# HD-Tomo Days

**6-8 April 2016**

Technical University of Denmark

**DTU Compute**
Department of Applied Mathematics and Computer Science

# Welcome

Tomography is the science of "seeing inside objects." Physical signals (e.g. waves, particles, currents) are sent through an object from many different angles, the response of the object to the signal is measured, and an image of the object's interior is reconstructed. Tomography is behind some of the most important and profound scientific discoveries of all times: the interior structure and processes of the earth, moon and sun, and the first maps showing the location of simple mental processes in the human brain are notable examples.

In High-Definition Tomography, the goal is to compute sharp reconstructions with both high contrast and high resolution, and in this way provide new possibilities for the monitoring and understanding of fundamental processes. Tomographic reconstruction problems are fundamentally ill-posed, and there is a strong need for better mathematical modelling, analysis, and computational algorithms that can incorporate prior information to guide and stabilize the reconstructions. With this in mind, it is a great pleasure to welcome you to *HD-Tomo Days* and to the Department of Applied Mathematics and Computer Science at the Technical University of Denmark, Kongens Lyngby, Denmark. We look forward to an exciting program with many interesting talks, splendid poster presentations, and lively discussions.

With kind regards,

*Martin S. Andersen*
*Yiqiu Dong*
*Mirza Karamehmedović*
*Kim Knudsen*
*Anne Mette Eltzholtz Larsen*
*Ekaterina Sherina*

This workshop was made possible thanks to generous support from DTU Compute, Otto Mønsteds Fond, The European Research Council (ERC Advanced Grant"HD-Tomo", grant no. 291405), and The Danish Council for Independent Research ("Hydbrid-Data", grant no. 4002-00123).

# Practical Information

## Internet Access

Participants from Eduroam-participating institutions may access the internet simply by connecting to the Eduroam wireless network. If you do not have access to Eduroam, please contact one of the organizers if you would like a temporary guest account for the DTU wireless network.

## Lunch

Lunch is not provided, but DTU's main canteen is located on the ground floor in building 101. We have reserved some tables so that workshop participants can enjoy their lunch together.

## Workshop Website

The workshop website is available at `hd-tomo-days.compute.dtu.dk`.

## Public transportation

The public transportation in Copenhagen is very reliable and takes you almost everywhere. You can get up-to-date travel information and plan your journey on "Rejseplanen.dk".

## Social Activities on Thursday, 7 April 2016

Workshop participants are invited to a guided tour and workshop dinner in central Copenhagen. Both are free of charge, but sign-up is required. You may choose between one of the two tours listed below, and sign-up will be handled on a first-come, first-served basis.

### Guided Tour of Slotsholmen

Join a 60-minute outdoor guided tour of Slotsholmen, an island located in the Copenhagen harbour. Often referred to as "The Island of Power", Slotsholmen is home to Christiansborg Palace, the Danish Parliament and several government institutions and ministries.

Maximum number of participants: 30

### Guided Tour of Christiansborg Palace

Join a 60-minute indoor guided tour of Christiansborg Palace. Learn about the history and ornamentation of the majestic rooms, the Queen's use of the palace for official functions, and visit the Great Hall with its renowned tapestries documenting the history of Denmark.

Maximum number of participants: 50

### Workshop Dinner

After the guided tours, please join us for dinner at Restaurant Ravelinen at 19:00. The restaurant is located in Christianshavn by the old rampart that was once part of the city's fortification ring. It is a 15-minute walk from Christiansborg Palace.

Restaurant Ravelinen
Torvegade 79
1400 København K

### Transportation

A bus will take participants from DTU to Copenhagen in time for the guided tours. Please meet at the main entrance of building 101A no later than 16:30. Please note that there will not be any organized transportation returning to DTU.

# Wednesday, 6 April 2016

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| 08:30 | Registration |
| 09:00 | Welcome |
| 09:05 | **Mini-tutorial: Computational Bayesian Inversion**<br>Klaus Mosegaard, University of Copenhagen |
| 10:00 | Coffee break |
| 10:15 | **Mini-tutorial (part II)** |
| 11:15 | **Bayesian Approximation Error Approach in Electroencephalography Source Imaging**<br>Ville Rimpiläinen, University of Auckland |
| 11:45 | Lunch |
| 13:00 | **Towards Real-Time Tomography**<br>Joost Batenburg, Centrum Wiskunde & Informatica |
| 14:00 | **ODL — A Rapid Prototyping Framework for Inverse Problems**<br>Holger Kohr, KTH Royal Institute of Technology |
| 14:30 | **A Limited Memory BFGS Method for a Nonlinear Inverse Problem in Digital Breast Tomosynthesis**<br>Elena Loli Piccolomini, University of Bologna |
| 15:00 | Coffee break |
| 15:30 | **Motion-Corrected Dynamic Tomography**<br>Martin Burger, University of Münster |
| 16:30 | **Inverse Problems and MRAI — Mapping the Pulse Wave Velocity**<br>Simon Hubmer, Johannes Kepler University Linz |
| 17:00 | Welcome reception & poster session |

## Poster Session (17:00–18:30)

**A Convex Model for X-ray Tomographic Imaging with Uncertain Flat-fields**
Hari Om Aggrawal, DTU Compute

**CT Reconstruction using Deformable Mesh with Explicit Interface**
Michael Andersen, DTU Compute

**Characterisation of Artifacts in a Special Limited-Angle Tomography Problem**
Leise Borg, University of Copenhagen

**A Nonsmooth Shearlet-Based Regularization Approach for the ROI CT Problem**
Tatiana A. Bubba, University of Modena and Reggio Emilia

**On Nonstationary Preconditioned Iterative Regularization Methods for Image Deblurring**
Alessandro Buccini, University of Insubria

**Infinite Dimensional Optimization Models and PDEs for Dejittering**
Guozhi Dong, University of Vienna

**Directional Total Variation Regularized CT-Reconstruction**
Rasmus Dalgas Kongskov, DTU Compute

**Improving the Reconstruction of Dynamic Processes by Including Prior Knowledge**
Heyndrickx Marjolein, Ghent University

**Variational Models for Digital Breast Tomosynthesis**
Elena Morotti, University of Padua

**Comparison of a CGO-Based Reconstruction Method and an Iterative Newton's Method for Electrical Impedance Tomography**
Ekaterina Sherina, DTU Compute

**Soft X-ray Transmission Microscopy at Mistral**
Andrea Sorrentino, ALBA Synchrotron Light Source

**Quantitative Optical Tomographic Image Reconstruction with High Numerical Aperture Lenses**
Anna Katharina Trull, TU Delft

**Optimization of an Axial PEM Design**
Defne Us, Tampere University of Technology

# Thursday, 7 April 2016

09:00 **Phase Retrieval and Phase Contrast Tomography: Uniqueness, Stability, and Reconstruction Methods**
Thorsten Hohage, University of Göttingen

10:00 **Reconstruction of Electric Fields with Non-Zero Divergence in a Homogeneous Domain Using Vector Tomography**
Alexandra Koulouri, University of Münster

10:30 Coffee break

10:45 **Inverse Problems in Adaptive Optics**
Ronny Ramlau, Johannes Kepler University Linz

11:45 Lunch

13:00 **Computational Approaches in Spectral CT**
James G. Nagy, Emory University

14:00 **Shape Based Image Reconstruction Using Linearized Deformations**
Chong Chen, KTH Royal Institute of Technology & Chinese Academy of Sciences

14:30 **Velocity-Space Tomography in Magnetized Fusion Plasmas**
Mirko Salewski, DTU Physics

15:00 Coffee break

15:30 **The Limitations of Classical Reconstruction Tools Applied to Time-Resolved Tomography**
Rajmund Mokso, Max IV Laboratory & Lund University

16:15 Break

16:30 Social activities

19:00 Workshop dinner

# Friday, 8 April 2016

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|---|---|
| 09:00 | **Variations of the Factorization Method for Penetrable Media**<br>Armin Lechleiter, University of Bremen |
| 10:00 | **The Monotonicity Method for EIT with Electrode Models**<br>Henrik Garde, DTU Compute |
| 10:30 | Coffee break |
| 10:45 | **An Adaptive Sparse Regularization Approach to Gas Tomography**<br>Ye Zhang, Örebro University |
| 11:15 | **Challenges and Opportunities in Optical Tomography**<br>Jeroen Kalkman, TU Delft |
| 11:45 | Lunch |
| 13:00 | **Small Volume Asymptotics for Elliptic Equations and Their Use in Impedance Tomography**<br>Martin Hanke-Bourgeois, University of Mainz |
| 14:00 | **The Reconstruction of Obstacles in a Waveguide Using Finite Elements**<br>Ruming Zhang, University of Bremen |
| 14:30 | Coffee break |
| 15:00 | **Dynamic Sparse X-ray Tomography**<br>Samuli Siltanen, University of Helsinki |
| 16:00 | Closing |

# Invited Speakers

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|---|---|
| Joost Batenburg | Centrum Wiskunde & Informatica |
| Martin Burger | University of Münster |
| Martin Hanke-Bourgeois | University of Mainz |
| Thorsten Hohage | University of Göttingen |
| Armin Lechleiter | University of Bremen |
| Klaus Mosegaard | University of Copenhagen |
| James G. Nagy | Emory University |
| Ronny Ramlau | Johannes Kepler University Linz |
| Samuli Siltanen | University of Helsinki |

# List of Participants

| | |
|---|---|
| Andrea Sorrentino | ALBA Synchrotron Light Source |
| Willem Jan Palenstijn | Centrum Wiskunde & Informatica |
| Bjørn Christian Skov Jensen | DTU |
| Adrian Kirkeby | DTU |
| Nicolai André Brogaard Riis | DTU |
| Hari Om Aggrawal | DTU Compute |
| Martin S. Andersen | DTU Compute |
| Michael Andersen | DTU Compute |
| Yiqiu Dong | DTU Compute |
| Jürgen Frikel | DTU Compute |
| Henrik Garde | DTU Compute |
| Per Christian Hansen | DTU Compute |
| Lauri Harhanen | DTU Compute |
| Mirza Karamehmedovic | DTU Compute |
| Hans Martin Kjer | DTU Compute |
| Kim Knudsen | DTU Compute |
| Rasmus Dalgas Kongskov | DTU Compute |
| Jinjin Mei | DTU Compute |
| Tuan T. Nguyen | DTU Compute |
| Marie Foged Schmidt | DTU Compute |
| Federica Sciacchitano | DTU Compute |
| Ekaterina Sherina | DTU Compute |
| Stratos Staboulis | DTU Compute |
| Malgorzata Makowska | DTU Energy |
| Mirko Salewski | DTU Physics |
| Jin Zhang | DTU Physics |
| Marjolein Heyndrickx | Ghent University |
| Farid Bozorgnia | Institute Superior Técnico |
| Simon Hubmer | Johannes Kepler University Linz |
| Holger Kohr | KTH Royal Institute of Technology |
| Chong Chen | KTH Royal Institute of Technology & Chinese Academy of Sciences |

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|---|---|
| Maddi Etxegarai | Laboratoire 3SR & Lund University |
| Rajmnund Mokso | Max IV Laboratory, Lund University |
| Anastasia Ingacheva | Russian Academy of Sciences |
| Defne Us | Tampere University of Technology |
| Jeroen Kalkman | TU Delft |
| Anna Katharina Trull | TU Delft |
| Jörn Zimmerling | TU Delft |
| Saeed Seyyedi | TU Munich |
| Viswanath P. Sudarshan | TU Munich |
| Phalgun C. Chintala | TU Munich |
| Sunghwan Moon | Ulsan National Institute of Science and Technology |
| Ville Rimpiläinen | University of Auckland |
| Elena Loli Piccolomini | University of Bologna |
| Ruming Zhang | University of Bremen |
| Leise Borg | University of Copenhagen |
| Zenith Purisha | University of Helsinki |
| Davide Bianchi | University of Insubria |
| Alessandro Buccini | University of Insubria |
| Ke Chen | University of Liverpool |
| Tatiana Alessandra Bubba | University of Modena and Reggio Emilia |
| Jonas Geiping | University of Münster |
| Alexandra Koulouri | University of Münster |
| Elena Morotti | University of Padua |
| Guozhi Dong | University of Vienna |
| Romeo Malik | University of Warwick |
| Kenneth Nielsen | Xnovo Technology ApS |
| Ye Zhang | Örebro University |

# Abstracts

6 April 2016, 09:05-11:10

## Computational Bayesian Inversion

Klaus Mosegaard
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### Abstract

Inverse problems are problems where physical data - in a wide sense - from indirect measurements are used to infer information about unknown parameters of physical systems. Noise-contaminated data and prior information on model parameters are basic elements of inverse problems, and in a Bayesian formulation we seek a consistent formulation using probability theory. From our fully probabilistic results we attempt to answer any question pertaining our state of information about the system when all information has been integrated. We shall give an overview over the Bayesian method and the way it is used in practice. We shall also try to answer a number of fundamental questions: What is probability, and how is it used to measure the quality of a solution? What is the connection between Bayesian methods and other inversion methods ? Is the use of probabilities more objective than other approaches? What are the pitfalls of probabilistic methods?

6 April 2016, 11:15-11:40

# Bayesian Approximation Error Approach in Electroencephalography Source Imaging

Ville Rimpiläinen
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## Abstract

In electroencephalography (EEG) brain imaging neural sources are estimated with the help of measured electric potentials around the head and prior information. The reliability of the result is highly dependent on the accuracy of the used head model, particularly the geometry and the conductivity modelling of different tissues. In practice, the geometry can be extracted using magnetic resonance imaging (MRI) and the conductivities can be modelled based on literature. However, MRI cannot always be carried out and the conductivity values of different tissues can have significant individual variation. Therefore, we propose to use the Bayesian approximation error (BAE) approach to alleviate these uncertainties associated with the head model. In BAE, first, a probabilistic model is postulated for the uncertainties and subsequently an approximate marginalization over these parameters is carried out. We show that BAE can alleviate the uncertainties and that reliable imaging results can be obtained without precise knowledge of the head parameters.

6 April 2016, 13:00-13:50

## Towards Real-Time Tomography

Joost Batenburg
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### Abstract

Just two decades ago, taking photographs was an elaborate endeavor, involving not just taking a picture and viewing it, but also various time-consuming steps to process the analog film into a printed result. Now that everyone has digital cameras providing instant access to our pictures, we see that this has not just resulted in more convenience, but it has dramatically changed the way we using imaging in ways that no one imagined before. In comparison, tomography is still a time-consuming process, where reconstructions are usually made only after the scan has been finished, and analyzed even later at a different location.

In this lecture I will discuss the various challenges involved in speeding up the tomography pipeline towards real-time tomography, where the object can already be analyzed during the scan. I will cover the unique opportunities of adjusting the scanning process in real-time, the key problems that must be addressed, and computational strategies for computing accurate reconstructions from limited data very fast.

6 April 2016, 14:00-14:25

## ODL — A Rapid Prototyping Framework for Inverse Problems

Holger Kohr
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### Abstract

The Operator Discretization Library (ODL) is an open-source Python package for rapid prototyping in inverse problems whose main goal is to greatly reduce the effort to apply advanced or new numerical reconstruction methods to a variety of imaging modalities and problem sizes that go beyond simple proof-of-concept examples. The software introduces the concepts of linear spaces, vectors and operators and equips them with mathematical rules as expected from functional analysis. For example, the operator derivative of the composition of two operators is composed in the correct way from the derivatives of the components, according to the chain rule. To numerically compute the action of an operator on an element in a vector space, continuous quantities need to be discretized. In ODL, this discretization is explicitly chosen by the user and applies to linear spaces as well as to operators. Such a discretized operator can then seamlessly be evaluated using fast third-party software like, e.g., the ASTRA toolbox for tomographic imaging. Bindings to fast external libraries include Numpy, Scipy, ASTRA, STIR and an own CUDA array implementation.

On top of the built-in vector space functionality and existing operator implementations in ODL, the development of a new reconstruction method can very often be done in a completely generic way. For example, the simplest possible implementation of the non-linear version of Landweber's method for the reconstruction of f from g = A(f) reads in ODL as

```python
def landweber(f, A, g, omega=1.0, niter):
    for i in range(niter):
        f -= omega * A.derivative(f).adjoint(A(f) - g)
```

Due to the simple and clean operator interface in ODL, it suffices to merely exchange operator and data in such a numerical method to switch between different applications. In a similar way, the same modality can be tested with many different reconstruction methods by using the same operator and data in different method implementations. The source code of ODL is available under `https://github.com/odlgroup/odl`.

6 April 2016, 14:30-14:55

## A Limited Memory BFGS Method for a Nonlinear Inverse Problem in Digital Breast Tomosynthesis

Elena Loli Piccolomini
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### Abstract

In digital tomosynthesis imaging, multiple projections of an object are obtained along a small range of different incident angles in order to reconstruct a pseudo-3D representation (i.e., a set of 2D slices) of the object. In this work, we consider a multimaterial polyenergetic model based on the linear attenuation coefficients, that explicitly takes into account various materials composing the object and the polyenergetic nature of the x-ray beam, and we formulate the DBT image reconstruction problem as a nonlinear least squares problem. We face the extremely high dimensionality of the tomosynthesis problem and we consider for its solution a limited memory BFGS quasi-Newton strategy with diagonal modification of the BFGS matrix. In the proposed approach, the computational cost and the memory requirement are reduced by avoiding the computation of the Jacobian matrix and by using a limited memory technique. Regularization is enforced by truncated iteration. Some numerical results are presented confirming the efficiency of the proposed method.

6 April 2016, 15:30-16:20

**Motion-Corrected Dynamic Tomography**

Martin Burger
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**Abstract**

We will discuss the problem of reconstructing the density of a moving subject from sparse angular measurements at each time step, a problem naturally appearing in dynamic CT and in PET imaging. We present appropriate models for the motion together with advanced variational regularization techniques for jointly reconstructing motion and images. We discuss their mathematical properties, numerical solution, practical applications, and some limitations (sample rate vs. motion speed, initial guesses). Finally we comment on the potential incorporation of (partial) motion information from other modalities as e.g. used in PET-MR imaging.

6 April 2016, 16:30-16:55

## Inverse Problems and MRAI — Mapping the Pulse Wave Velocity

Simon Hubmer
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### Abstract

Magnetic Resonance Advection Imaging (MRAI) is a recently developed method for mapping the pulsatory signal component of dynamic EPI data of the brain, such as acquired in functional and resting state functional MRI experiments. Its underlying model is based on an advection equation. It has been shown that MRAI depicts the location of major arteries as well as some venous structure. In addition, colour direction maps allow for visualization of the orientation direction of blood vessels.

It has been suggested that MRAI may potentially serve as a biomarker for the health of the cerebrovascular system. The reason for this is that MRAI is designed to reflect the spatiotemporal properties of travelling waves, and pulse wave velocities (PWV) are a main indicator for the physical properties of blood vessels.

First results in MRAI were achieved using a multiple regression approach for the underlying advection equation. In this talk, we present a different approach which is based on a classical inverse problem of parameter estimation type. The resulting method for estimating the PWV in the brain from functional MRI data yields improved results, as will be demonstrated numerically using a model problem and a real-world MRI data set.

7 April 2016, 09:00-09:50

## Phase Retrieval and Phase Contrast Tomography: Uniqueness, Stability, and Reconstruction Methods

Thorsten Hohage
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### Abstract

As opposed to conventional computed tomography, phase contrast tomography does not only yield information on the imaginary part, but also the real part of the refractive index of the sample. The former gives rise to attenuation, whereas the latter causes phase shifts of the x-ray beam. Phase contrast tomography is particularly well-suited for imaging optically thin objects, e.g. soft tissue of small length scale since phase contrast for x-rays is typically several orders of magnitude larger than absorption contrast. In this talk we only consider propagation based contrast tomography: Here phase variations are turned into measurable intensity variations simply by propagation, i.e. the intensity is not measured immediately behind the sample, but at some distance to the sample. For point sources this also provides magnification.

At each direction of the incident beam a phase retrieval problem has to be solved: The missing phase information of the field in the detector plane have to be reconstructed from the measurable intensities using a-priori information. Then the exit field (i.e. the field in a fictious plane parallel to the detector plane immediately behind the sample) can be computed by back-propagation. The values of the exit field are functions of line integrals over the refractive index. Surprisingly, for compactly supported objects the complex-valued field in the exit field is uniquely determined by the amplitude of the field in the detector plane. Even more, we show that the corresponding linearized inverse problem is well-posed. However, the condition number grows exponentially with the Fresnel number. For real-valued refractive indices one has a much more favorable linear growth with the Fresnel number.

Finally, we discuss the solution of phase retrieval problems by regularized Newton method. In particular we show that joint reconstruction of phase and amplitude is possible for moderate Fresnel numbers. Moreover, we present three-dimensional reconstructions from experimental tomographic data using a Newton-Kaczmarcz method.

7 April 2016, 10:00-10:25

## Reconstruction of Electric Fields with Non-Zero Divergence in a Homogeneous Domain Using Vector Tomography

Alexandra Koulouri
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### Abstract

In this work we describe how vector tomography (VT) framework can be used to reconstruct electric fields induced by focal sources considering Neumann homogeneous boundary conditions. In particular, we study reconstruction of electric fields that are generated by dipole sources which is a case that is often met, for example, in EEG source imaging.

To the best of our knowledge, non-zero divergence vector fields in bounded domains have not been previously studied with VT. The previous work related to VT has dealt with divergence-free (or source-free) cases which are mathematically much easier to solve. These previously studied smooth fields have been, for example, velocity fields of moving liquids which can numerically be solved from longitudinal integral measurement using algebraic reconstruction techniques (ART).

In this problem we do not use ART; instead we formulate a convex minimization problem with the help of longitudinal line measurements and sparsity constraints. The constraints were selected based on the physical properties of the problem. In particular, by employing the Radon transform properties, we show how the transverse integral measurements are related to the focal sources and how they can be used as a sparsity constraint even though they cannot be physically measured. We validate our analysis using simulated data. Our simulations show that the patterns of the electric fields can be correctly estimated and that the location of the source activity can be pointed out from the reconstructed magnitudes of the field.

7 April 2016, 10:45-11:35

**Inverse Problems in Adaptive Optics**

Ronny Ramlau
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**Abstract**

The image quality of ground based astronomical telescopes suffers from turbulences in the atmosphere. Adaptive Optics (AO) systems use wavefront sensor measurements of incoming light from guide stars to determine an optimal shape of deformable mirrors (DM) such that the image of the scientific object is corrected after reflection on the DM. The solution of this task involves several inverse problems: First, the incoming wavefronts have to be reconstructed from wavefront sensor measurements. The next step involves the solution of the Atmospheric Tomography problem, i.e., the reconstruction of the turbulence profile in the atmosphere. Finally, the optimal shape of the mirrors has to be determined. As the atmosphere changes frequently, these computations have to be done in real time. We will present fast algorithms as well as related numerical reconstructions for each of the sub-tasks that achieve the required accuracy and speed.

7 April 2016, 13:00-13:50

## Computational Approaches in Spectral CT

James G. Nagy
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### Abstract

Standard CT reconstruction algorithms assume that the x-ray beam is mono- energetic and does not change throughout the imaged object. In situations where it is possible to use high energy, heavily filtered x-ray spectra, this may be an appropriate assumption. Moreover, in cases such as this, it might be possible to collect multiple projection data, using different energy distributions to obtain quantitative information of the objects material. However, in cases where it is necessary to use low energy, relatively unfiltered spectra, such as in breast imaging, the mono-energetic assumption results in additional reconstruction inaccuracies, loss of contrast and a larger cupping artifact, making quantitative analysis challenging.

In this work we consider algorithms that exploit poly-energetic assumptions of the x-ray source, combined with a multi-spectral single pass imaging approach to reduce beam hardening artifacts and with an aim to achieve material quan- tification in the imaged object. We will describe our current efforts, provide numerical experiments, and discuss open problems.

7 April 2016, 14:00-14:25

### Shape Based Image Reconstruction Using Linearized Deformations

Chong Chen
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#### Abstract

We introduce a reconstruction framework that can account for shape related a priori information in ill-posed linear inverse problems in imaging. It is a variational scheme that uses a shape functional defined using deformable templates machinery from shape theory. As proof of concept, we apply the proposed shape based reconstruction to 2D tomography with very sparse measurements, and demonstrate strong empirical results.

7 April 2016, 14:30-14:55

## Velocity-Space Tomography in Magnetized Fusion Plasmas

Mirko Salewski
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### Abstract

In magnetized fusion plasmas, ions move on spiraling trajectories. The velocities of the ions can be adequately described by just two coordinates in 2D velocity space. In Fast-ion D-alpha spectroscopy one measures light emitted at 651.1nm by these ions after neutralization. This light is Doppler-shifted due to the motion of the ions, forming a spectrum of different wavelengths due to their 2D velocity distribution function. We calculate this 2D velocity distribution function from the measured spectra by velocity-space tomography.

7 April 2016, 15:30-16:10

## The Limitations of Classical Reconstruction Tools Applied to Time-Resolved Tomography

Rajmund Mokso
Max IV Laboratory, Lund University
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### Abstract

With the latest developments in CMOS technology, it has been possible to exploit tomographic microsco- py at bright synchrotron facilities to unprecedented levels. We can routinely acquire 20 tomographic scans per second. Many hardware limitation in fast tomography has recently been solved with a develop- ment that puts tremendous pressure onto data handling as the state-of-the-art systems can acquire and stream continuously up to 8 BG/s directly to the server. In the meanwhile it opens new possibilities for data reduction schemes and even online 4D data analysis directly on the RAM of the server before images are saved to disk. The idea is to save only valuable data and filter out unnecessary projection images.

In Sweden the MAX IV facility is preparing for the future challenges in fast tomographic microscopy. I will present some plans and the search for sustainable solutions for reconstructing and handling Big Data with particular emphasis to dynamic in vivo and in situ tomographic microscopy.

8 April 2016, 09:00-09:50

**Variations of the Factorization Method for Penetrable Media**

Armin Lechleiter
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**Abstract**

The factorization method is well-known to identify the shape of scattering objects from measurements of near or far field data for various models of time-harmonic wave propagation. In the framework of scattering from inhomogeneous media, we show extensions of the method towards the characterization of numerical values of material parameters and the characterization of the support of possibly indefinite inhomogeneous media. (Joint work with Evgeny Lakshtanov)

8 April 2016, 10:00-10:25

## The Monotonicity Method for EIT with Electrode Models

Henrik Garde
DTU Compute
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### Abstract

In the inverse problem of electrical impedance tomography (EIT) the interior electrical conductivity is reconstructed from current and voltage measurements taken at electrodes on the surface of the domain. In practice, however, it is often sufficient to determine inclusions/inhomogeneities from some known or uninteresting reference conductivity. This simplification allows for very fast reconstruction methods that scales well for higher dimensions; one such direct reconstruction method is based on applying the monotonicity properties of the current-to-voltage map. In this talk I generalize the monotonicity method from the well-understood continuum model to, in practice, more precise discrete electrode models. A regularization parameter choice is given, which guarantees that the inclusions are detected from noisy measurements. It is proved that there is convergence to the correct shape of the inclusions when the boundary is densely covered by electrodes and noise tends to zero.

8 April 2016, 10:45-11:10

**An Adaptive Sparse Regularization Approach to Gas Tomography**

Ye Zhang
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**Abstract**

In this talk, I will present an algorithm to be used by an inspection robot to produce a gas distribution map and localize gas sources in a large complex environment. The robot, equipped with a remote gas sensor, measures the total absorption of a tuned laser beam and returns integral gas concentrations. A mathematical formulation of such measurement facility is a sequence of Radon transforms. To tackle the ill-posedness of the model, we develop a new regularization method based on the sparse representation property of gas sources and the adaptive finite element method. The proposed algorithm provides us not only a solution map but also a mesh map. The solution map more accurately locates gas sources, and the mesh map provides the real gas distribution map.

8 April 2016, 11:15-11:40

## Challenges and Opportunities in Optical Tomography

Jeroen Kalkman
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### Abstract

In optical tomographic techniques such as optical projection tomography (OPT) or diffuse optical tomography (DOT) the optical attenuation or fluorescence emission is determined based on the measurement of projections at various locations around the object. Because of strong optical light scattering the measured projections are heavily distorted. As a solution, either the scattering is reduced, as is the case in OPT, or the transport of light in the medium is modeled in the tomographic reconstruction, as for DOT. Both approaches have significant disadvantages. Here I present a novel low coherence based technique that can filter the non-scattered light transmitted through the object and thereby measures non-distorted projections without the use of optical clearing. I will show initial reconstruction results and discuss challenges that are present in the reconstruction of our measurements.

8 April 2016, 13:00-13:50

**Small Volume Asymptotics for Elliptic Equations and Their Use in Impedance Tomography**

Martin Hanke-Bourgeois
University of Mainz
hanke@mathematik.uni-mainz.de

**Abstract**

We reconsider the impact of small volume perturbations of the conductivity coefficient of second order elliptic equations in divergence form. The asymptotic expansion of the associated Neumann-Dirichlet operators on bounded domains allows the development and analysis of sophisticated algorithms to solve corresponding inverse boundary value problems of impedance tomography. Examples of such algorithms are the MUSIC scheme and the topological derivative. Novel applications include the incorporation of discrete electrode models and the ex- ploitation of multiple driving frequencies.

8 April 2016, 14:00-14:25

**The Reconstruction of Obstacles in a Waveguide Using Finite Elements**

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**Abstract**

This paper concerns the reconstruction of a penetrable obstacle embedded in a waveguide from the scattered data due to point sources. The inverse problem is formulated as an optimization problem. We propose a fast reconstruction method based on a carefully designed finite element method for the direct scattering problem. The method has several merits: 1) the linear sampling method is used to quickly obtain a good initial guess; 2) finite Fourier series are used to approximate the boundary of the obstacle, which it is different from the boundary used by the finite element method; and 3) the mesh is fixed and thus the stiffness matrix, mass matrix, and right hand side are assembled once and only minor changes are made at each iteration. The effectiveness of the proposed method is demonstrated by numerical examples.

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## Dynamic Sparse X-ray Tomography

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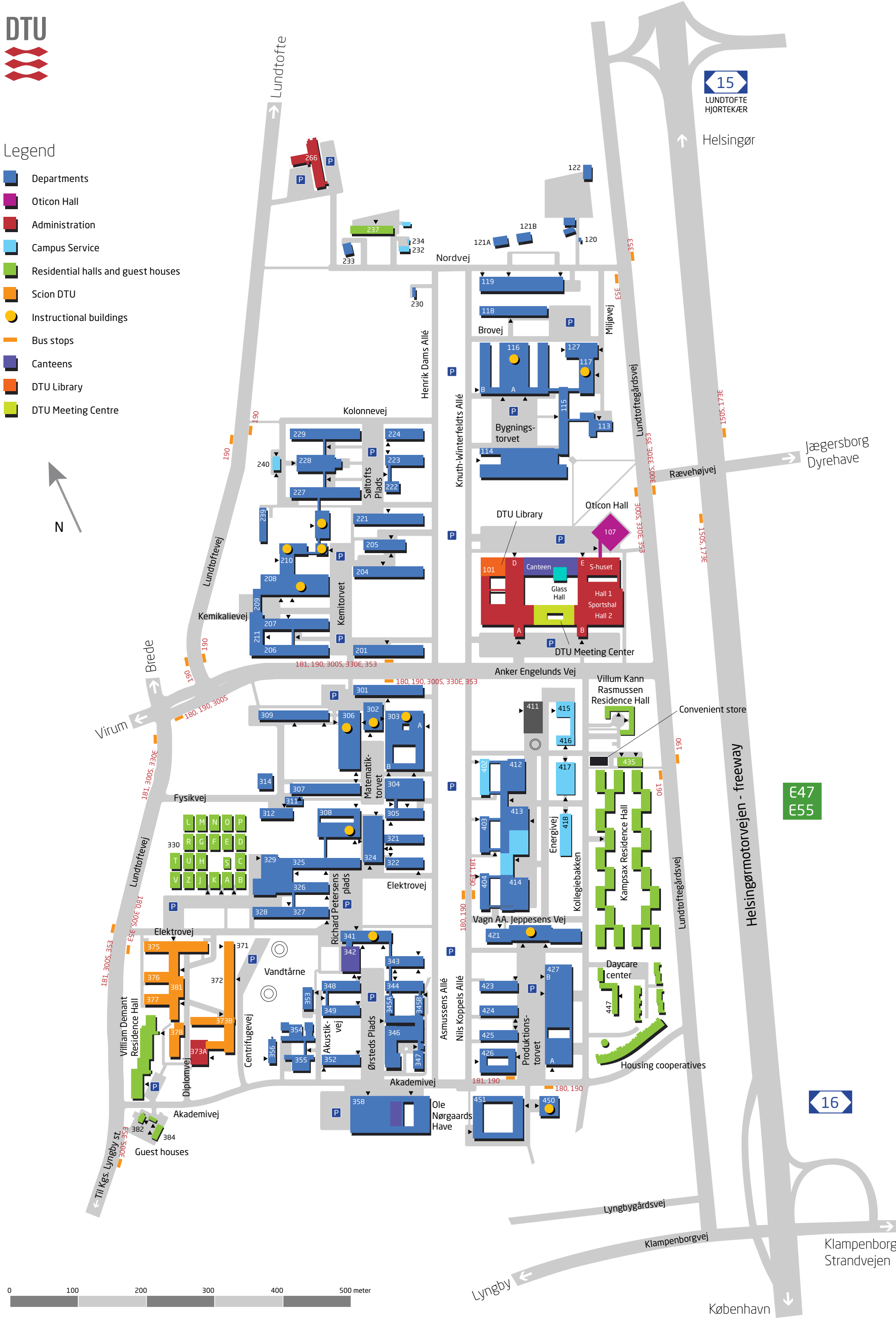
### Abstract

In recent years, mathematical methods have enabled three-dimensional medical X-ray imaging using much lower radiation dose than before. One example of products based on such approach is the 3D dental X-ray imaging device called VT, manufactured by Palodex Group. The idea is to collect fewer projection images than traditional computerized tomography machines and then use ad- vanced mathematics to reconstruct the tissue from such incomplete data. The idea can be taken further by placing several pairs of X-ray source and detector ”filming” the target from many directions at the same time. This allows in prin- ciple recovering the three-dimensional inner structure as a function of time. For example, one could observe the internal organs of a living and unsedated organism such as a laboratory mouse. Tentative computational results are shown, based on both simulated and measured data. The results suggest that the new imaging modality is promising for biological applications.

## Notes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Kollegiebakken
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Helsingørmotorvejen - freeway
E47
E55
Richard Petersens plads
Vagn AA. Jeppesens Vej
Vandtårne
Centrifugevej
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Ørsteds Plads
Asmussens Allé
Nils Koppels Allé
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Daycare center
Housing cooperatives
William Demant Residence Hall
Diplomvej
Akademivej
Ole Nørgaards Have
Guest houses
Til Kgs. Lyngby st.
16
Lyngbygårdsvej
Klampenborgvej
Lyngby
Klampenborg
Strandvejen
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100
200
300
400
500 meter

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