11.12
16:00-16:30
Hall A-301

Joonas Ilmavirta
University of Jyväskylä

Is a non-zero constant function in the range of the X-ray transform in a Euclidean domain or a manifold with boundary? This turns out to be possible on very few domains and manifolds. I will present some phenomena related to this question, including boundary singularities and geometrical restrictions.

This is joint work with Gabriel Paternain.

Inverse Problems in Spectral Computed Tomography

Wednesday 12.12
12:00-12:30
Hall B-200

Mikael A. K. Juntunen
University of Oulu

In spectral computed tomography (SCT), the X-ray attenuation of specific photon energy ranges of a polychromatic beam are measured separately. Due to the tissue-specific energy-dependence of X-ray attenuation, this energy-specific information can be harnessed to quantitatively decompose the measured data into different basis materials, e.g. bone, soft tissue, and iodine. Obtaining accurate material-specific reconstructions from the SCT data is a challenging task where inverse problems have an integral part.

This presentation will give an overview of SCT with a specific focus on the inverse mathematics at its core. We also present our recent results in quantitative SCT and low-dose iterative reconstruction of tissue-specific projection data.

Uncertainty quantification for stroke EIT imaging using sparse grids

Tuesday 11.12
14:00-14:30
Hall A-304

Vesa Kaarnioja
University of New South Wales

The past decade has been a renaissance for uncertainty quantification with the development of efficient numerical methods for finding accurate functional expressions that describe the dependence of the output response of a mathematical model based on uncertain inputs. In the field of inverse problems, these techniques have immediate applications for, e.g., parameter estimation.

In this talk, it is demonstrated how stochastic collocation based on sparse grids can be used to overcome computational difficulties associated with electrical impedance tomography (EIT) involving uncertainties in the measurement setting. These ideas are implemented to the problem of stroke imaging using EIT, and the effectiveness of this approach is assessed in numerical experiments involving realistic 2D human head models.

Bernstein–von Mises Theorems and Uncertainty Quantification

Thursday 13.12
9:00-9:30
Hall B-200

Hanne Kekkonen
University of Cambridge

We consider the statistical inverse problem of approximating an unknown function f from a linear measurement corrupted by additive Gaussian white noise. We employ a nonparametric Bayesian approach with standard Gaussian priors for f and prove a semi-parametric Bernstein–von Mises theorem for a large collection of functionals of f, which implies that semiparametric posterior-based inferences and uncertainty quantification are valid and optimal from a frequentist point of view. Since the Tikhonov regulariser $\bar{f}$, with a Cameron-Martin space norm penalty, coincides with the conditional mean estimator for f, the results imply that the asymptotic distribution of $\bar{f}$ attains the information lower bound. Furthermore, the achieved credible sets for $\bar{f}$ have correct frequentist coverage and optimal diameter.

Acousto-electric tomography with complete wave modelling

Thursday 13.12
14:30-15:00
Hall A-301

Adrian Kirkeby and Bjørn Jensen
Danish Technical University

In acousto-electric tomography the goal is to reconstruct the interior conductivity distribution in a bounded domain. The data is in the form of boundary measurements of currents and voltages taken while the domain is penetrated by an externally generated acoustic wave. This leads to a coupled-physics inverse problem consisting of two steps: First, reconstruction of the power density from boundary measurements. Second, reconstruction of conductivity from power density. The second step of reconstructing the conductivity from the power density has been extensively studied theoretically and numerically. For the first step some theoretical results exist but the problem has remained mostly unstudied numerically and in practically feasible settings. We approach the problem in two steps: first, we model carefully the acoustic wave and derive a framework for the reconstruction of the interior power density based on the corresponding boundary measurements; second, an optimization scheme using total variation regularization is used for the reconstruction of the conductivity distribution from the power density. The reconstruction algorithm is implemented numerically and the feasibility, stability and efficiency is investigated on various numerical examples.

New pressure estimation methods for synthetic schlieren tomography

Wednesday 12.12
15:00-15:30
Hall A-301

Eero Koponen
University of Eastern Finland

Synthetic schlieren tomography can be a feasible option for imaging and measurement of ultrasound fields. In this optical imaging technique, ultrasound waves are used to change propagation of light by inducing a change in refractive index via acousto-optic effect. The propagation of light is observed using a camera, and it manifests as optical distortions in an imaged target that carry information of the ultrasound field. The ultrasound field can be reconstructed three-dimensionally from the captured images as an inverse problem. In this talk, simulation results of new pressure estimation methods for synthetic schlieren tomography are presented.

This is joint work with Jarkko Leskinen, Tanja Tarvainen, and Aki Pulkkinen.

Inverse scattering and tomography on probability distributions

Wednesday 12.12
12:00-12:30
Hall A-301

Antti Kujanpää
University of Helsinki

Scattering from a non-smooth random field on the time domain is studied for plane waves that propagate simultaneously through the potential in variable angles. We first derive sufficient conditions for stochastic moments of the field to be recovered from empirical correlations between amplitude measurements of the leading singularities, detected in the exterior of a region where the potential is almost surely supported. The result is then applied to show that if two sufficiently regular random fields yield the same correlations, they have identical laws as function-valued random variables. This is a joint work with Pedro Caro, Tapio Helin and Matti Lassas.

Example of an ill-posed coupling problem

Tuesday 11.12
15:00-15:30
Hall B-200

Juha Kuortti
Aalto University

We consider synthesis and parameter estimation of lossless LC-circuits in state-space. Using passive realisations makes it possible to treat the system in frequency domain, time domain and also in parameter space in a unified framework. The coupled complicated systems can be obtained by Redheffer-feedbacks of regularised component systems without sacrificing the explicit parametrizations. Regularisation is needed since the internal feedback loops in circuits are typically ill-posed. We also consider the removal of singularities in system matrices, caused by ill-posedness, at the limit of vanishing regularisation. This process is illuminated by the low-pass Butterworth filter of degree five. This is a joint work with Jarmo Malinen.

Application of Dimension Reduction MCMC for OCO-2 Surrogate Forward Model XCO2 retrieval

Wednesday 12.12
14:00-14:30
Hall B-200

Otto Lamminpää
Finnish Meteorological Institute

The operational XCO_2 retrieval algorithm of NASA's Orbiting Carbon Observatory 2 (OCO-2) satellite is based on an optimisation algorithm in which it is assumed that the posterior distribution of the retrieval problem is close to linear near the Maximum a Posteriori (MAP) estimate point, and hence the related uncertainty quantification is performed using a multivariate normal distribution. It is, however, well known that the underlying problem is not Gaussian and thus this approach may be misleading. In this work we investigate the non-linearity and identifiability of the model parameters in the OCO-2 retrieval. This is done using Markov Chain Monte Carlo (MCMC) methods to sample the full multidimensional posterior distribution. We focus on a surrogate forward model, which fits a state vector that consists of CO_2 density profile, surface pressure, surface albedo and aerosol moment parameters. We implement a Likelihood Informed Subspace (LIS) dimension reduction scheme to the MCMC sampler to reduce the size of the problem and thus speed up the convergence of the algorithm. The sampled MCMC chain represents the multidimensional posterior distribution, which is analysed in detail.

Manifold learning and inverse problems

Thursday 13.12
9:30-10:00
Hall B-200

Matti Lassas
University of Helsinki

We consider applications of the geometric Whitney problem on how a Riemannian manifold (M, g) can be constructed to approximate a metric space (X, d_X). This problem is closely related to manifold interpolation (or manifold learning) where a smooth n-dimensional surface $S \subset \mathbb{R}^m$, $m > n$ needs to be constructed to approximate a point cloud in $\mathbb{R}^m$. These questions are encountered in differential geometry, machine learning, and in many inverse problems encountered in applications. The determination of a Riemannian manifold includes the construction of its topology, differentiable structure, and metric. We consider the recent developments on the problem from the geometric and statistical point of views.

The results are done in collaboration with C. Fefferman, S. Ivanov, Y. Kurylev, and H. Narayanan.

References:

[1] C. Fefferman, S. Ivanov, Y. Kurylev, M. Lassas, H. Narayanan: Reconstruction and interpolation of manifolds I: The geometric Whitney problem. arXiv:1508.00674

[2] C. Fefferman, S. Ivanov, Y. Kurylev, M. Lassas, H. Narayanan: Fitting a putative manifold to noisy data. Proceedings of Machine Learning Research vol 75:1-32, 2018

Exploring the limits of atmospheric turbulence parameter estimation

Wednesday 12.12
15:00-15:30
Hall B-200

Jonatan Lehtonen
University of Helsinki

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 about the turbulence statistics, which is characterized by some physical parameters. This presentation will focus on quantifying the uncertainty in recovering these parameters from AO system telemetry.

The Calderón problem for the fractional Schrödinger equation with drift

Tuesday 11.12
15:00-15:30
Hall A-301

Yi-Hsuan Lin
University of Jyväskylä

We investigate the Calderón problem for the fractional Schrödinger equation with drift, proving that the unknown drift and potential in a bounded domain can be determined simultaneously and uniquely by an infinite number of exterior measurements. In particular, in contrast to its local analogue, this nonlocal problem does *not* enjoy a gauge invariance. The uniqueness result is complemented by an associated logarithmic stability estimate under suitable apriori assumptions. Also uniqueness under finitely many measurements is discussed. The inverse problem is formulated as a partial data type nonlocal problem; it is considered in any dimensions $n \geq 1$.

Iterative methods for the reconstruction of 3D X-ray Tomographic images from sparse data

Wednesday 12.12
9:30-10:00
Hall B-200

Elena Loli Piccolomini
University of Bologna

The acquisition of a reduced number of projections in 3d X-ray tomography is very attracting, for reducing both the radiation dose and the acquisition time. However, the image reconstruction process is challenging and different iterative algorithms are proposed. I present in this talk a model based approach with possibly convex and nonconvex regularization and iterative algorithms for the optimization problem solution. The possibility of using GPU based computation allow very good reconstructions in almost real time.

Structural Priors in Multi-Energy CT Reconstruction.

Wednesday 12.12
11:00-11:30
Hall B-200

Alexander Meaney
University of Helsinki

A significant limitation of conventional computed tomography is that no bijective relation exists between the composition of the material and the attenuation coefficient value in the reconstruction. More information on the material composition can be obtained with multi-energy imaging, which involves obtaining projections using different X-ray energies, and then computing reconstructions for each energy. Improved image quality in the multi-energy reconstructions can be obtained through exploitation of data redundancies: although the attenuation values will differ at each energy, it is reasonable to assume that the underlying structural properties of the imaged object, i.e., its boundaries and interfaces, will remain in the same locations at each energy. We investigate various structural priors in joint reconstruction of multi-energy CT images. In this approach, all of the data is combined into one inverse problem that is solved simultaneously for all of the X-ray energies, and the priors promote structural similarities the reconstructions.

On convergence of total variation regularized linear inverse problems in Banach spaces

Thursday 13.12
11:30-12:00
Hall B-200

Gwenael Mercier
University of Vienna

In a recent paper written with J.A. Iglesias and O. Scherzer and presented last year in the Inverse Days, we investigate the convergence, as both the regularization parameter and the noise go to zero at a controlled speed, of total variation regularized linear inverse problems in the plane with a L^2 data term. More precisely, we show the convergence with respect to the Hausdorff distance of level-sets of the the regularized solution to the level-sets of the true data. This talk deals with the extension of this result to any dimension with a L^p fidelity term. We see how the p has to be chosen with respect to the dimension to expect this geometrical convergence. We will also discuss the source condition assumption under which our theorem holds. This is a collaboration with José A. Iglesias (RICAM, Linz).

Codomain Rigidity of the Dirichlet to Neumann Operator for the Riemannian Wave Equation

Tuesday 11.12
17:00-17:30
Hall A-301

Tristan Milne
University of Toronto

We study the Dirichlet to Neumann operator for the wave equation on a compact Riemannian manifold with boundary, where sources are applied and fields observed on disjoint sets. This operator was recently studied by Lassas and Oksanen, who used it to prove a unique reconstruction result for the Riemannian metric. As an extension of their research, we prove that the Dirichlet to Neumann operator for disjoint source and observation areas determines the analogous operator when sources and observations are on the same set, provided a spectral condition on the Laplace-Beltrami operator is satisfied. An immediate corollary is that a compact Riemannian manifold can be reconstructed from the Dirichlet to Neumann operator where sources and observations are on disjoint sets, and we provide a constructive procedure for doing so, as well as stability estimates in the case of noisy data. This is a joint work with Abdol-Reza Mansouri.

Use of the Bayesian Approximation Error Approach to Account for Model Discrepancy: The Robin Problem Revisited

Thursday 13.12
11:30-12:00
Hall A-301

Ruanui (Ru) Nicholson
University of Auckland

We address the problem of accounting for model discrepancy by the use of the Bayesian approximation error (BAE) approach in the context of inverse problems. In many inverse problems when one wishes to infer some primary parameter of interest there are other secondary parameters which are also uncertain. In the standard Bayesian (or deterministic) approach such nuisance parameters are either inverted for or are ignored (perhaps by assignment of some nominal value). However, it is well understood that the ill-posedness of general inverse problems means they do not handle modelling errors well. The BAE approach has been developed as an efficient means to approximately pre-marginalize over nuisance parameters so that one can systematically incorporate the effects of neglecting these secondary parameters at the modelling stage. We use the method to consider a generalised Robin problem governed by the Poisson equation.

Statistical inversion for characterising poroelastic materials

Wednesday 12.12
14:00-14:30
Hall A-301

Matti Niskanen
University of Eastern Finland

Porous materials have a wide range of uses in many areas such as material science, filtration, acoustics, and soil mechanics. Due to the variety and complexity of porous materials, many experimental ways to characterise them have been developed. Inverse characterisation methods based on acoustic experiments are an attractive option because the measurements can be relatively simple to do. However, inter-laboratory tests have shown that the reproducibility of such characterisation methods is currently poor. In this talk, we discuss reasons for this and offer a potential improvement by carrying out the inversion in the Bayesian framework. In particular, we use state-of-the-art MCMC techniques to sample the true posterior density.

Photoacoustic Reconstruction based on Sparsity in Curvelet Frame

Tuesday 11.12
14:30-15:00
Hall A-304

Bolin Pan
University College London

In photoacoustic tomography, the acoustic propagation time across the specimen is the ultimate limit on sequential sampling frequency. Any further speed-up can only be obtained by parallel acquisition and subsampling/compressed sensing. In this talk, we consider the photoacoustic reconstruction problem from compressed/subsampled measurements utilizing the sparsity of photoacoustic data or photoacoustic image in the Curvelet frame. We discuss the relative merits of the two approaches and demonstrate the results on simulated and 3D real data.

This is a joint work with Felix Lucka, Simon R. Arridge, Ben T. Cox, Nam Huynh, Edward Z. Zhang, Paul C. Beard and Marta M. Betcke.

Strict local martingales and asset price bubbles

Thursday 13.12
12:00-12:30
Hall A-301

Petteri Piiroinen
University of Helsinki

The martingale theory of asset price bubbles has attracted considerable interest both from the theoretical and practical point of view over the last years. An asset price bubble appears when the market value of an asset exceeds its fundamental value. Several author have proposed to use a discounted underlying asset price process which is a strict local martingale, i.e., a local martingale but not a martingale, in order to model asset price bubbles.

In this talk, we consider two asset price models given by (systems of) stochastic differential equations. We show that for certain parameter values these admit strict local martingale behaviour and therefore, admit price bubbles. For one of the price models, we also propose a statistical indicator that can be used for detecting bubbles from real market data with Bayesian methods.

This talk is based on joint work with Lassi Roininen (Lappeenranta University of Technology), Tobias Schoeden and Martin Simon (Deka Investment GmbH).

Zeffiro user interface for electromagnetic brain imaging: a GPU accelerated FEM tool for forward and inverse computations in Matlab

Tuesday 11.12
16:00-16:30
Hall A-304

Sampsa Pursiainen
Tampere University of Technology

Zeffiro interface (ZI) for brain imaging. ZI is an attempt to provide a simple and accessible and multimodal open source platform for FEM based forward and inverse computations. Zeffiro is Italian for a 'gentle breeze'. ZI has been implemented for the Matlab environment. It allows one to (1) generate the FE mesh for a given multi-layer head model, (2) form a basis for computing a LF matrix and inverting a given set of measurements, and (3) to visualize the reconstructions on the FE mesh. To tackle the issue of the high computational cost, ZI uses graphics processing unit (GPU) acceleration for each of the processing stages (1)–(3). In its current configuration, ZI includes forward solvers for E/MEG and linearized EIT LF matrices and and a set of inverse solvers utilizing the hierarchical Bayesian model (HBM). In this paper, we describe the mathematics behind the ZI, describe the principle operations and usage of ZI, concentrating especially on EEG/MEG, and introduce some central points for the developer perspective. We also give examples of computing times, and analyze numerically how the inversion parameters should be selected, when inverting brain activity with HBM.

Identification of conductivity inclusions in the monodomain model of the heart

Thursday 13.12
14:30-15:00
Hall B-200

Luca Ratti
Politecnico di Milano

The cardiac electrical activity can be comprehensively described throughout the monodomain model, consisting in a semilinear parabolic equation coupled with a nonlinear ordinary differential equation.

In this talk, I introduce the inverse problem of identifying discontinuous parameters in the monodomain system, taking advantage of a single measurement of the electrical potential acquired on the boundary of the domain. I describe an algorithm for the reconstruction of the inclusion's position, size and shape, without *a priori* assumptions on it. The procedure is based on the minimization of a suitable mismatch functional, enhanced with a regularization term which penalizes the perimeter of the inclusion. A phase-field approach is considered, relaxing the minimization problem by means of Modica-Mortola functionals.

The algorithm is first presented on a simplified, stationary version of the model, consisting in a semilinear elliptic problem. Particular attention is given to the rigorous derivation of the proposed reconstruction algorithm, to its convergence properties and to the comparison with different state-of the-art techniques. Moreover, I will show several numerical results, assessing the effectiveness and robustness of the reconstruction. The same approach is finally generalized to the full complexity of the monodomain model: I will provide both theoretical and numerical preliminary results.

This is a joint work with Elena Beretta, Cecilia Cavaterra and Marco Verani.

A block coordinate variable metric linesearch based approach for blind deconvolution

Thursday 13.12
12:00-12:30
Hall B-200

Simone Rebegoldi
University of Ferrara

Many applications arising from image and signal processing, such as blind deconvolution, image inpainting and compression, non-negative matrix and tensor factorization, can be cast into the form

$$\underset{x_i\in\mathbb{R}^{n_i},i=1,\dots,p}{\operatorname{argmin}} f(x_1,\dots,x_p)\equiv f_0(x_1,\dots,x_p)+\sum_{i=1}^{p} f_i(x_i) \tag{1}$$

where f_0 is a continuously differentiable function and $f_1,\dots,f_p$ are convex terms defined on disjoint blocks of variables. A popular strategy to address problem (1) is the block coordinate descent method, which cyclically minimizes f with respect to a single block of variables while the other ones are fixed. However, in its standard implementations, such algorithm is not guaranteed to converge to a stationary point of f and, even when it does, it exhibits a slow convergence rate towards its limit point. Therefore, variable metric strategies are frequently adopted in order to make such alternating scheme efficient.
In this spirit, we propose a novel block coordinate forward–backward algorithm aimed at efficiently solving problem (1). The proposed approach is characterized by the possibility of performing several variable metric forward–backward steps on each block of variables, in combination with an Armijo backtracking linesearch to ensure the sufficient decrease of the objective function. The forward–backward step may be computed approximately, according to an implementable stopping criterion, and, unlike other existing methods in the literature, the parameters defining the variable metric may be chosen using any desired adaptive rule, provided that they belong to compact sets.
From a theoretical viewpoint, we show that each limit point of the iterates sequence is stationary and we prove convergence to the limit point when the objective function satisfies the Kurdyka–Łojasiewicz inequality, the gradient of the differentiable part is locally Lipschitz continuous and the proximal operator is computed exactly. Then, we discuss some convenient practical rules to adaptively select the parameters and we report a numerical experience on an image blind deconvolution problem, showing the benefits obtained by combining the variable metric of the forward–backward operator with a variable number of the blockwise iterations. This is a joint work with Silvia Bonettini and Marco Prato.

Robust sound field control for outdoor concerts using Gaussian processes to describe model discrepancy

Tuesday 11.12
14:30-15:00
Hall B-200

Nicolai A. B. Riis
Scientific Computing, DTU Compute

One challenge of outdoor concerts is to ensure adequate volume for the audience while avoiding disturbance of surrounding residential areas. Sound field control is a way to handle this issue by having a secondary set of speakers control the acoustic contrast between the bright zone (audience area) and dark zone (residential area) by destructive interference. The challenge is that the physical model necessary to calculate the control strategy is only partially known due to disturbances such as wind, temperature and reflections. This model discrepancy is necessary to take into account to attain a high acoustic contrast. We present a method for calibrating the model using Gaussian processes to describe the model discrepancy from measurements of the true physical model at sparse locations. The calibrated model is then used to design a control strategy that is robust to these disturbances. This is a joint work with Diego Caviedes-Nozal and Franz M. Heuchel.

Stochastic sparse photoacoustic solver using the Hamilton-Green algorithm

Tuesday 11.12
15:00-15:30
Hall A-304

Francesc Rul·lan
University College London

In this talk we present the use of high frequency asymptotic approximation to the solution of the wave equation in photoacoustic tomography (PAT). We use ray tracing, a technique that involves solving the wave equation along the trajectories of a Hamiltonian system, as a means of discretization. This discretization, combined with an approximation of the Green's function, constitutes the core of our Hamilton-Green (HG) solver. We apply the HG algorithm to obtain solutions to the forward and adjoint PAT problems in a 3D scenario. We evaluate the quality of the HG solutions to both the forward and adjoint problems against a full wave solution obtained with the k-space method implemented in k-Wave Toolbox.

The major benefit of the HG approach versus the full wave solution, as e.g. obtained with k-Wave, is that the solution at each sensor can be obtained independently and at a much lower cost than the full k-Wave solution. This flexibility affords an advantage in the construction of an approximate solver for use in iterative schemes. We combine the fast partial forward and adjoint HG operators (obtained when taking a single sensor) with a stochastic gradient descent scheme and show the results in a 3D domain. This is a joint work with Marta M. Betcke.

Seeing inside the Earth with micro earthquakes

Tuesday 11.12
16:30-17:00
Hall A-301

Teemu Saksala
Rice University, Houston

Earthquakes produce seismic waves. They provide a way to obtain information about the deep structures of our planet. The typical measurement is to record the travel time difference of the seismic waves produced by an earthquake. If the network of seismometers is dense enough and they measure a large number of earthquakes, we can hope to recover the wave speed of the seismic wave from the travel time differences. In this talk we will consider geometric inverse problems related to different data sets produced by seismic waves. We will state some uniqueness results for these problems and consider the mathematical tools needed for the proofs.

The talk is based on joint works with: Maarten de Hoop, Joonas Ilmavirta, Matti Lassas and Hanming Zhou.

Inverting a forest reflectance model using a Bayesian approach and Sentinel-2 and Landsat 8 satellite images

Wednesday 12.12
14:30-15:00
Hall B-200

Daniel Schraik
Aalto University

Forests form the largest terrestrial biome and play a key role in environmental policies, particularly related to climate change and biodiversity. Observing forests using multispectral satellite images is currently the only feasible means of monitoring this biome on a large scale. There are a variety of techniques to estimate variables of interest which describe forest stands based on satellite images. The majority of techniques rely on field observations, and commonly empirical regression models are used to estimate forest variables from satellite data. This modelling approach is difficult to generalize, since it is dependent on the regional and temporal state of forests, and it is specific to a satellite sensor. Forest reflectance models provide a means to physically model the forest radiation regime, or the relationship between forest variables and the multispectral signal received by a satellite sensor, thus becoming independent of regional and temporal dynamics as well as sensor configuration. It is necessary to invert these forest reflectance models to obtain estimates of forest variables, which is non-trivial due to the ill-posed nature of the radiative transfer problem. Efforts are made to overcome the ill-posedness, usually by relying on field observations that constrain forest variables to realistic ranges, i.e. their ecologically meaningful values. This is possible only because forest reflectance models have inherent physical meaning. Field observations in forests are often laborous, and sometimes even practically impossible in inaccessible terrain or remote areas. In addition to the difficulty to obtain field data, currently used inversion techniques do not provide explicit uncertainty estimates.

This study aims at tackling these two problems by applying a Bayesian approach to forest reflectance model inversion. This approach enables to make extensive use on existing knowledge about forest variables and their relationships. This results in a complex prior model that can sufficiently constrain the ill-posed problem. The Bayesian approach also enables a more detailed analysis of inversion results compared to traditional methods, which often provide only point estimates. In this study, we used the PyMC3 implementation of the MCMC No-U-Turn sampler together with the complex prior model to estimate forest variables of 746 plots in Suonenjoki, Central Finland. The forest reflectance model PARAS was inverted using data from the two sensors Sentinel-2 Multispectral Imager and Landsat 8 Operational Land Imager. We analyzed the posterior distribution for three key forest variables: (1) The leaf area index (LAI), which describes the density of the forest canopy, (2) the leaf clumping index (CI), which augments the LAI due to non-random distribution of leaves in the canopy, and (3) tree species ratios, which influence estimates due to variation in both forest structural and spectral properties. Validation data was only available for LAI, hence the other variables were only analyzed based on their effect on LAI estimates. Preliminary results were very promising. LAI point estimates showed root mean square errors of less than 0.4 (20%) for both sensors with negligible mean deviation (< 0.08, or 6%) compared to field observations. These results are comparable to empirical regression methods, however no field data was needed for the inversion. Leaf clumping estimates indicated that aggregation of leaves in sparse coniferous tree stands is higher than previously thought. Tree species identification was not always possible; the spectral properties of tree species could not always be distinguished by the MCMC method we used. Overall, these results show the benefits of Bayesian reflectance model inversion and its potential to generalize forest monitoring from optical satellite observations. Joint work with Petri Varvia, Lauri Korhonen, Miina Rautiainen.

Bayesian approach to analyzing aerosol particle counter data – estimation of time-varying particle formation, growth and loss rates

Tuesday 11.12
11:30-12:00
Hall B-200

Aku Seppänen

University of Eastern Finland

The effects of atmospheric aerosols are recognized as main uncertainties when quantifying the anthropogenic radiative forcing and its contribution to global warming. The inadequate knowledge on the new particle formation at its initial stages calls for the development of methods used in the analysis of aerosol particle counter data. Estimating the microphysical processes of aerosols (such as rates of particle formation, growth and loss) based on incomplete and noisy particle counter data is an ill-posed and non-stationary inverse problem. In this work, we cast the problem of estimating these time-varying process rates in the framework of Bayesian state-estimation. We model the evolution of particle size distribution by the General Dynamics Equation, which includes the process rate parameters. Further, we model these time-varying and size class-dependent parameters as stochastic processes, and estimate them based on sequentially measured particle counter data by using Kalman filtering/smoothing. The feasibility of the approach to estimating the aerosol process rates and quantifying estimate uncertainties is demonstrated by numerical examples.

Inverse Medium Problem For Singular Contrast

Tuesday 11.12
11:00-11:30
Hall B-200

Valery Serov
University of Oulu

We consider inverse medium problem in two and three dimensional cases. Namely, we investigate the problem of reconstruction of unknown compactly supported refractive index (contrast) from L^2 with fixed positive wave number. The proof is based on the new estimates for the Faddeev's Green function in L^∞ space. The main goal of the work is to prove the uniqueness results in two and three dimensional cases and to discuss some possible constructive methods for solving the problem.

Electrical impedance tomography and virtual X-rays

Thursday 13.12
15:00-15:30
Hall B-200

Samuli Siltanen
University of Helsinki

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 X-ray 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. In practical imaging, measurement noise causes strong blurring in the recovered profile functions. However, machine learning algorithms can be combined with the nonlinear PDE techniques in a fruitful way. As an example, simulated strokes are classified into hemorrhagic and ischemic using EIT measurements.

Towards Tomography of Structures

Wednesday 12.12
14:30-15:00
Hall A-301

Danny Smyl
Department of Mechanical Engineering, Aalto University

The most common methods for monitoring the health of civil infrastructure, aircraft, sea vessels, etc. are visual inspection and interpretation of data from point measurements. The former is prone to human error and the latter often offers insufficient spatial information. As a consequence, researchers have recently become interested in using distributed measurements coupled with inverse methods for 2D and 3D imaging of structures. Inverse methods offer the advantage of incorporating structural prior information, simultaneous solutions including data from numerous measurements, and constraints based on physical realizations. In this presentation, we highlight the recent developments and challenges associated with three promising inverse methods for structural tomography: Digital Image Correlation, Electrical Resistance Tomography, and Quasi Static Elasticity Imaging.

Identifying bias caused by multi-type HPV infections in type-specific progression parameter estimates

Thursday 13.12
11:00-11:30
Hall A-301

Anna Suomenrinne-Nordvik
University of Helsinki, Institute for Health and Welfare

Human Papillomavirus is a sexually transmitted disease which is the culprit of most cervical cancers. There are a high number of HPV types in circulation and type-specific parameters are typically estimated for each HPV type separately. However, such estimates may be influenced by multi-type infections.

To investigate the potential difference between single-type and multi-type estimation a deterministic progression model was built for two HPV types. For given type-specific progression and clearance parameters screening data was simulated. Both single-type and multi-type estimation procedures were applied to test how the pre-determined parameters are obtained. Under the conditions considered the single-type estimates showed a clear bias. The multi-type estimation procedure provided reliable and accurate estimates of the progression and clearance parameters.

This result shows there is a demand for modelling multiple types simultaneously. As multi-type progression models are inherently complicated and challenging to make inference on, the full model will require more advanced modelling and estimation methods.

On inverse scattering problems for perturbations of the biharmonic operator in 3D

Wednesday 12.12
11:30-12:00
Hall A-301

Teemu Tyni
University of Oulu

We study the perturbed biharmonic operator $H_4 := \Delta^2 + \vec{q} \cdot \nabla + V$ with two coefficients $\vec{q}$ and V. These coefficients are vector- and scalar-valued functions, respectively. They are allowed to be complex-valued and singular. We show that the direct scattering problem has a unique solution in certain Sobolev space and that this scattering solution satisfies a suitable asymptotic form. The asymptotic form gives raise to the scattering amplitude which can be measured in practise and used to define the inverse problem. We show that the inverse scattering problem of recovering a combination of the coefficients $\vec{q}$ and V from the scattering amplitude has a unique solution under full data. Given backscattering data we also show that the inverse Born approximation recovers essential information about a combination of the unknown coefficients $\vec{q}$ and V. Namely, all singularities can be recovered from the backscattering data in three dimensions. Also, in certain sense, the shape of any domain can be detected. Numerical examples are presented to demonstrate these theoretical results.

Semi-discrete iteration methods in X-ray tomography

Tuesday 11.12
17:00-17:30
Hall A-304

Jonas Vogelgesang
Saarland University

In practice, many applications of X-ray computed tomography suffer from incomplete data. For example when inspecting large objects or objects with extremely different diameters in longitudinal and transversal directions in non-destructive testing, the physical limitations of the scanning device do not allow a full rotation of the inspected object. Although more specific scanning geometries like computed laminography allow for a full rotation of such objects, the measured data is inherently incomplete.

Due to non-standard scanning geometries and restricted data, it is reasonable to use a semi-discrete model for the measured data resulting in a system of linear operator equations. In this talk, we present a framework to solve these linear systems iteratively in a Hilbert space setting. With the help of a basis function-type approximation of the operator domain we introduce a semi-discrete model for the emerging linear operators. Besides incorporating additional information about the inspected object such as the knowledge of the outer contours or material information, the semi-discrete model allows to make use of the operator properties. In particular, we present the semi-discrete Landweber-Kaczmarz method and provide numerical results for its application to X-ray tomography in non-destructive testing. Further, the classical and widely-used Simultaneous Algebraic Reconstruction Technique (SART) appears as a special case of our approach and can be analyzed within the presented framework.

Inverse Problems in Magnetic Particle Imaging

Tuesday 11.12
12:00-12:30
Hall B-200

Anne Wald
Saarland University

Magnetic particle imaging (MPI) is a novel tracer-based medical imaging modality with a potentially high resolution that can be used, e.g, to visualize blood flow. To this end, magnetic particles are injected into the blood stream. A strong external magnetic field with a field-free point (FFP) is applied, such that the magnetic moments of the particles align with this field, with the exception of the FFP. A second external field, the so-called excitation field, is applied to change the magnetization of the particles that are situated in the FFP. This change in the magnetization induces an electric current in the receive coils, which yields the data for this imaging technique. In order to obtain an image of the entire body, the FFP is moved along a trajectory that covers the area of interest. Both the calibration as well as the imaging process itself require the solution of inverse problems. This talk is intended to give an overview of MPI, and to introduce a current approach to incorporate relaxation effects in a model-based calibration process, using the Landau-Lifshitz-Gilbert equation, which describes the evolution of the magnetization in response to a time-dependent external field.

Uniqueness for a Space-Time Fractional Diffusion Equation

Tuesday 11.12
14:30-15:00
Hall A-301

Lauri Ylinen
University of Helsinki

Given a closed Riemannian manifold, we consider a space-time fractional diffusion equation with an interior source that is supported on a small open subset V of the manifold. The time-fractional part of the equation is given by a Caputo derivative of order $\alpha \in (0,1]$, and the space fractional part by $(-\Delta_g)^\beta$, where $\beta \in (0,1]$ and Δ_g is the Laplace-Beltrami operator on the manifold. We construct a source such that measuring the local evolution of the corresponding solution on the small set V determines the manifold up to a Riemannian isometry.

This is joint work with Tapio Helin, Matti Lassas, and Zhidong Zhang.

Expectation Propagation for Poisson Data

Tuesday 11.12
16:30-17:00
Hall A-304

Chen Zhang
Department of Computer Science, University College London

The Poisson distribution arises naturally when dealing with data involving counts, and it has found many applications in inverse problems and imaging. In this work, we develop an approximate Bayesian inference technique based on expectation propagation for approximating the posterior distribution formed from the Poisson likelihood function and a Laplace type prior distribution, e.g., the anisotropic total variation prior. The approach iteratively yields a Gaussian approximation, and at each iteration, it updates the Gaussian approximation to one factor of the posterior distribution by moment matching. We derive explicit update formulas in terms of one-dimensional integrals, and also discuss stable and efficient quadrature rules for evaluating these integrals. The method is showcased on two-dimensional PET images.

This is a joint work with Simon Arridge and Bangti Jin.

Posters

Simultaneous imaging of gamma-ray emission and attenuation in spent nuclear fuel

Tuesday 11.12
18:00-19:00
Hall B-200A

Rasmus Backholm
Helsinki Institute of Physics

In the context of safeguards for spent nuclear fuel, testing for missing or replaced nuclear fuel rods can be done via gamma-ray tomography. The self-attenuation of gamma-rays by the fuel material has a significant effect on the quality of the image reconstruction and, in the context of safeguards, assumptions made about the materials present should be minimal. Thus, an image reconstruction technique wherein the gamma-ray attenuation is evaluated simultaneously with the gamma-ray emission rate is a powerful safeguards tool. We attempt to solve this non-linear inverse problem using a regularized least-squares approach where the minimization is done iteratively with a trust region method. Feasibility of the technique is evaluated using simulated data.

This is joint work with C. Bélanger-Champagne, T. Bubba, P. Dendooven, T. Helin and S. Siltanen.

Modelling precessing asteroids with a dynamically self-consistent ellipsoidal model

Tuesday 11.12
18:00-19:00
Hall B-200A

Josef Ďurech
Astronomical Institute, Charles University

Most asteroids in our solar system rotate in a state of minimum energy – they are called principal-axis rotators (PA). Their shapes and spins states (direction of the rotation axis and the rotation period) can be modelled from disk-integrated photometry by the lightcurve inversion method of Kaasalainen et al. (2001, Icarus 153, 37). However, there are also asteroids that rotate in an excited mode of free precession – so called non-principal axis rotation (NPA). The method of deriving their shape and spin state (the angular momentum vector and principal axes of inertia tensor) is a generalization of inversion of PA rotators (Kaasalainen 2001, A&A 376, 302). In practice, the modelling is done using the periods of precession and rotation as free parameters, their initial values are estimated from the Fourier analysis of the lightcurve signal. The shape is described by a convex polyhedron. The inertia tensor of this shape is not coupled with the dynamical parameters describing the free precession. This may lead to a situation when the model formally fits the data but is not physically self-consistent.

I will describe an alternative approach to the inversion of lightcurves of NPA asteroids where the shape model is a geometrically scattering ellipsoid. In that case the dynamical parameters (moments of inertia) describing the excited rotation are always consistent with the shape, which cannot be automatically fulfilled when using convex shape models. The brightness of an ellipsoidal model for a given orientation can be computed analytically, which speeds up the search for the best-fitting model. The inversion is robust, fast, and the model is physically self-consistent. This enables us to scan a large space of model parameters even without any apriori estimate of periods in the signal, which is important for inversion of sparsely sampled photometric data.

Subjective parameter choice for total variation denoising of real noisy images

Tuesday 11.12
18:00-19:00
Hall B-200A

Markus Juvonen
University of Helsinki

We compare a subjective choice for regularization parameters with objective methods like the S-curve method in the case of total variation denoising. As our data we use natural images with different levels of real noise.

Inverse problems for a generalized subdiffusion equation with final overdetermination

Tuesday 11.12
18:00-19:00
Hall B-200A

Nataliia Kinash and Jaan Janno
Tallinn University of Technology

We consider two inverse problems for a generalized subdiffusion equation. Firstly, we study a problem of reconstruction of a specific space-dependent component in a source term under the final overdetermination condition. We prove existence, uniqueness and stability of the solution by means of a positivity principle and the Fredholm alternative. Based on these results we consider an inverse problem of identification of a space-dependent coefficient of a linear reaction term, again under the final overdetermination condition. We prove the uniqueness and local existence and stability of the solution to this problem. This is a joint work with Jaan Janno.

Torus computed tomography

Tuesday 11.12
18:00-19:00
Hall B-200A

Olli Koskela
Tampere University of Technology

We present a new computed tomography (CT) method for inverting the Radon transform in 2D based on the recent work of Ilmavirta (2015). The idea explores the geometry of torus, hence we call the new method Torus CT. The geodesic X-ray transform on the flat torus has a reconstruction formula which can be applied to objects in $\mathbb{R}^2$ with compact support. We also introduce a new regularization strategy for the CT imaging that is analogous to the Tikhonov regularization. This regularization is a simple post-processing low-pass filter for the Fourier series of the target function. The inversion method is meshless in the sense that it gives out a closed form function that can be evaluated at any point of interest. We have implemented the Torus CT method using MATLAB and tested it with simulated data. This is a joint work with Joonas Ilmavirta and Jesse Railo.

Spectral Computed Tomography of a Moving Heart with Projection-based Material Decomposition and Sparse Angle Geometry

Tuesday 11.12
18:00-19:00
Hall B-200A

Satu I. Inkinen

University of Oulu

In cardiac CT, the movement of the heart causes motion artifacts in the reconstructed images. One common method for reducing these artifacts is the extraction of single cardiac motion phases and reconstructing them separately. However, the acquired data is usually sparse, and conventional reconstruction algorithms such as FDK perform poorly, with undersampling artifacts arising from low projection numbers.

Spectral imaging enables decomposition of the projection images into material-specific density images. Subsequently, these images can be further used for tissue characterization, such as evaluation of the calcification concentration of a coronary plaque. However, the material decomposed projection data is very noisy, and strong regularization is needed in image reconstruction. Our previous work has focused on material decomposition of cardiac phantom data in projection space for bone (calcification) and soft tissue basis images, and applying iterative reconstruction methods to the basis images without cardiac movement.

This study focuses on applying the developed techniques for dynamic spectral cardiac CT. We have simulated dual energy projections using a virtual XCAT phantom with cardiac motion to investigate the effects of movement in material-specific reconstruction. The cardiac motion cycle was divided into 20 phases and a full dual-energy data set with 360 projection images was simulated for each phase. We aim at investigating the effect of cardiac motion in the quantitative values of calcium concentration estimates determined from the reconstructions. The reconstruction requires suppressing both the streaking artifacts arising from low angular sampling, and the noise arising from the material decomposition. We expect that when iterative reconstruction algorithms with strong priors are combined with motion correction techniques, the quantitative properties obtained from the spectral cardiac data are preserved.

This is a joint work with Alexander Meaney.

The research visit to Computational Imaging Group of CWI Centrum Wiskunde & Informatica

Tuesday 11.12
18:00-19:00
Hall B-200A

Salla Latva-Äijö

University of Helsinki

Centrum Wiskunde & Informatica (CWI) is the national research institute for mathematics and computer science in the Netherlands. The research group of computational imaging in Amsterdam, lead by professor Joost Batenburg, is developing methods for real-time 3D X-ray imaging. Ten people from the Finish Inverse Problems tomography team of Helsinki (STOM) carried out a visit to CWI to explore the state-of-the-art X-ray scanner and to do scientific collaboration. As a result, two X-ray datasets (dynamic and static) were measured with the flex-ray scanner. Here the experiments, the methods and the reconstruction results are introduced. The measured data is intended to be publicly available for everyone.

A resolvent estimate for the magnetic Schrödinger operator in the presence of short and long-range potentials

Tuesday 11.12
18:00-19:00
Hall B-200A

Leyter Potenciano-Machado
University of Jyväskylä

This is a joint work with Mikko Salo (University of Jäskylä, Finland) and Cristóbal Meroño (Universidad Autónoma de Madrid, Spain). It is well known that the *resolvent* of the free Schrödinger operator at energy λ has norm decaying as $\lambda^{-\frac{1}{2}}$ on weighted L^2-spaces. This is known as the *Limiting Absorption Principle.* Combining elementary techniques like integration by parts with a positive commutator argument and a suitable Carleman estimate, we show that this result is also valid for perturbations of the free case by *magnetic* and *electric* potentials satisfying *short* and *long-range* conditions at infinity. This result was already proved by Vodev in dimension $n \geq 3$. We extend it to $n \geq 2$. This work is still in preparation.

The geodesic ray transform with matrix weights for piecewise constant functions

Tuesday 11.12
18:00-19:00
Hall B-200A

Jesse Railo
University of Helsinki

We show that on a two-dimensioncal compact nontrapping manifold with stictly convex boundary, a piecewise constant complex vector-valued function is determined by its matrix weighted integrals over geodesics. In higher dimensions, we obtain a similar result if the manifold satisfies a foliation condition. This work extends the earlier results by Ilmavirta, Lehtonen and Salo (2017) for the piecewise constant scalar functions without weights, and is analogous to the geodesic X-ray transform with matrix weights studied by Paternain, Salo, Uhlmann and Zhou (2016). This is joint work with Joonas Ilmavirta.

Denoising of CT projection images using deep learning

Tuesday 11.12
18:00-19:00
Hall B-200A

Siiri Rautio
University of Helsinki

Deep convolutional neural networks have recently been successfully used in medical image processing problems such as image denoising. In this poster, we explain how to use CNNs to denoise computed tomography (CT) projection images in the context of cardiological imaging and material decomposed data. CT imaging requires taking hundreds of X-ray images around the patient causing a significant amount of radiation exposure. The amount can be reduced by lowering the radiation dose used in the X-ray projection images, but this leads to poor quality CT reconstructions as low-dose images tend to be noisy. In addition, the process of material decomposition used to improve tissue differentiation in the images increases the noise even more. The occurring noise can be approximated as Gaussian noise which makes the use of CNNs suitable, as loads of training data can be fairly simply created with computer simulations. After the neural network has been successfully trained with numerous noisy and corresponding noiseless pairs of images, it is able to denoise given material decomposed X-ray projection images of the heart. These denoised projection images can then be used for computing the final CT reconstruction.

Iterative Gaussian Smoothing For Statistical Inverse Problems

Tuesday 11.12
18:00-19:00
Hall B-200A

Filip Tronarp

Department of Electrical Engineering and Automation, Aalto University

This poster gives an overview in advances on iterative Gaussian estimation for statistical inverse problems with particular emphasis on inference in state space models. The method is based on iteratively approximating the system by a linear system using the current best Gaussian approximation to the posterior by statistical linear regression. The well known Gauss-Newton method come out as a particular approximation to the statistical linear regression solution. Furthermore, this methodology can be extended to non-Gaussian measurements under some assumptions on the conditional expectation/covariance of the measurements.

New Online Courses on Computational Inverse Problems

Tuesday 11.12
18:00-19:00
Hall B-200A

Heli Virtanen

University of Helsinki

In the previous years, professor Samuli Siltanen has shared his lecture videos online and he has gotten feedback to make the course materials available to others as well. Now, the materials have been collected to two courses on computational inverse problems and a third course is in the planning state.

The courses are based on University of Helsinki course Inverse Problems, which has now been divided into two courses. The first course is an entry level course to Computational Inverse Problems with a main focus on convolution and deconvolution, especially in 1D cases. The second course is focused on computational tomography. The first course is suited for master level students, who have basic idea of linear algebra and some background in Matlab. Based on the feedback on the first pilot version of the first course, not much Matlab skills were needed to pass it, and the students also learned how to use Matlab. The second course offers more theoretic background for the topics already covered in the first part and 2D examples in the form of tomographic images. The third course will focus on nonlinear inverse problems.

The first two courses were piloted during Autumn term 2018. The courses are timed and the next starting time is September 2019 on the University of Helsinki MOOC (Massive Open Online Course) platform. All the exercises on the course will be automatically graded and students will have access to video lectures to help solve the exercises.

Author index