Pacific Institute for the Mathematical Sciences

AIP 2007
First International Congress of IPIA
Conference on Applied Inverse Problems 2007: Theoretical and Computational Aspects

PIMS at the University of British Columbia

June 25 – 29, 2007

Cosponsored by

MITACS

Conference Guide

Jun 25, 2007

Contact Information
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Conference Website: http://www.pims.math.ca/science/2007/07aip/

Foreword

Dear Participants:

The enormous increase in computing power and the development of powerful algorithms has made it possible to apply the techniques of Inverse Problems to real-world problems of growing complexity. Applications include a number of medical as well as other imaging techniques, location of oil and mineral deposits in the earth's substructure, creation of astrophysical images from telescope data, finding cracks and interfaces within materials, shape optimization, model identification in growth processes and, more recently, modelling in the life sciences.

The series of AIP Conferences aim to provide a primary international forum for academic and industrial researchers working on all aspects of inverse problems, such as mathematical modelling, functional analytic methods, computational approaches, numerical algorithms etc.

The success of the first conference in Montecatini in 2001 with more than 150 participants and several parallel sessions led to the proposal to have this Conference every two years, alternating between North or South America and Europe or a site outside the western hemisphere. A second equally successful conference was thus held in Lake Arrowhead, California in 2003 and finally a third was held in Cirencester in the UK Cotswold region from June 26th to 30th in 2005. The fourth will be held in Vancouver from June 25th to 29th in 2007.

Each AIP Conference will follow the pattern of a number of invited talks from international experts and a set of mini-symposia on topical themes. The venues will been chosen to encourage the maximum interaction between all participants.

Organizing Committee:
Uri Ascher (UBC),
Richard Froese (UBC),
Gary Margrave (University of Calgary),
Gunther Uhlmann, Chair (University of Washington)

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PIMS General Information

Offices

The main PIMS offices at UBC are located in the south end of the West Mall Annex at 1933 West Mall. There are computer terminals in Room 110 for participants to use.

Programme Coordinator Hours

The PIMS Programme Coordinator will hold office hours in Room 205 from 9:00 am – 1:00 pm and 2:00 pm – 4:30 pm, Monday to Friday. Please see the Programme Coordinator for inquiries regarding accommodation or for any other general inquiries.

Name Tags

Please wear your name tag when you are in the Forest Science Centre and the PIMS facility.

Library Information

Math Library:
Location: 1984 Mathematics Road
Monday – Friday
9:00 am – 5:00 pm

Computer Information

Wireless Connection

Wireless access is available in most locations at UBC's Vancouver campus during the AIP conference. Details of connecting to the wireless network will vary between operating systems, but the basic information you'll need is:

* Network name or SSID: ubc
* Security should be turned off
* Your network address will be assigned automatically (via DHCP)

Once associated with the network, you need to authenticate in order to get access to the Internet. To do so, start up a web browser; you should be redirected automatically to the UBC Wireless Network Login page. Use the following credentials to log in:

Username: pimswl
Password: cromulent78

Please note that you need to authenticate before any Internet access will work. This includes web browsers, mail programs, and VPN/SSH clients.

If you have any problems accessing the wireless service, please see the PIMS System Administrator in room 207 in the main PIMS offices (1933 West Mall).

Usage of the wireless network service is subject to the policies of UBC's IT department.

PIMS Computer Access, Help and Questions

For any inquiries regarding computers at PIMS, please see Hugh Brown. His office is located in Room 207 at PIMS.

AIP 2007

First International Congress of IPIA

Schedule

June 25–29, 2007
University of British Columbia Campus
Vancouver, Canada

GENERAL SCHEDULE
AIP 2007
First International Congress IPIA

Time	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
8:30 AM	8:30–9:30 AM Coffee and Registration				
9:00–9:45 AM	9:30–9:45 AM Opening and Calderon Prize	W. Symes	Calderon Prize lecture	S. Smale	O. Ghattas
9:45–10:30 AM	I. Daubechies	J. Schotland	J. McLaughlin	D. Isaacson	F-T. Kroode
10:30–11:00 AM	⟨⟨ Coffee ⟩⟩	⟨⟨ Coffee ⟩⟩	⟨⟨ Coffee ⟩⟩	⟨⟨ Coffee ⟩⟩	⟨⟨ Coffee ⟩⟩
11:00–11:45 AM	M. Burger	P. Stefanov	E. Candes	K. Astala	J-K. Seo
11:45–12:30 AM	G. Bal	D. Calvetti	M. Fink	J. Zou	F. Santosa
12:30–2:00 PM	⟨⟨ Lunch ⟩⟩	⟨⟨ Lunch ⟩⟩	⟨⟨ Lunch ⟩⟩	⟨⟨ Lunch ⟩⟩	⟨⟨ Lunch ⟩⟩
2:00–4:00 PM	Mini-symposia	Mini-symposia	Mini-symposia	Mini-symposia	Mini-symposia
4:00–4:30 PM	⟨⟨ Coffee ⟩⟩	⟨⟨ Coffee ⟩⟩	⟨⟨ Coffee ⟩⟩	⟨⟨ Coffee ⟩⟩	⟨⟨ Coffee ⟩⟩
4:30–6:30 PM	Mini-symposia	Mini-symposia	Mini-symposia	Mini-symposia	Mini-symposia
7:30 PM	Reception (see below)				
7:45 PM				Banquet (see below)	
8:00 PM			IPIA Meeting (FSC 1005)		

All invited talks will be held in FSC 1005.

Reception, 7:30 PM Monday June 25: Rich Ocean Seafood Restaurant, 777 West Broadway. (Directions are available on the Social Events link of the conference website.)

Banquet, 7:45 PM Thursday June 28: Sun Sui Wah Seafood Restaurant, 3888 Main Street. (Directions are available on the Social Events link of the conference website.)

Invited Talks, Monday June 25

9:45–10:30 AM

Speaker: Ingrid Daubechies (Princeton University)

Title: "*Sparsity and Inverse problems*"

11:00–11:45 AM

Speaker: Martin Burger (Westfaelische Wilhelms Universitaet Muenster)

Title: "*Regularization with Singular Energies*"

11:45 AM – 12:30 PM

Speaker: Guillaume Bal (Columbia University)

Title: "*Imaging in random media and kinetic models*"

Invited Talks, Tuesday June 26

9:00–9:45 AM

Speaker: Bill Symes, (Rice University)

Title: "*The inverse problem of seismic velocities*"

9:45–10:30 AM

Speaker: John Schotland (University of Pennsylvania)

Title: "*Inverse Scattering and Nanoscale Optical Imaging*"

11:00–11:45 AM

Speaker: Pleman Stefanov (Purdue University)

Title: "*Recovering anisotropic metrics from travel times*"

11:45 AM – 12:30 PM

Speaker: Daniela Calvetti (Case Western Reserve University)

Title: "*Statistical analysis of computational metabolic models in cell biology*"

Invited Talks, Wednesday June 27

9:45–10:30 AM

Speaker: Joyce McLaughlin (RPI)

Title: "*Imaging Shear Stiffness in Tissue from Dynamic Wave Propagation Data*"

11:00–11:45 AM

Speaker: Emmanuel Candes (California Institute of Technology)

Title: "*Compressed Sensing*"

11:45 AM – 12:30 PM

Speaker: Matthias Fink (University Denis Diderot

Title: "*Time-Reversed Waves and Super-Resolution*"

Invited Talks, Thursday June 28

9:00–9:45 AM

Speaker: Stephen Smale (Toyota Technology Institute at Chicago)

Title: "*Learning Theory and Sampling*"

9:45–10:30 AM

Speaker: David Isaacson (RPI)

Title: "*Electrical Impedance Tomography and Spectroscopy*"

11:00–11:45 AM

Speaker: Kari Astala (University of Helsinki)

Title: "*Complex analytic methods in inverse problems*"

11:45 AM – 12:30 PM

Speaker: Jun Zou (The Chinese University of Hong Kong)

Title: "*Inverse Obstacle Scattering: Some Theory and Numerics*"

Invited Talks, Friday June 29

9:00–9:45 AM

Speaker: Omar Ghattas (The University of Texas at Austin)

Title: "*Prospects for Scaling of Seismic Inversion to Petaflops Systems*"

9:45–10:30 AM

Speaker: Fons Ten Kroode (Shell EP R&D)

Title: "*Amundsen inversion - an alternative for surface related multiple elimination?*"

11:00–11:45 AM

Speaker: Jin Keun Seo (Yonsei University)

Title: "*Electrical Impedance Tomography and Magnetic Resonance EIT*"

11:45 AM – 12:30 PM

Speaker: Fadil Santosa (University of Minnesota)

Title: "*An inverse problem arising in photolithography*"

Schedule of Mini-Symposia

Date/Room	FSC 1005	FSC 1221	FSC 1003	FSC 1001	MCLD 228	MCLD 254	MCLD 214
Monday 2:00–4:00	Qian–Zhao	Kubo I	Massone–Pike I	Caponnetto–Rosasco	Piana I	Kabanikhin	
Monday 4:30–6:30	Lassas–Päivärinta	Arridge	Massone–Pike II	Gibson–Lamoureux	Piana II	Nakamura–Potthast	Klibanov–Yamamoto
Tuesday 2:00–4:00	Hermann	Kang–Ammari	Kubo II	Finch	Somersalo	Celler–Trummer	
Tuesday 4:30–6:30	De Hoop I	Munk I	Kubo III	Scherzer	Fox	Cakoni	Contributed I
Wednesday 2:00–4:00	Borcea I	Munk II	Kinahan	Oberai	Mueller–Siltanen I	Neubauer–Ramlau I	Contributed II
Wednesday 4:30–6:30	Borcea II	Cristobal	Beretta–Francini	Haber–0ldenburg	Mueller–Siltanen II	Cimrak–Slodicka	Contributed III
Thursday 2:00–4:00	Santosa	Qian–Zhao II	Seo	Isakov	Neubauer–Ramlau II	Bryan	Lesnic
Thursday 4:30–6:30	Kubo IV	Quinto	Kang–Ammari II	De Hoop II	Leitao	Arens	
Friday 2:00–4:00	Herrmann–Symes	Kubo V	Weder	Luke–Potthast–Sylvester	Ring	Contributed IV	Contributed V

Unless indicated otherwise, all talks in mini-symposia will begin on the hour or half-hour.

Mini-Symposia, Monday June 25

Monday June 25, 2:00–4:00 PM

Traveltime tomography: theory, numerics and applications (I) – FSC 1005
(Jianliang Qian and Hongkai Zhao)

Image reconstruction in Optics and Astronomy (I) – FSC 1003
(Anna Maria Massone and Roy Pike)

Identification of defects and cracks (I) – FSC 1221
(Shiro Kubo)

Learning from Examples as an Inverse Problem – FSC 1001
(Andrea Caponnetto and Lorenzo Rosasco)

The Magnetoencephalography (MEG) Problem (I) – MCLD 228
(Michele Piana)

Numerical Methods for Multidimensional Inverse Hyperbolic Problems – MCLD 254
(Sergey Kabanikhin)

Monday June 25, 4:30–6:30 PM

Optical Tomography – FSC 1221
(Simon Arridge)

Advances on Analytic and Geometrical Methods for Inverse Problems – FSC 1005
(Matti Lassas and Lassi Päivärinta)

Wavelets in Inverse Problems – FSC 1001
(Peter Gibson and Michael Lamoureux)

Recent methods for identifying discontinuities in media – MCLD 254
(Gen Nakamura and Roland Potthast)

The Magnetoencephalography (MEG) Problem (II) – MCLD 228
(Michele Piana)

Carleman estimates in inverse problems: theory and numerical methods – MCLD 214
(Mihael Klibanov and Masahiro Yamamoto)

Image reconstruction in Optics and Astronomy (II) – FSC 1003
(Anna Maria Massone and Roy Pike)

Mini-Symposia, Tuesday June 26

Tuesday June 26, 2:00–4:00 PM

Recovery from incomplete data: applications to imaging – FSC 1005
(Felix Herrmann)

Current Trends in Biomedical Imaging (I) – FSC 1221
(Habib Ammari and Hyeonbae Kang)

Identification of defects and cracks (II) – FSC 1003
(Shiro Kubo)

Mixed mode medical imaging – FSC 1001
(David Finch)

Inverse Problems in Cell Biology – MCLD 228
(Erkki Somersalo)

New Frontiers in Nuclear Medicine Image Reconstruction – MCLD 254
(Anna Celler and Manfred Trummer)

Tuesday June 26, 4:30–6:30 PM

Phase Space Transforms, Computation, and Inverse Scattering (I) – FSC 1005
(Maarten de Hoop)

Statistical inverse problems and shape constraints (I) – FSC 1221
(Axel Munk)

Identification of defects and cracks (III) – FSC 1003
(Shiro Kubo)

Spherical Means in Action – FSC 1001
(Otmar Scherzer)

Computational Inference in Inverse Problems – MCLD 228
(Colin Fox)

Inverse Problems in Electromagnetic Scattering Theory – MCLD 254
(Fioralba Cakoni)

Contributed (I) – MCLD 214

Mini-Symposia, Wednesday June 27

Wednesday June 27, 2:00–4:00 PM

Inverse Problems for Wave Propagation (I) – FSC 1005
(Liliana Borcea)

Statistical inverse problems and shape constraints (II) – FSC 1221
(Axel Munk)

Inverse Problems in Biomechanics – FSC 1001
(Assad Oberai)

Adaptive Regularization Techniques (I) – MCLD 254
(Andreas Neubauer and Ronny Ramlau)

Medical Image Reconstruction for PET and CT – FSC 1003
(Paul Kinahan)

Advances in Electrical Impedance Tomography (I) – MCLD 228
(Jennifer Mueller and Samuli Siltanen)

Contributed (II) – MCLD 214

Wednesday June 27, 4:30–6:30 PM

Inverse Problems for Wave Propagation (II) – FSC 1005
(Liliana Borcea)

Superresolution Imaging – FSC 1221
(Gabriel Cristobal)

Numerical methods for distributed parameter estimation in PDE's – FSC 1001
(Eldad Haber and Doug Oldenburg)

Determination of defects from boundary measurements – FSC 1003
(Elena Beretta and Elisa Francini)

Recovery of Missing Parameters in PDE Models – MCLD 254
(Ivan Cimrak and Marian Slodicka)

Advances in Electrical Impedance Tomography (II) – MCLD 228
(Jennifer Mueller and Samuli Siltanen)

Contributed (III) – MCLD 214

Mini-Symposia, Thursday June 28

Thurday June 28, 2:00–4:00 PM

Inverse Problems from Industrial Applications – FSC 1005
(Fadil Santosa)

Inverse Problems in Engineering – MCLD 214
(Daniel Lesnic)

Inverse Problems in Thermal Imaging – MCLD 254
(Kurt Bryan)

Adaptive Regularization Techniques (II) – MCLD 228
(Andreas Neubauer and Ronny Ramlau)

New techniques in Electrical Impedance Imaging – FSC 1003
(Jin-Keung Seo)

Inverse Problems for Systems – FSC 1001
(Victor Isakov)

Traveltime tomography: theory, numerics and applications (II) – FSC 1221
(Jianliang Qian and Hongkai Zhao)

Thurday June 28, 4:30–6:30 PM

Identification of defects and cracks (III) – FSC 1005
(Shiro Kubo)

The Factorization Method in Inverse Problems and its Applications – MCLD 254
(Tilo Arens)

Nonstationary inverse problems – MCLD 228
(Antonio Leitao)

New Topics in Tomography – FSC 1221
(Eric T. Quinto)

Phase Space Transforms, Computation, and Inverse Scattering (II) – FSC 1001
(Maarten de Hoop)

Current Trends in Biomedical Imaging (II) – FSC 1003
(Habib Ammari and Hyeonbae Kang)

Mini-Symposia, Friday June 29

Friday June 29, 2:00–4:00 PM

Identification of defects and cracks (V) – FSC 1221
(Shiro Kubo)

Software for Inverse Problems – FSC 1005
(Felix Herrmann and William Symes)

Inverse Spectral and Scattering Theories and Inverse Boundary Value Problems – FSC 1003
(Ricardo Weder)

Level-Set Methods for Shape Identification Problems – MCLD 228
(Wolfgang Ring)

Limited Data Inverse Scattering Techniques – FSC 1001
(Russel Luke, Roland Potthast and John Sylvester)

Contributed (IV) – MCLD 254

Contributed (V) – MCLD 214

Traveltime tomography: theory, numerics and applications (I)

Monday June 25, 2:00–4:00 PM
Room: FSC 1005
Organizer(s): Jianliang Qian and Hongkai Zhao

Speaker: Uhlmann, Gunther (University of Washington)
Title: "*Travel Time Transmission and Reflection Tomography*"

Speaker: Symes, William (Rice University)
Title: "*A tale of two tomographies: traveltime and waveform*"

Speaker: Blanch, Joakim (Nexus Geosciences)
Title: "*Modeling of, and considerations in cross-well and VSP (pre-) survey design*"

Speaker: Zhao, Hongkai (UC Irvine)
Title: "*Fast sweeping method for convex Hamilton-Jacobi equations*"

Image reconstruction in Optics and Astronomy (I)

Monday June 25, 2:00–4:00 PM
Room: FSC 1003
Organizer(s): Anna Maria Massone and Roy Pike

Speaker: Pike, Roy (King's College)
Title: "*An update of Hopkins' analysis of the optical disc player using singular system theory*"

Speaker: Poonawala, Amyn and Peyman, Milanfar (University of California, Santa Cruz)
Title: "*Mask Design for Resolution Enhancement: An Inverse Problem in Optical Microlithography*"

Speaker: Ramlau, Ronny (RICAM)
Title: "*A Non-Iterative Regularization Scheme for Blind Deconvolution*"

Identification of defects and cracks (I)

Monday June 25, 2:00–4:00 PM
Room: FSC 1221
Organizer(s): Shiro Kubo

Speaker: Gibson, Nathan (Oregon State University)
Title: "*Electromagnetic Characterization of Damage in Complex Dielectrics*"

Speaker: Steiner, Gerald (Graz University of Technology)
Title: "*A Bayesian filtering approach for inclusion detection with ultrasound reflection tomography*"

Speaker: Scherzer, Otmar (University Innsbruck)
Title: "*Kaczmarz methods for the solution of nonlinear ill-posed equations*"

Speaker: Pereverzyev (junior), Sergei (Technische Universitity Kaiserslautern)
Title: "*Approximate Solution of Nonlinear Inverse Problems*"

Learning from Examples as an Inverse Problem

Monday June 25, 2:00–4:00 PM
Room: FSC 1001
Organizer(s): Andrea Caponnetto and Lorenzo Rosasco

Speaker: De Mol, Christine (Universite Libre de Bruxelles)
Title: "*Sparse and smooth solutions for learning and inverse problems*"

Speaker: Pereverzyev, Sergei (Austrian Academy of Sciences, Johann-Radon-Institute (RICAM)
Title: "*Adaptive Regularization Algorithms in Learning Theory*"

Speaker: Belkin, Mikhail (Ohio State University)
Title: "*Regularization and Geometry of Learning*"

Speaker: Yao, Yuan (Stanford University)
Title: "*Topology Learning of High Dimensional Probability Density Functions*"

The Magnetoencephalography (MEG) Problem (I)

Monday June 25, 2:00–4:00 PM
Room: MCLD 228
Organizer(s): Michele Piana

Speaker: Van Veen, Barry (University of Wisconsin)
Title: "*Space-Time Sparse MEG Reconstruction*"

Speaker: Zumer, Johanna (University of California, San Francisco)
Title: "*Probabilistic methods for MEG source reconstruction incorporating noise suppression*"

Speaker: Pursiainen, Sampsa (Helsinki University of Technology)
Title: "*Effective EEG/MEG forward simulation through hp-FEM*"

Numerical Methods for Multidimensional Inverse Hyperbolic Problems

Monday June 25, 2:00–4:00 PM
Room: MCLD 254
Organizer(s): Sergey Kabanikhin

Speaker: Shishlenin, Maxim (Russian Academy of Science)
Title: "*Numerical analysis of methods for solving inverse acoustic problems*"

Speaker: Klibanov, Michael (University of North Carolina at Charlotte)
Title: "*Some Numerical Methods for Hyperbolic Inverse Problems*"

Speaker: Iskakov, Kazizat (KazNPU)
Title: "*Optimization method for solving two dimensional inverse problem for hyperbolic equation*"

Speaker: Kabanikhin, Sergey (Russian Academy of Science)
Title: "*Dirichlet-to-Neumann map and direct numerical methods in inverse multidimensional hyperbolic problems*"

Optical Tomography

Monday June 25, 4:30–6:30 PM
Room: FSC 1221
Organizer(s): Simon Arridge

Speaker: Schweiger, Martin (University College London)
Title: "*Jacobian-free Newton-Krylove reconstruction of model parameters in optical tomography*"

Speaker: Kolehmainen, Ville (University of Kuopio)
Title: "*Approximation Errors and Model Reduction in Optical Tomography*"

Speaker: Ripoll, Jorge (FORTH)
Title: "*Challenges and Applications of Optical Tomography in Microscopy*"

Speaker: Dorn, Oliver (Universidad Carlos III de Madrid)
Title: "*Optical and Fluorescence Tomography using a Transport Model in 2D*"

Advances on Analytic and Geometrical Methods for Inverse Problems

Monday June 25, 4:30–6:30 PM
Room: FSC 1005
Organizer(s): Matti Lassas and Lassi Päivärinta

Speaker: Greenleaf, Allan (University of Rochester)
Title: "*An FIO calculus for linearized marine seismic imaging*"

Speaker: Dos Santos Ferreira, David (Universite Paris 13)
Title: "*Determining a magnetic Schrödinger operator from partial Cauchy data*"

Speaker: Ylinen, Lauri (University of Helsinki)
Title: "*Two-Dimensional Tomography with Unknown View Angles*"

Speaker: Kirpichnikova, Anna (The University of Edinburgh)
Title: "*Inverse boundary spectral problem for Riemannian polyhedra*"

Wavelets in Inverse Problems

Monday June 25, 4:30–6:30 PM
Room: FSC 1001
Organizer(s): Peter Gibson and Michael Lamoureux

Speaker: Louis, Alfred K. (Saarland University)
Title: "*Dynamic Inverse Problems: Efficient Algorithms and Approximate Inverse*"

Speaker: Fornasier, Massimo (Princeton University)
Title: "*Accelerated iterative thresholding algorithms*"

Speaker: Saab, Rayan (University of British Columbia)
Title: "*Source Separation Via Iterative Thresholding in Some Transform Domain*"

Speaker: Daubechies, Ingrid (Princeton University)
Title: "*Sparse wavelet expansions for an inverse problem in Astrophysics*"

Recent methods for identifying discontinuities in media

Monday June 25, 4:30–6:30 PM
Room: MCLD 254
Organizer(s): Gen Nakamura and Roland Potthast

Speaker: Cakoni, Fioralba (University of Delaware)
Title: "*The Computation of Lower Bounds for the Norm of the Index of Refraction in an Anisotropic Media from Far Field Data*"

Speaker: Munk, Axel (Georg-August Universiät Göttingen)
Title: "*Jump Estimation in Inverse Problems – Distributional Results*"

Speaker: Heck, Horst (TU Darmstadt)
Title: "*Reconstruction of obstacles immersed in an incompressible fluid*"

Speaker: Sini, Mourad (Austrian Academy of Sciences)
Title: "*Determination of complex obstacles from scattering data*"

The Magnetoencephalography (MEG) Problem (II)

Monday June 25, 4:30–6:30 PM
Room: MCLD 228
Organizer(s): Michele Piana

Speaker: Pizzella, Vittorio (Universit di Chieti)
Title: "*Integrating MEG/EEG with fMRI*"

Speaker: Lin, Fa-Hsuan (Athinoula A. Martinos Center for Biomedical Imaging)
Title: "*Optimization of high spatiotemporal resolution brain imaging using combined MEG, MRI and fMRI*"

Speaker: Jun, Sung Chan (Los Alamos National Laboratory)
Title: "*Source inversion technique using probabalistic Bayesian inference: MEG/EEG/fM*"

Speaker: Sorrentino, Alberto (Universita di Genova)
Title: "*Solving the magnetoencephalography inverse problem with particle filters*"

Carleman estimates in inverse problems: theory and numerical methods

Monday June 25, 4:30–6:30 PM
Room: MCLD 214
Organizer(s): Mihael Klibanov and Masahiro Yamamoto

Speaker: Clason, Christian (Zentrum Mathematic, TU Mnchen)
Title: "*A non-standard numerical method for variational data assimilation for a convection diffusion equation*"

Speaker: Gaitan, Patricia (Universit de Provence)
Title: "*Inverse problem for the Schrödinger operator in an unbounded strip*"

Speaker: Kaltenbacher, Barbara (University of Stuttgart)
Title: "*Uniqueness for a Parameter Identification Problem for a Nonlinear Parabolic Equation with Application in Population Dynamics and Magnetics*"

Speaker: Poisson, Olivier (Universit de Provence)
Title: "*Uniqueness for discontinuous coefficients in an inverse problem for the heat equation*"

Speaker: Klibanov, Michael (University of North Carolina at Charlotte)
Title: "*Carleman estimates and inverse problems: theory and numerical methods*"

Image reconstruction in Optics and Astronomy (II)

Monday June 25, 4:30–6:30 PM
Room: FSC 1003
Organizer(s): Anna Maria Massone and Roy Pike

Speaker: Anthoine, Sandrine (CNRS)
Title: "*Simultaneous separation and deconvolution of multispectral data*"

Speaker: Bertero, Mario (Universita di Genova)
Title: "*Recent advances in the reconstruction of astronomical images*"

Speaker: Massone, Anna Maria (CNR-INFM LAMIA)
Title: "*Imaging Spectroscopy of hard x-ray sources in solar flares using regularized analysis of source visibilities*"

Speaker: Theys, Celine (Laboratoire Universitaire d'Astrophysique de Nice)
Title: "*Restoration of astrophysical images, statistical influence of the camera*"

Recovery from incomplete data: applications to imaging

Tuesday June 26, 2:00–4:00 PM
Room: FSC 1005
Organizer(s): Felix Herrmann

Speaker: Simons, Frederik J (Princeton University)
Title: "*On the recovery of potential field anomalies on the surface of a sphere from incomplete and noisy data taken at an altitude above their source*"

Speaker: Wakin, Michael (California Institute of Technology)
Title: "*Sparse representations and low-dimensional geometry in image recovery*"

Speaker: Demanet, Laurent (Stanford University)
Title: "*Fourier Sketching: how to approximate the FFT in sublinear time*"

Speaker: Herrmann, Felix (University of British Columbia)
Title: "*Stable Seismic Data Recovery*"

Current Trends in Biomedical Imaging (I)

Tuesday June 26, 2:00–4:00 PM
Room: FSC 1221
Organizer(s): Habib Ammari and Hyeonbae Kang

Speaker: Sinkus, Ralph
Title: "*MR-Elastography: A unique tool to non-invasively measure the complex shear modulus of tissue – application to breast, livver, Alzheimer's disease and rheology.*"

Speaker: Van Veen, Barry (University of Wisconsin)
Title: "*Dimensionality Reduction in Inverse Scattering: Applications to Microwave Imaging for Breast Cancer Detection*"

Speaker: Bauer, Frank (Johannes Kepler University, Linz)
Title: "*An Alternative Approach to Parallel MRI*"

Speaker: Tanter, Mickael
Title: "*Time reversal in ultrasound medical applications*"

Identification of defects and cracks (II)

Tuesday June 26, 2:00–4:00 PM
Room: FSC 1003
Organizer(s): Shiro Kubo

Speaker: Kaltenbacher, Barbara (University of Stuttgart)
Title: "*Determination of cracks in piezoelectric media by Newton-multilevel methods*"

Speaker: Fujiwara, Hiroshi (Kyoto University)
Title: "*Identifying discontinuity in real inversion of the Laplace transform with the Tikhonov regularization method*"

Speaker: Leitao, Antonio (Federal University of Santa Catarina)
Title: "*Identification of a discontinuous coefficient in semiconductor equations*"

Speaker: Klibanov, Michael (University of North Carolina at Charlotte)
Title: "*Some Inverse Problems for Partial Differential Equations*"

Mixed mode medical imaging

Tuesday June 26, 2:00–4:00 PM
Room: FSC 1001
Organizer(s): David Finch

Speaker: Xu, Yuan (Ryerson University)
Title: "*Magneto-Acousto-Electrical Tomography: a New Imaging Modality for Electrical Impedance*"

Speaker: Kunyansky, Leonid (University of Arizona)
Title: "*A series solution and a fast algorithm for the inversion of the spherical mean Radon transform*"

Speaker: Anastasio, Mark (Illinois Institute of Technology)
Title: "*Fourier-based image reconstruction in photoacoustic tomography*"

Speaker: Clason, Christian
Title: "*The quasi-reversibility method for thermoacoustic tomography in a heterogeneous medium*"

Inverse Problems in Cell Biology

Tuesday June 26, 2:00–4:00 PM
Room: MCLD 228
Organizer(s): Erkki Somersalo

Speaker: Kuceyeski, Amy (Case Western Reserve University)
Title: "*A spatially distributed metabolic model of the liver in fasted, resting state*"

Speaker: Heino, Jenni (Helsinki University of Technology)
Title: "*Computational modelling of cellular level metabolism*"

Speaker: Occhipinti, Rossana (Case University)
Title: "*Bayesian Model Selection for Brain Metabolism*"

Speaker: Bell, Brad (University of Washington)
Title: "*MCMC Estimation of Nonlinear Dynamical Systems*"

New Frontiers in Nuclear Medicine Image Reconstruction

Tuesday June 26, 2:00–4:00 PM
Room: MCLD 254
Organizer(s): Anna Celler and Manfred Trummer

Speaker: Gullberg, Grant (E.O. Lawrence Berkelely National Lab)
Title: "*The Challenge of Uniqueness in the Application of Dynamic SPECT*"

Speaker: Sitek, Arkadiusz (Harvard Medical School)
Title: "*Image Reconstruction in Emission Tomography using Point Clouds*"

Speaker: Shcherbinin, Sergey (University of British Columbia)
Title: "*An Investigation of an Accuracy of Iterative Reconstructions in Quantitative SPECT*"

Speaker: Qranfal, Joe (Simon Fraser University)
Title: "*Regularized Kalman algorithm for dynamic SPECT reconstruction*"

Phase Space Transforms, Computation, and Inverse Scattering (I)

Tuesday June 26, 4:30–6:30 PM
Room: FSC 1005
Organizer(s): Maarten de Hoop

Speaker: Loris, Ignace (Vrije Universiteit Brussel)
Title: "*Tomographic inverson with wavelets and l1-norm penalization*"

Speaker: Stolk, Chris (University of Twente)
Title: "*Amplitudes in seismic migration*"

Speaker: Andersson, Fredrik (Lund)
Title: To be announced

Speaker: Duchkov, Anton (Purdue University)
Title: "*Migration velocity analysis using velocity continuation of seismic image gathers*"

Statistical inverse problems and shape constraints (I)

Tuesday June 26, 4:30–6:30 PM
Room: FSC 1221
Organizer(s): Axel Munk

Speaker: Scherzer, Otmar (University Innsbruck), (60 mins)
Title: "*Taut-String for High Dimensional Data*"

Speaker: Hohage, Thorsten (University of Goettingen)
Title: "*Newton Methods for Nonlinear Inverse Problems with Random Noise*"

Speaker: Bigot, Jeremie (University Paul Sabatier)
Title: "*Estimation of the mean of a set of noisy images using a random diffeomorphic matching parametric model*"

Identification of defects and cracks (III)

Tuesday June 26, 4:30–6:30 PM
Room: FSC 1003
Organizer(s): Shiro Kubo

Speaker: Ivanyshyn, Olha (Georg-August University of Goettingen)
Title: "*Inverse Scattering for Planar Cracks via Nonlinear Integral Equations*"

Speaker: Tanuma, Kazumi (Gunma University)
Title: "*Perturbation formulas for phase velocity and polarization of Rayleigh waves in prestressed anisotropic media*"

Speaker: Hyvonen, Nuutti (Helsinki University of Technology)
Title: "*Locating transparent cavities in optical absorption and scattering tomography*"

Speaker: Kang, Hyeonbae (Seoul National Univeristy)
Title: "*Three methods of internal corrosion detection*"

Spherical Means in Action

Tuesday June 26, 4:30–6:30 PM
Room: FSC 1001
Organizer(s): Otmar Scherzer

Speaker: Haltmeier, Markus (University Innsbruck)
Title: "*Limited Angle Photoacoustic Tomography with Line detector*"

Speaker: Fidler, Thomas (University of Innsbruck)
Title: "*An integral invariant for star-shaped domains*"

Speaker: Grasmair, Markus (University of Innsbruck) joint with Patch, Sarah (Milwaukee)
Title: "*Integral Invariants*"

Speaker: Finch, David (Oregon State University)
Title: "*Inversion of spherical means and the wave equation*"

Computational Inference in Inverse Problems

Tuesday June 26, 4:30–6:30 PM
Room: MCLD 228
Organizer(s): Colin Fox

Speaker: Fox, Colin (Auckland University)
Title: "*Bayesian Inference for Geothermal Model Calibration*"

Speaker: Moulton, David (Los Alamos National Laboratory)
Title: "*Multilevel approximations in sample-based inversion from the Dirichlet-to-Neumann map*"

Speaker: Herbei, Radu (Ohio State University)
Title: "*Quasi-3D Statistical Inversion of Oceanograpic Tracer data*"

Inverse Problems in Electromagnetic Scattering Theory

Tuesday June 26, 4:30–6:30 PM
Room: MCLD 254
Organizer(s): Fioralba Cakoni

Speaker: Cakoni, Fioralba (University of Delaware)
Title: "*A variational approach for the solution of the electromagnetic interior transmission problem for anisotropic media*"

Speaker: Arens, Tilo (Universität Karlsruhe)
Title: "*Convergence of the Linear Sampling Method*"

Speaker: Piana, Michael (Universit di Verona)
Title: "*A new formulation of the linear sampling method: spatial resolution and post-processing*"

Speaker: Pieper, Martin (Georg-August University of Goettingen)
Title: "*Nonlinear integral equations for an inverse electromagnetic scattering problem*"

Contributed (I)

Tuesday June 26, 4:30–6:30 PM
Room: MCLD 214

Speaker: Sacks, Paul (Iowa State University)
Title: "*Singular inverse spectral problems*"

Speaker: Timonov, Alexandre (University of South Carolina Upstate)
Title: "*A numerical study of some globally convergent algorithms for solving non-overdetermined coefficient inverse problems*"

Speaker: Gaburro, Romina (University of Limerick, Ireland)
Title: "*Microlocal Analysis of Synthetic Aperture Radar Imaging in the Presence of a Vertical Wall*"

Speaker: Smirnova, Alexandra (Georgia State University)
Title: "*Iteratively Regularized Guass-Newton Method with Parameter Decomposition*"

Inverse Problems for Wave Propagation (I)

Wednesday June 27, 2:00–4:00 PM
Room: FSC 1005
Organizer(s): Liliana Borcea

Speaker: Solna, Knut (University of California, Irvine)
Title: "*Detection and Imaging with Incoherent Signals*"

Speaker: Kim, Arnold (University of California, Merced)
Title: "*Reconstructing a thin absorbing obstacle in a half space of tissue*"

Speaker: Borcea, Liliana (Rice University)
Title: "*Optimal Waveform Design for Array Imaging*"

Speaker: Guevara Vasquez, Fernando (Stanford University)
Title: "*Selective illumination of extended targets in array imaging*"

Statistical inverse problems and shape constraints (II)

Wednesday June 27, 2:00–4:00 PM
Room: FSC 1221
Organizer(s): Axel Munk

Speaker: Somersalo, Erkki (Helsinki University of Technology), (60 mins)
Title: "*Recovery of Shapes, Hypermodels and Bayesian Learning*"

Speaker: Jongbloed, Geurt (Technische Universiteit Delft)
Title: "*Density estimation in the Current Status model*"

Speaker: Mizera, Ivan (University of Alberta)
Title: "*Regularized estimation of probability density: likelihoods, penalties, and algorithms*"

Inverse Problems in Biomechanics

Wednesday June 27, 2:00–4:00 PM
Room: FSC 1001
Organizer(s): Assad Oberai

Speaker: Gockenbach, Mark (Michigan Technical University)
Title: "*Numerical Analysis of Elliptical Inverse Problems with Interior Data*"

Speaker: Barbone, Paul (Boston University)
Title: "*Forward and inverse problems in multiphase mechanics of soft tissues*"

Speaker: Renzi, Daniel (Rensselaer Polytechnic Institute)
Title: "*Recovering the shear wave speed parameters in an anisotropic medium*"

Speaker: Oberai, Assad (Rensselaer Polytechnic Institute)
Title: "*Nonlinear elasticity imaging*"

Adaptive Regularization Techniques (I)

Wednesday June 27, 2:00–4:00 PM
Room: MCLD 254
Organizer(s): Andreas Neubauer and Ronny Ramlau

Speaker: Egger, Herbert (University of Achen)
Title: "*Y-Scale Regularization*"

Speaker: Kindermann, Stefan (University of Linz)
Title: "*A relaxation algorithm for solving inverse interface problems*"

Speaker: Lorenz, Dirk (University of Bremen)
Title: "*On the convergence speed of iterative methods for linear inverse problems with sparsity constraints*"

Speaker: Neubauer, Andreas (University of Linz)
Title: "*Solution of Ill-Posed Problems via Adaptive Grid Regularization*"

Medical Image Reconstruction for PET and CT

Wednesday June 27, 2:00–4:00 PM
Room: FSC 1003
Organizer(s): Paul Kinahan

Speaker: Champley, Kyle (University of Washington)
Title: "*Planogram Rebinning with the Frequency-Distance Relationship*"

Speaker: Courdurier, Matias (University of Washington)
Title: "*Solving the Interior Problem in Computed Tomography Using a Priori Knowledge*"

Speaker: Noo, Frederic (University of Utah)
Title: "*Two-dimensional SPECT imaging with trucated projections*"

Speaker: Pan, Xiaochuan (University of Chicago)
Title: "*Image Reconstruction in Diffraction Tomography*"

Advances in Electrical Impedance Tomography (I)

Wednesday June 27, 2:00–4:00 PM
Room: MCLD 228
Organizer(s): Jennifer Mueller and Samuli Siltanen

Speaker: Eckel, Harry (Universität Gttingen)
Title: "*An idea to couple a BEM and a grid-based methkod for EIT via an evolutionary algorithm*"

Speaker: Gonzalez-Lima, Raul (University of Sao Paulo)
Title: "*Online transition matrix identification of the state evolution model for the extended Kalman filter in electrical impedance tomography* "

Speaker: Takanori Ide (Tokyo Metropolitan University)
Title: "*Detection of inclusions from localized boundary measurements in the electrical conductivity problem*"

Speaker: Kolehmainen, Ville (University of Kuopio)
Title: "*Sedimentation monitoring using EIT*"

Contributed (II)

Wednesday June 27, 2:00–4:00 PM
Room: MCLD 214

Speaker: McCarthy, Maeve (Murray State University)
Title: "*Parameter Identification in a Parabolic System Modeling Chemotaxis*"

Speaker: Boverman, Gregory (Rensselaer Polytechnic Institute)
Title: "*Spatio-Temporal Imaging of Compression-Induced Hemodynamics in the Breast With Diffuse Optical Tomography: Simulation Study and Preliminary Clinical Results*"

Speaker: Marcuzzi, Fabio (Universita di Padova)
Title: "*Efficient reconstruction of corrosion profiles by infrared thermography*"

Speaker: Bell, Brad (University of Washington)
Title: "*Semi-Blind Deconvolution*"

Inverse Problems for Wave Propagation (II)

Wednesday June 27, 4:30–6:30 PM
Room: FSC 1005
Organizer(s): Liliana Borcea

Speaker: Fishman, Lou (MDF International)
Title: "*Some Thoughts on the Inclusion of Multiple Scattering in a Phase-Space-Based Marching Velocity Field Reconstruction Algorithm*"

Speaker: Issa, Leila (Rice University)
Title: "*Imaging in cluttered waveguides*"

Speaker: Moskow, Shari (University of Florida)
Title: "*Scattering and resonances of thin dielectric structures*"

Speaker: Poliannikov, Oleg G. (Massachussetts Institute of Technology)
Title: "*Focusing of time reversed random coda*"

Superresolution Imaging

Wednesday June 27, 4:30–6:30 PM
Room: FSC 1221
Organizer(s): Gabriel Cristobal

Speaker: Nagy, James (Emory University)
Title: "*Numerical Methods for Coupled Super-Resolution*"

Speaker: Sroubek, Filip (Institute of Information Theory and Automation)
Title: "*Simultaneous Superresolution and Blind Deconvolution*"

Speaker: van Vliet, Lucas (Delft University of Technology)
Title: "*Robust Super-Resolution without Regularization*"

Speaker: Pickering, Mark (University of New South Wales)
Title: "*Robust Super-Resolution Mosaicing of Compressed Images*"

Numerical methods for distributed parameter estimation in PDE's

Wednesday June 27, 4:30–6:30 PM
Room: FSC 1001
Organizer(s): Eldad Haber and Doug Oldenburg

Speaker: Biros, George (University of Pennsylvania)
Title: "*Multigrid algorithms for reconstruction problems with parabolic PDE constraints*"

Speaker: Bangerth, Wolfgang (Texas A&M University)
Title: "*Adaptive finite element methods for inverse imaging problems*"

Speaker: Najm, Habib N., (Sandia)
Title: To be announced

Speaker: Haber, Eldad (Emory University)
Title: "*Adaptive multilevel refinement for parameter estimation problems*"

Determination of defects from boundary measurements

Wednesday June 27, 4:30–6:30 PM
Room: FSC 1003
Organizer(s): Elena Beretta and Elisa Francini

Speaker: Ammari, Habib (CNRS)
Title: "*Electrical Impedance Tomography by Elastic Perturbation*"

Speaker: Beretta, Elena (joint with E. Francini and S. Vessella), (Sapienza University of Rome)
Title: "*Determination of a linear crack in an elastic body from boundary measurements - Lipschitz Stability*"

Speaker: Kress, Rainer (University of Goettingen)
Title: "*Integral equations for inverse problems in corrosion detection*"

Speaker: Rondi, Luca (Universita degli Studi di Triest)
Title: "*Stable determination of polyhedra by a single far-field measurement*"

Recovery of Missing Parameters in PDE Models

Wednesday June 27, 4:30–6:30 PM
Room: MCLD 228
Organizer(s): Ivan Cimrak and Marian Slodicka

Speaker: Slodicka, Marian (Ghent University)
Title: "*Recovery of missing boundary data for magnetic field in eddy-current problems: An iterative approach*"

Speaker: Melicher, Valdemar (Ghent University)
Title: "*Source identification in low-frequency electromagetism*"

Speaker: Cimrak, Ivan (Ghent University)
Title: "*Determination of precession and dissipation parameters in the micromagnetics*"

Speaker: Malengier, Benny (Ghent University)
Title: "*Inverse determination of interdiffusion coefficients in Si-Al-Fe alloys*"

Advances in Electrical Impedance Tomography (II)

Wednesday June 27, 4:30–6:30 PM
Room: MCLD 254
Organizer(s): Jennifer Mueller and Samuli Siltanen

Speaker: Mikyoung Lim (Ecole Polytechnique)
Title: "*Reconstructing small perturbations of scatterers from electric or acoustic far-field measurements*"

Speaker: Mueller, Jennifer (Colorado State University)
Title: "*Reconstructions of experimental and simulated discontinuous conductivities by the D-bar method for EIT*"

Speaker: Siltanen, Samuli (Tampere University of Technology)
Title: "*Direct reconstruction of discontinuous conductivities using Beltrami equation* "

Speaker: Vauhkonen, Paivi Johanna (University of Kuopio)
Title: "*Computational aspects of EIT in cylindrical geometry*"

Contributed (III)

Wednesday June 27, 4:30–6:30 PM
Room: MCLD 214

Speaker: Rantala, Maaria (PaloDEx Group)
Title: "*Wavelet-based reconstruction for limited angle X-ray tomography*"

Speaker: Chen, Xudong (National University of Singapore)
Title: "*Electromagnetic Imaging of Small Scatterrers using MUSIC*"

Speaker: Sincich, Eva (Austrian Academy of Sciences)
Title: "*Lipschitz stability for the inverse Robin problem*"

Speaker: Janicki, Marcin (Technical University of Lodz)
Title: "*Real TIme Temperature Estimation of Heat Sources in Integrated Circuits with Remote Temperature Sensors*"

Inverse Problems from Industrial Applications

Thursday June 28, 2:00–4:00 PM
Room: FSC 1005
Organizer(s): Fadil Santosa

Speaker: Abubakar, Aria (Schlumberger Doll Research)
Title: "*Nonlinear inversion algorithms for the controlled-source electromagnetic data*"

Speaker: Madej, Darek (Motorola)
Title: "*Inverse problems in bar code decoding*"

Speaker: Voth, Eric (St Jude Medical, Inc.)
Title: "*Reconstruction of Cardiac Electrical Activity*"

Speaker: Toews, Carl (University of Minnesota)
Title: "*Position Registration from Voltage Measurements*"

Inverse Problems in Engineering

Thursday June 28, 2:00–4:00 PM
Room: MCLD 214
Organizer(s): Daniel Lesnic

Speaker: Kaipio, Jari (University of Kuopio)
Title: "*Estimation of fluid flow in unsaturated porous medium*"

Speaker: Lesnic, Daniel (University of Leeds)
Title: "*Restoring Boundary Conditions in Heat Conduction*"

Speaker: Bonnet, Marc (Ecole Polytechnique)
Title: "*Higher-order topological sensitivity for elastodynamic inverse scattering*"

Speaker: Kassab, Alain (University of Central Florida)
Title: "*Singular-Superposition Method for the Inverse Geometric Problem - applications in heat transfer and electricity*"

Inverse Problems in Thermal Imaging

Thursday June 28, 2:00–4:00 PM
Room: MCLD 254
Organizer(s): Kurt Bryan

Speaker: Ammari, Habib (CNRS)
Title: "*Direct Algorithms for Thermal Imaging of Small Inclusions*"

Speaker: Caudill, Lester (University of Richmond)
Title: "*Optimal Design Parameters for a Parabolic Inverse Problem*"

Speaker: Rondi, Luca (Universita degli Studi di Triest)
Title: "*Stability and instability for the determination of unknown isothermal surfaces*"

Speaker: Fasino, Dario (Universita di Udine)
Title: "*Boundary Conditions for nodestructive evaluation based on stationary infrared thermography*"

Adaptive Regularization Techniques (II)

Thursday June 28, 2:00–4:00 PM
Room: MCLD 228
Organizer(s): Andreas Neubauer and Ronny Ramlau

Speaker: Ramlau, Ronny (RICAM)
Title: "*Regularization of Inverse Problems using sparsity constraints - Analysis and Applications*"

Speaker: Rauhut, Holger (University of Vienna)
Title: "*Algorithms for inverse problems with joint sparsity constraints*"

Speaker: Zhariy, Mariya (Zuse Institute Berlin)
Title: "*Frame-Based Adaptive Strategies for Iteratively Solving Linear Ill-posed Inverse Problems*"

New techniques in Electrical Impedance Imaging.

Thursday June 28, 2:00–4:00 PM
Room: FSC 1003
Organizer(s): Jin-Keung Seo

Speaker: Woo, Eung Je (Kyung Hee University)
Title: "*Conductivity Image Reconstruction in Magnetic Resonance Electrical Impedance Tomography (MREIT)*"

Speaker: Kim, Sungwhan (Hanbat National University)
Title: "*Breast Cancer Detection using Multi-frequency Electrical Impedance Imaging Technique*"

Speaker: Habib Zribi(Impedance Imaging Research center)
Title: "*Multi-frequency Electrical Impedance Tomography for Anomaly Detection and Imaging*"

Speaker: Teayong Ha(National Institute of Mathematical Science, Korea)
Title: "*Concrete Crack Detection Model using Electrical Impedance Tomography*"

Inverse Problems for Systems

Thursday June 28, 2:00–4:00 PM
Room: FSC 1001
Organizer(s): Victor Isakov

Speaker: Eller, Matthias (Georgetown University)
Title: "*Carleman estimates for some first-order systems of partial differential equations*"

Speaker: Mazzucato, Anna L (Pennsylvania State University)
Title: "*On uniqueness in the boundary inverse problem for anisotropic elastodynamics*"

Speaker: Valdivia, Nicolas P. (Naval Research Laboratory)
Title: "*Near-field Electromagnetic Holography: The inverse problem of electromagnetic continuation*"

Speaker: Wang, Jenn-Nan (National Taiwan University)
Title: "*Special solutions for some elliptic systems and applications*"

Traveltime tomography: theory, numerics and applications (II)

Thursday June 28, 2:00–4:00 PM
Room: FSC 1221
Organizer(s): Jianliang Qian and Hongkai Zhao

Speaker: Stefanov, Plamen (Purdue University)
Title: "*Local lens rigidity for a class of non-simple manifolds*"

Speaker: Chung, Eric (California Institute of Technology)
Title: "*A new phase space method for recovering index of refraction from travel times*"

Speaker: Leung, Shingyu (University of California, Irvine)
Title: "*Transmission Traveltime Tomography Based on Paraxial Liouville Equations and Level Set Formulations*"

Speaker: Qian, Jianliang (Wichita State University)
Title: "*An Adjoint State Method for Three-Dimensional Transmission Traveltime Tomography Using First-Arrivals*"

Identification of defects and cracks (IV)

Thursday June 28, 2:00–4:00 PM
Room: FSC 1005
Organizer(s): Shiro Kubo

Speaker: Rondi, Luca (Universita degli Studi di Triest)
Title: "*A variational approach to the reconstruction of cracks by boundary data*"

Speaker: Lam, Heung Fai (City University of Hong Kong)
Title: "*Crack detection of beam-type structures following the Bayesian system identification framework*"

Speaker: Kubo, Shiro (Osaka University)
Title: "*Passive Electric Potential CT Method for Crack Identification*"

The Factorization Method in Inverse Problems and its Applications

Thursday June 28, 4:30–6:30
Room: MCLD 254
Organizer(s): Tilo Arens

Speaker: Gebauer, Bastian (Austrian Academy of Sciences)
Title: "*Electric potentials with localized divergence properties*"

Speaker: Lechleiter, Armin (University of Karlsruhe)
Title: "*Factorization and Perturbation*"

Speaker: Hyvonen, Nuutti (Helsinki University of Technology)
Title: "*An implementation of the factorization method within the complete electrode model of electrical impedance tomography*"

Speaker: Luke, Russell
Title: "*On the Construction of Nonscattering Fields*"

Nonstationary inverse problems

Thursday June 28, 4:30–6:30 PM
Room: MCLD 228
Organizer(s): Antonio Leitao

Speaker: Louis, Alfred K. (Saarland University)
Title: "*Dynamic Inverse Problems: Efficient Algorithms and Approximate Inverse*"

Speaker: Pikkarainen, Hanna Katriina (Austrian Academy of Sciences)
Title: "*State estimation approach to nonstationary inverse problems*"

Speaker: Kindermann, Stefan (University of Linz)
Title: "*Dynamic programming principle for static and dynamic inverse problems*"

Speaker: Kuegler, Philipp (University of Linz / RICAM)
Title: "*Online parameter identification*"

New Topics in Tomography

Thursday June 28, 4:30–6:30
Room: FSC 1221
Organizer(s): Eric T. Quinto

Speaker: Kunyanksy, Leonid (University of Arizona)
Title: "*Explicit inversion formulas for the inversion of the spherical mean Radon transform*"

Speaker: Quinto, Eric Todd (Tufts University)
Title: "*Local tomography in electron microscopy*"

Speaker: Faridani, Abel (Oregon State University)
Title: "*Sampling Conditions and Numerical Analysis for 3D Helical CT*"

Speaker: Chou, Cheng-Ying (Illinois Institute of Technology)
Title: "*Image Reconstruction in X-Ray Phase-Contrast Tomography*"

Phase Space Transforms, Computation, and Inverse Scattering (II)

Thursday June 28, 4:30–6:30
Room: FSC 1001
Organizer(s): Maarten de Hoop

Speaker: de Hoop, Maarten V. (Purdue University)
Title: "*Inverse scattering of reflection seismic data in the reverse-time approach*"

Speaker: Salo, Mikko (University of Helsinki)
Title: "*Stability for solutions of wave equations*"

Speaker: Knudsen, Kim (Aalborg University)
Title: "*The Calderón problem with partial measurements*"

Speaker: Rachele, Lizabeth (Rensselaer Polytechnic Institute)
Title: "*Uniqueness of the travel time for any disjoint mode in anisotropic elastic media*"

Current Trends in Biomedical Imaging (II)

Thursday June 28, 4:30–6:30
Room: FSC 1003
Organizer(s): Habib Ammari and Hyeonbae Kang

Speaker: Dassios, George (University of Cambridge)
Title: "*The scalar magnetic potential in meg.*"

Speaker: Lee, Hyundae
Title: "*A method of biological tissues elasticity reconstruction using msgnetic resonance elastography measurements*"

Speaker: Schotland, John (University of Pennsylvania)
Title: "*Optical Tomography with Large Data Sets*"

Speaker: Lassas, Matti (Helsinki University of Technology)
Title: "*Invisibility and Inverse problems*"

Identification of defects and cracks (V)

Friday June 29, 2:00–4:00 PM
Room: FSC 1221
Organizer(s): Shiro Kubo

Speaker: El Badia, Abdellatif (University of Technology of Compiegne)
Title: "*Inverse source problem in an advection dispersion reaction system*"

Speaker: Luke, Russell (University of Delaware)
Title: "*A MUSIC Algorithm for Crack Identification*"

Speaker: Suzuki, Toshio (Osaka University)
Title: "*Active Use of Piezoelectric Film for Identification of Cracks*"

Software for Inverse Problems

Friday June 29, 2:00–4:00 PM
Room: FSC 1005
Organizer(s): Felix Herrmann and William Symes

Speaker: William W. Symes (Rice)
Title: "*Software for Time-dependent Inverse Problems*"

Speaker: Fomel, Sergey (University of Texas at Austin)
Title: "*Reproducible computational experiments using the Madagascar software package*"

Speaker: Herrmann, Felix (University of British Columbia)
Title: "*Seismic inversion through operator overloading*"

Inverse Spectral and Scattering Theories and Inverse Boundary Value Problems

Friday June 29, 2:00–4:00 PM
Room: FSC 1003
Organizer(s): Ricardo Weder

Speaker: Eskin, Gregory (UCLA)
Title: "*Inverse problems for the Schrödinger equations with time-dependant electromagnetic potentials and the Aharonov-Bohm effect*"

Speaker: Ralston, James (UCLA)
Title: "*Inverse Spectral Problems in Rectangular Domains*"

Speaker: Li, Xiaosheng (University of Washington)
Title: "*Determination of viscosity in the stationary Navier-Stokes equations*"

Speaker: Weder, Ricardo (UNAM)
Title: "*A Rigorous Time-Domain Analysis of Full-Wave Electromagnetic Cloaking*"

Level-Set Methods for Shape Identification Problems

Friday June 29, 2:00–4:00 PM
Room: MCLD 228
Organizer(s): Wolfgang Ring

Speaker: Ring, Wolfgang
Title: "*Level-set techniques for the solution of geometric inverse problems*"

Speaker: Villegas, Rossmary
Title: "*A generalized level set technique for the simultaneous reconstruction of geological regions and region-specific model-based internal permeability profiles of petroleum reservoirs from production data*"

Speaker: Klann, Esther (Radon Institute for Computational and Applied Mathematics)
Title: "*A Mumford-Shah level-set approach for the inversion and segmentation of SPECT data*"

Speaker: Burger, Martin (Westfaelische Wilhelms Universitaet Muenster)
Title: "*Preconditioned Level Set Flows*"

Limited Data Inverse Scattering Techniques

Friday June 29, 2:00–4:00 PM
Room: FSC 1001
Organizer(s): Russel Luke, Roland Potthast and John Sylvester

Speaker: Tanoh, Germain (Simon Fraser University)
Title: "*Proximal Reconstruction Methods for Dynamic Inverse Problems in Emission Tomography*"

Speaker: Sylvester, John (University of Washington)
Title: "*Non-radiating Sources, Transmission Eigenvalues, and the Born Approximation*"

Speaker: Potthast, Roland (University of Reading)
Title: "*On the convergence of the no response test*"

Speaker: Kusiak, Steven (New Frontier Advisors)
Title: "*Identification and Characterization of a Moving Source in a General Parabolic Equation*"

Contributed (IV)

Friday June 29, 2:00–4:00 PM
Room: MCLD 254

Speaker: Griesmaier, Roland (Johannes Gutenberg-University Mainz)
Title: "*An asymptotic factorization method for detecting small objects using electromagnetic scattering*"

Speaker: Lange, Arnaud (Institut Francais du Petrole)
Title: "*Genetic-based Characterization of Fractured Reservoirs from Interpreted Well Tests*"

Speaker: Trucu, Dumitru (University of Leeds)
Title: "*The Inverse Time-dependent Coefficient Identification Problem in Bio-Heat Transient Flow Equation*"

Speaker: Ji, Xiao-Yi (Texas Tech University)
Title: "*Frèchet-differentiation of functions of operators with application to testing the equality of covariance operators*"

Contributed (V)

Friday June 29, 2:00–4:00 PM
Room: MCLD 214

Speaker: Routh, Partha (ConocoPhillips)
Title: "*Source Estimation from Pre-Stack Seismic Data using Nonlinear Bounded Minimization Technique*"

Speaker: Krishnan, Venky (University of Washington)
Title: "*A support theorem for the geodesic ray transform on real-analytic Riemannian manifolds*"

Speaker: Helin, Tapio (Helsinki University of Technology)
Title: "*A stochastic interpretation of the Mumford-Shah functional*"

Speaker: Ryan, Niall (University of Limeric)
Title: "*High-frequency anisotopic elastic inversion*"

Speaker: Ebrahimi, Mehran (University of Waterloo)
Title: "*Regularization schemes involving self-similarity in imaging inverse problems*"

Aria Abubakar (Schlumberger-Doll Research)
Nonlinear inversion algorithms for the controlled-source electromagnetic data

The marine controlled-source electromagnetic (CSEM) technology has attracted much attention for its capability in directly detecting thin hydrocarbon reservoirs. The approach is based on comparing the electric field amplitude as a function of the source-receiver offset with a similar measurement for a non-hydrocarbon bearing reservoir. The presence of hydrocarbon raises the amplitude of the measured electric field indicating the existence and to some degree determining the horizontal extent of the hydrocarbon zone; however with this approach it is difficult to know the reservoir's depth and shape. A more rigorous approach to address this type of application is the full nonlinear inversion. In this presentation we present two rigorous nonlinear inversion algorithms. The first method is the so-called pixel-based inversion (PBI). In this approach the investigation domain is subdivided into pixels, and by using an optimization process the conductivity distribution of the investigated domain is reconstructed. The optimization process uses the Gauss-Newton minimization method augmented with various types of regularization. This PBI approach has demonstrated its ability to retrieve reasonably good conductivity images. However, the reconstructed boundaries and conductivity values of the imaged anomalies are still not adequately resolved. Nevertheless, the PBI approach can provide some useful information on the location, the shape and the conductivity of the hydrocarbon reservoir. The second method is the so-called parametric inversion algorithm (PIA), which uses a priori information on the geometry to reduce the number of unknown parameters and to improve the quality of the reconstructed conductivity image. This PIA approach can be also used to refine the conductivity image that we obtained using the PBI algorithm. The PIA also adopts the Gauss-Newton minimization method. The parameters that govern the location and the shape of an anomaly include the depth and the location of the user-defined nodes for the boundary of the region. The unknown parameter that describes the physical property of the region is the conductivity. We will show some inversion results of synthetic and field data to illustrate the PBI and PIA approaches. We further show that by combining both inversion algorithms we arrive at a better interpretation of the controlled-source electromagnetic data.

Jonathan Ajo-Franklin (Lawrence Berkeley National Laboratory)
Optimal Design of Seismic Sensor Arrays with Applications to Continuous Tomographic Monitoring

Geophysical monitoring techniques offer the only approach capable of assessing both the spatial and temporal dynamics of subsurface fluid processes. Historically, monitoring datasets have consisted of surveys sequentially collected using acquisition geometries and sensor platforms similar to static measurements. Unfortunately, a host of logistical constraints hamper the repeatability of such surveys, particularly difficulties replicating the source/receiver geometry. Increasingly, permanent sensor arrays in boreholes and on the ocean floor are being deployed to improve the repeatability and increase the temporal sampling of monitoring surveys. Because permanent arrays require a large up-front capital investment and are difficult (or impossible) to re-configure once installed, a premium is placed on selecting a geometry capable of imaging the desired target at minimum cost. We will present a simple approach to optimizing downhole sensor arrays for monitoring experiments making use of differential seismic traveltime tomography. In our case, we use a design quality metric based on the accuracy of tomographic reconstructions for a suite of imaging targets. By not requiring an explicit SVD of the forward operator, evaluation of this objective function scales to problems with a large number of unknowns. We also restrict the design problem by recasting the array geometry into a low dimensional form more suitable for optimization. A side effect of using these restrictive parameterizations for experiment geometry is a well-behaved objective function more amenable to local search techniques. To demonstrate the efficacy of our algorithm, we will consider a series of possible designs for a next-generation tomographic monitoring experiment still within the conceptual development phase.

Habib Ammari (CNRS)
Direct Algorithms for Thermal Imaging of Small Inclusions

Our goal is to reconstruct a collection of small inclusions inside a homogeneous object by applying a heat flux and measuring the induced temperature on its boundary. Taking advantage of the smallness of the inclusions, we design efficient noniterative algorithms for locating the inclusions from boundary measurements of the temperature. We illustrate the feasibility and the viability of our algorithms by numerical examples. (joint work with E. Iakovleva, H. Kang, and K. Kim).

Mark Anastasio (Illinois Institute of Technology)
Fourier-based image reconstruction in photoacoustic tomography

Photoacoustic tomography (PAT), also known as optoacoustic or thermoacoustic tomography, is a hybrid imaging technique that possesses great potential for a wide range of biomedical imaging applications. Image reconstruction in PAT is tantamount to solving an inverse source problem, where the source represents the optical energy absorption distribution in the object that is induced by an interrogating pulsed optical waveform. In this work, we reexamine the PAT image reconstruction problem from a Fourier domain perspective by use of established time-harmonic inverse source concepts. A mathematical relationship between the photoacoustic pressure wavefield data on an aperture that encloses the object and the three-dimensional Fourier transform of the optical absorption distribution evaluated on a collection of concentric spheres is investigated. In addition to providing a framework for deriving both exact and approximate analytic reconstruction formulas, we demonstrate that this mapping provides an intitive means of understanding certain spatial resolution characteristics of PAT and reveals features of the limited angular-view reconstruction problem.

Sandrine Anthoine (CNRS)
Simultaneous separation and deconvolution of multispectral data

In this talk, we present theoretical results on the convergence and stability of a particular iterative algorithm to regularize inverse problems. The algorithm seeks the minimizer of a functional which balances a discrepancy term with an l^p regularization term. The originality of the method is to consider adaptive discrepancy term instead of the classical l^2 discrepancy term.

We then illustrate the theoretical results on a particular astrophysical application: the simultaneous deconvolution and separation maps of astrophysical phenomena. This problem is encountered for example in the treatment of the data acquired by the mission

Planck, which will image the anisotropies of the cosmic microwave background with unprecented resolution for a full sky coverage mission.

Tilo Arens (Universität Karlsruhe)
Convergence of the Linear Sampling Method

The Linear Sampling Method is one in a new class of methods for the reconstruction of domains in inverse scattering problems. In this class of methods, the reconstruction is obtained directly from spectral properties of a linear integral operator defined by the data. In particular, no solutions of direct problems are necessary for the reconstruction. In a number of papers, the Linear Sampling Method has also recently been extended to electromagnetic scattering problems.

A drawback of the method is that many aspects of the mathematical theory remain open. First results in this direction have been published some years ago [1]. In this talk, some new results in this direction will be presented. On the one hand, regularization strategies can be formulated, that preserve the convergence properties proven in [1] in the presence of noisy data. On the other hand it is proved that the reconstruction of a domain using the Linear Sampling Method can be obtained solely by pointwise evaluations of certain Herglotz wave functions.

These new results form an important step towards a solid mathematical basis for the Linear Sampling Method. In particular, some aspects of the ususal application of Linear Sampling are shown to be problematic while some numerical observations on improving the method are confirmed theoretically.

Kari Astala (University of Helsinki)
Complex analytic methods in inverse problems

In elliptic inverse problems the methods from geometric complex analysis and quasiconformal mappings have recently enabled striking advances and new breakthroughs, in particular in Calderon's problem in two dimensions. Indeed, for the planar elliptic PDE's with rough coefficients these methods seems unavoidable.

In this talk, based on joint works with M. Lassas and L. Pivrinta, we give a presentation of the quasiconformal approach to impedance tomography, including the degenerate setting. As a particular example, we study cloaking in two dimensions, and see how the methods of geometric complex analysis reveal us the limits of invisibility.

Guillaume Bal (Columbia University)
Imaging in random media and kinetic models

Forward and Inverse problems for waves in random media. Application to imaging in highly heterogeneous media.

Wolfgang Bangerth (Texas A&M University)
Adaptive finite element methods for inverse imaging problems

In many realistic 3d imaging problems, such as biomedical tumor diagnostics, the resolution requested by practitioners is unachiavable using globally refined meshes. However, while now the leading paradigm in PDE solvers, adaptivity has not been widely used for inverse problems. We will present a mathematical framework for imaging applications using automatically adapted meshes, and present results obtained for three-dimensional optical tomography for tumor detection using multiple measurements obtained when illuminating a body with different light patterns.

Paul Barbone (Boston University)
Forward and inverse problems in multiphase mechanics of soft tissues

A host of imaging techniques are currently available that can image and quantify tissue displacement and strain in vivo. Combining these displacement measurements with a constitutive equation for the tissue and appropriate conservation laws results in an inverse problem for the tissue biomechanical properties. In most previous applications, the constitutive model for the tissue is assumed to be elastic or viscoelastic. It is well recognized, however, that soft tissues contain both fluid and solid phases. Furthermore, the fluid may flow within and between several different compartments. In earlier work, we used a mathematical model of vascularized soft tissue, which includes the effects of fluid flow and the possibility of exchange between fluid compartments, to show the spatio-temporal patterns of elastic strain in soft tissue relaxation resulting from interstitial fluid flow. In the present work we formulate and solve an inverse problem consisting of reconstructing the filtration coefficient given the stiffness distribution and the spatio-temporal pattern of strain relaxation. The knowledge of the spatial distribution of the filtration coefficient may be used to detect and characterize regions of angiogenesis, which may strongly indicate cancer and be used for staging, prognosis and monitoring treatment.

Frank Bauer (Johannes Kepler University Linz)
An Alternative Approach to Parallel MRI

Magnetic Resonance Imaging with parallel data acquisition requires algorithms for reconstructing the patient's image from a small number of measured k-space (Fourier space) lines.

Well-known algorithms like SENSE and GRAPPA and its flavors require a very good a priori knowledge of the receiver sensitivity information. In contrast to that we consider the problem as a non-linear inverse problem where we compute the image and the receiver sensitivities simultaneously and hence can cope with rough estimations of the receivers.

Fast computation algorithms for the necessary Frechet derivative and reconstruction algorithms are given. We will present corresponding reconstructions from real data.

Mikhail Belkin (Ohio State University)
Regularization and Geometry of Learning

In this talk I will discuss the role of geometry of the data distribution in machine learning. It turns out that certain geometric assumption about the shape of the probability distribution can be utilized to create families of data-dependent regularizers, and to develop algorithms to learn from both labeled and unlabeled examples. Theoretical properties and some applications of these ideas will be discussed.

Brad Bell (University of Washington)
Semi-Blind Deconvolution

We consider the semi-blind deconvolution problem; i.e., estimating an unknown input function to a linear dynamical system using a finite set of linearly related measurements where the dynamical system is known up to some system parameters. Without further assumptions, this problem is often ill-posed and ill-conditioned. We overcome this difficulty by modeling the unknown input as a realization of a stochastic process with a covariance that is known up to some finite set of covariance parameters. We first present an empirical Bayes method where the unknown parameters are estimated by maximizing the marginal likelihood/posterior and subsequently the input is reconstructed via a Tikhonov estimator (with the parameters set to their point estimates). Next, we introduce a Bayesian method that recovers the posterior probability distribution, and hence the minimum variance estimates, for both the unknown parameters and the unknown input function. Both of these methods use the eigenfunctions of the random process covariance to obtain an efficient representation of the unknown input function and its probability distributions. Simulated case studies are used to test the two methods and compare their relative performance.

Brad Bell (University of Washington)
MCMC Estimation of Nonlinear Dynamical Systems

We consider the smoothing problem of estimating a sequence of state vectors given a nonlinear state space model with additive white Gaussian noise, and measurements of the system output. The system output may also be nonlinearly related to the system state. It is often not analytically tractable to compute the minimum variance estimate for the state sequence. A Markov chain Monte Carlo (MCMC) method that approximates the minimum variance estimate, as well as confidence intervals, is presented in this talk. The proposal density for this method efficiently draws samples from the Laplace approximation for the posterior distribution of the state sequence given the measurement sequence. This proposal density is combined with the Metropolis-Hastings algorithm to generate realizations of the state sequence that converges to the proper posterior distribution The minimum variance estimate and confidence intervals are approximated using these realizations. Simulations of a fed-batch bioreactor model are used to demonstrate that the proposed method can obtain significantly better estimates than the iterated Kalman-Bucy smoother.

Elena Beretta and Elisa Francini (Universitá di Roma and Universitá di Firenze)
Determination of a linear crack in an elastic body from boundary measurements - Lipschitz Stability

We consider a plane isotropic homogeneous elastic body that may contain a linear crack. The model for the crack originates from the asymptotic expansion of the diplacement field for a body containing a thin inclusion. We show that the linear crack is uniquely determined by one single boundary measurement and we also prove Lipschitz stability for this problem.

Mario Bertero (Universita di Genova)
Recent advances in the reconstruction of astronomical images

The development of Adaptive Optics (AO) and the design and construction of new ground-based telescope utilizing this technique, has increased the relevance of image reconstruction/devolution methods in the processing of astronomical images. Indeed, in general, AO provides only a partial correction of the atmospheric blur and a further correction can be obtained by image deblurring. Moreover, interferometric instruments, as that under construction for the Large Binocular Telescope, will require routinely the use of image deconvolution for getting significant images.

An important point in Astronomy is that the reconstructed images must be sufficiently accurate for quantitative analysis (photometry, astronomy, dynamic range); in addition the images are very often characterized by a very high dynamic range (the same image can contain objects with very different magnitudes, a logarithmic scale used for characterizing the brightness of the objects). These features require a very accurate modeling of noise and the addition of suitable constraints on the solution.

In this talk, after an analysis of the constrained optimization methods that are relevant in Astronomy, we discuss an approach that has been recently proposed for the design of iterative methods based on a suitable scaling of the gradient. Convergence and implementation methods are briefly discussed.

Jeremie Bigot (University Paul Sabatier)
Estimation of the mean of a set of noisy images using a random diffeomorphic matching parametric model

Originating in Grenander's pattern theory, the problem of defining appropriate distances between shapes or images and the use of transformation groups to model the variability of natural images is now an active field of research. However, most of the existing results are stated in a deterministic setting while results in a random framework that are concerned with the estimation of deformations or a template image are scarce. In this talk, we consider a set of images randomly warped from a mean pattern which has to be recovered. For this, we define an appropriate statistical parametric model to generate random diffeomophic deformations in two-dimensions. Then, we focus on the problem of estimating the mean pattern when the images are observed with noise. This problem is challenging both from a theoretical and a practical point of view. M-estimation theory enables us to build an estimator defined as a minimizer of a well-taylored empirical criterion. We prove the convergence of our estimator and we propose an iterative algorithm to compute our M-estimator in practice. Some simulated images and a problem of image classification are used to illustrate the methodology.

George Biros (University of Pennsylvania)
Multigrid algorithms for reconstruction problems with parabolic PDE constraints

We will present a multigrid algorithm for the solution of distributed parameter estimation problems with variable coefficients. The main feature of the method is that it is mesh-independent even in the case of zero regularization (when the data is in the range of the inversion operator). This makes the method algorithmically robust to the value of the regularization parameter. The method is based on a reduced space formulation in which we iterate in the inversion parameter space. We use a full multigrid scheme with a spectrally filtered stationary approximate-Hessian stationary smoother and standard intergrid transfer operators. We use Fourier analysis to estimate the overall performance of the scheme, and we provide numerical experiments that demonstrate the effectiveness of the method for different diffusion coefficients and regularization parameters. We have observed mesh-independent convergence factors resulting in O(N) complexity, where N is the number of state variables. We present and compare two smoothers, one based on simple spectral thresholding and one based on reduced Hessian approximation, based on inexact domain-decomposition approximations of the forward solvers. The latter approach is found to be robust, i.e., it results in a mesh independent convergence for all diffusion coefficient and regularization parameter values. Although the spectral filtering preconditioner has negligible computational cost it does not converge in all the cases unlike pointwise preconditioner, e.g., it only works for large values of the regularization parameter. We also discuss the overall multigrid by using a 2-step iterative smoother, and Fourier transforms to do the intergrid transfers. We have shown that this scheme is extends to nonlinear reaction problems. Even in case of partial observations, these schemes result in near optimal algorithmic complexity.

Joakim Blanch (Nexus Geosciences)
Modeling of, and considerations in cross-well and VSP (pre-) survey design

Cross-well and VSP surveys are usually performed to image certain reflectors more accurately in a previously imaged part of the sub-surface. By employing modeling of wave propagation in a preliminary estimated Earth model, it is possible to determine the appropriate positions of sources and receivers to successfully image the reflector of interest. Using novel techniques based on eikonal equation solvers we show that modestly complicated Earth models commonly produce several illumination points on a reflector in typical cross-well geometries. Thus, proper source and receiver positions may yield more information about a certain reflector than poorly chosen positions. The techniques used will yield reflection points, which may be missed using standard ray-tracing techniques, while maintaining the computational efficiency of ray-based calculations in complex Earth models.

Kirk Blazek (Rice University)
Continuous Dependendence of Solution on Coefficients for the Viscoelastic Wave Equation

Stolk established existence, uniqueness, and continuous dependence on data (including coefficients) for finite energy solutions of initial/boundary value problems for second order hyperbolic systems with bounded and measurable coefficients, by means of energy estimates in the style of Lions-Magenes. We extend Stolkś results to first order hyperbolic integro-differential systems with dissipation mechanisms, including the viscoelasticity system. We show that the solution is a differentiable function of the coefficients, with loss of one derivative, and observe that this result is sharp.

Marc Bonnet (Ecole Polytechnique)
Higher-order topological sensitivity for elastodynamic inverse scattering

To identify hidden obstacles from external measurements (eg. overspecified boundary data) associated with the scattering of known incident waves, it is customary to invoke optimization algorithms. However, sensitivity to initial guesses, and also high computational costs for solving the forward problems in this context, have prompted the definition of so-called “sampling”, or “probe”, methods which aim at delineating in a computationally fast way the hidden obstacle(s), see e.g. the review paper. Such techniques include the linear sampling, not pursued here, and the concept of topological sensitivity, whereby the sensitivity of a cost functional with respect to the creation of an infinitesimal object of small characteristic radius ε is quantified as a function of the small object location x_s. If $J(\varepsilon, x_s)$ denotes the value achieved by the cost function used for solving the inverse problem when only the infinitesimal obstacle located at x_s is present, then in 3D situations the topological derivative $\mathcal{T}_3(x_s)$ associated with the nucleation of a small obstacle of volume $O(\varepsilon^3)$ and specfied shape appears through the expansion $J(\varepsilon, x_s) - J(0, x_s) = \varepsilon^3 \mathcal{T}_3(x_s) + o(\varepsilon^3)$.

In this communication, an extension of the topological derivative is presented, whereby $J(\varepsilon, x_s)$ is expanded further in powers of ε. The expansion to order $O(\varepsilon^6)$ for 3D elastic scattering by a cavity, of the form $J(\varepsilon, x_s) = J(0, x_s) = \varepsilon_3^3 \mathcal{T}(x_s) + \varepsilon^4 \mathcal{T}_4(x_s) + \varepsilon^5 \mathcal{T}_5(x_s) + \varepsilon^6 \mathcal{T}(x_s) + o(\varepsilon^6)$, is considered, the order $O(\varepsilon^6)$ being important for cost functions J of least-squares format because the perturbations of the residuals featured in J are of order $O(\varepsilon^3)$ under the present conditions. General expressions for the coefficients, suitable for numerical computations, are given. In particular, for any *centrally-symmetic* infinitesimal cavity of characteristic radius ε centered at x_s, one finds that $\mathcal{T}_4(x_s) = 0$, while $\mathcal{T}_3(x_s)$ is the so-called *topological derivative*, known from previous studies.

An approximate global search procedure can then be defined on the basis of the functions $\mathcal{T}_3(x_s)\mathcal{T}_5(x_s), \mathcal{T}_6(x_s)$. Such procedure and its attendant computational issues will be discussed. In particular, multipole expansions for elastodynamic fundamental solutions will be shown to substantially ehnance its computational efficiency.

Liliana Borcea (Rice University)
Optimal Waveform Design for Array Imaging

This talk is concerned with an inverse problem for the wave equation. More specifically, it considers coherent imaging of reflectors from measurements of the echoes at a remote array of transducers. The main question raised is how to design optimally the waveform used by the array to illuminate the reflectors, so that the image has the best resolution.

Gregory Boverman (Rensselaer Polytechnic Institute)
Spatio-Temporal Imaging of Compression-Induced Hemodynamics in the Breast With Diffuse Optical Tomography: Simulation Study and Preliminary Clinical Results

In the context of breast cancer screening, the dynamics of the oxygenation and blood flow within the breast, particularly in combination with breast compression, may prove to be of diagnostic relevance. We propose an algorithm for imaging the hemodynamics of the breast using DOT based on the use of spatio-temporal basis functions. As the disambiguation of the calibration parameters and the temporal variation can be difficult, we make use of differential measurements in order to reconstruct the temporal variation. Simultaneously considering all of the data at once, we have implemented and tested a Newton-based nonlinear reconstruction algorithm for estimation of the coefficients of the temporal basis functions, where iterative methods have been applied to make the high-dimensional estimation problem computationally tractable. We have also examined the use of temporal regularization to impose a further degree of smoothing. Simulation results have shown the quantitative accuracy of the algorithm in a realistic breast-shaped geometry, and preliminary results are shown for a screening subject whose mammogram did not present any abnormalities.

Martin Burger (Westfaelische Wilhelms Universitaet Muenster)
Regularization with Singular Energies

In this talk we shall discuss some issues in the regularization with singular (nondifferentiable and nonconvex) energies such as total variation or Besov norms, which became popular in imaging and inverse problems recently. We shall discuss the analysis of such schemes based on dual concepts, i.e. a study of subgradients of the regularization energies, and numerical schemes based on primal-dual discretizations. Moreover we provide various possibilities to construct improved schemes for nonlinear inverse problems using such regularization, and we discuss some future challenges related to integrating such schemes into efficient solvers for large-scale inverse problems.

Fioralba Cakoni (University of Delaware)
A variational approach for the solution of the electromagnetic interior transmission problem for anisotropic media

The interior transmission problem plays a basic role in the study of inverse scattering problems for inhomogeneous medium. In this paper we study the interior transmission problem for Maxwell's equations in the electromagnetic scattering problem for an anisotropic inhomogeneous object. We introduce a new variational approach to study the solvability of the interior transmission problem and also describe the structure of the corresponding eigenvalues. In addition, we show that under certain assumptions a lower bound on the norm of the (matrix) index of refraction can be obtained from a knowledge of the smallest transmission eigenvalue corresponding to the medium which can be computed from the measured far field data.

Fioralba Cakoni (University of Delaware)
The Computation of Lower Bounds for the Norm of the Index of Refraction in an Anisotropic Media from Far Field Data

We consider the scattering of time harmonic electromagnetic plane waves by a bounded, inhomogeneous, anisotropic dielectric medium and show that under certain assumptions a lower bound on the norm of the (matrix) index of refraction can be obtained from a knowledge of the smallest transmission eigenvalue corresponding to the medium and the first Dirichlet eigenvalue of the negative Laplacian on D. Since a reconstruction of D can be obtained from the linear sampling method, it is possible to estimate the first Dirichlet eigenvalue. Furthermore, we show that the transmission eigenvalues can be obtained from the far field operator provided that this operator is known for an appropriate range of frequencies.Numerical examples are given showing the efficaciousness of our estimates.

Daniela Calvetti (Case Western Reserve University)
Statistical analysis of computational metabolic models in cell biology

The paradigm in systems biology is shifting from the traditional reductionist approach of studying small solvable subsystems or lumped large scale models towards complex multiscale models, the large scale phenomena emerging as the result of the interplay between numerous small scale processes. In this paradigm, human metabolism is described via multi-compartment models consisting of different organs. These organs, in turn, are decomposed into different cell types, each of which is further divided in subcellular compartments. The complexity of the resulting multiscale model may become a big obstacle when it comes to identifying the system because measured data are hard to obtain, scarce, noisy and fluctuate from individual to individual. In this talk we discuss some of the challenges of complex cellular metabolic models and we show how we can overcome the lack of data by integrating numerical and statistical methods. Applications of this integrated approach to several cellular metabolic models are presented.

Emmanuel Candes (California Institute of Technology)
Compressed Sensing

One of the central tenets of signal processing and data acquisition is the Shannon/Nyquist sampling theory: The number of samples needed to capture a signal is dictated by its bandwidth. This talk introduces a novel sampling or sensing theory which goes against this conventional wisdom. This theory, now known as "Compressed Sensing" or "Compressive Sampling," allows the faithful recovery of signals and images from what appear to be highly incomplete sets of data, i.e. from far fewer measurements or data bits than used by traditional methods. We will present the key ideas underlying this new sampling or sensing theory, and will survey some of the most important results. We will emphasize the practicality and the broad applicability of this technique, and discuss what we believe are far reaching implications; e.g. procedures for sensing and compressing data simultaneously and much faster. Finally, there are already many ongoing efforts to build a new generation of sensing devices based on compressed sensing and we will discuss remarkable recent progress in this area as well.

Lester Caudill (University of Richmond)
Optimal Design Parameters for a Parabolic Inverse Problem

We focus on issues bearing on the practical implementation of a numerical algorithm for an inverse problem for the heat equation. One induces a heat flux on a portion of the boundary of an object, measures the temperature-response on that boundary portion, and uses this information to determine a hidden portion of the boundary. This has important applications to corrosion detection and non-destructive testing. Practical implementation of the relevant numerical algorithm requires many decisions to be made, such as the input heat flux pattern and the time period over which the temperature-response data is to be measured. We will present mathematical analysis which provides guidance in making these (and other) decisions in an intelligent way.

Kyle Champley (University of Washington)
Planogram Rebinning with the Frequency-Distance Relationship

We present an approximate, but efficient rebinning algorithm for positron emission tomography (PET) systems with parallel planar detectors. Theoretical error bounds and numerical experiments are included.

Xudong Chen (National University of Singapore)
Electromagnetic Imaging of Small Scatterrers using MUSIC

The multiple signal classification (MUSIC) method has been successfully applied to determine the location of point-likes scatterers in acoustic imaging. In electromagnetic imaging, most research work on MUSIC considers 2-dimensional case under the TM incidence. Recently, the application of MUSIC method to electromagnetic imaging is extended to the determination of a collection of small 3-dimensional scatterers. For a small scatterer whose permittivity and permeability are different from those of the background medium, there are usually six (three electric and three magnetic) independent dipoles induced, and the Greens function for each dipole source could be used as the test function in the MUSIC method. However, there are less than three electric or magnetic independent dipoles in the following cases.

1. The special configuration of the transmitting/receiving antennas. For example, when the antennas that form a linear antenna array are oriented in the array direction, only two independent electric dipoles and one magnetic dipole are induced.

2. The special shape of the scatterers. When the scatterers are needle like or disk like, both the electric and the magnetic independent dipoles are less than three.

3. The special composition of the scatterers. For example, for the case of scatterers composed of uniaxial or biaxial materials, when the permittivity or permeability in one of the principal axes is equal to that of the background medium, the electric or the magnetic independent dipoles are less than three.

This paper presents a MUSIC model that deals with the aforementioned degenerate cases. After the positions of the scatterers are determined, the entries of the polarization tensors are obtained by solving a linear equation system.

In conclusion, the paper presents a non-iterative method to solve the nonlinear inverse problem of estimating the positions and the polarization tensors of small scatterers. The proposed method is able of dealing with the degenerate cases and accounts for the multiple scattering between small scatterers.

Cheng-Ying Chou (Illinois Institute of Technology)
Image Reconstruction in X-Ray Phase-Contrast Tomography

X-ray phase-contrast imaging is a technique that aims to recon- struct the projected absorption and refractive index distributions of an object. This can be accomplished by employing independent intensity measurements (i.e., phase-contrast radiographs) acquired at distinct measurement states. Quantitative phase-contrast imaging methods are computed-imaging methods and require the application of reconstruc- tion algorithms for image formation. However, one common feature of these reconstruction formulas is the presence of isolated Fourier do- main singularities, which can greatly amplify the noise levels in the estimated Fourier domain and lead to noisy and/or distorted images in spatial domain. In this article, we develop a statistically optimal re- construction method that employs multiple (¿ 2) measurement states to mitigate the noise amplication eects due to singularities in the re- construction formula. Linear estimators are proposed to combine the available intensity measurements in such a way that the poles present in estimates obtained by use of any two measurements are canceled. Computer-simulation studies are carried out to quantitatively and sys- tematically investigate the developed method, within the context of propagation-based X-ray phase-contrast imaging. The reconstructed images are shown to possess dramatically reduced noise levels and greatly enhanced imaging contrast.

Eric Chung (California Institute of Technology)
A new phase space method for recovering index of refraction from travel times

In this talk, we present a new phase space method for reconstructing the index of refraction of a medium from travel time measure- ments. The method is based on the so-called Stefanov-Uhlmann identity which links two Riemannian metrics with their travel time infor- mation. We design a numerical algorithm to solve the resulting inverse problem. The new algorithm is a hybrid approach that combines both Lagrangian and Eulerian formulations. In particular the Lagrangian formulation in phase space can take into account multiple arrival times naturally, while the Eulerian formulation for the index of refraction allows us to compute the solution in physical space. This is a joint work with Gunther Uhlmann, Jianliang Qian and Hongkai Zhao.

Ivan Cimrák (Ghent University)
Determination of precession and dissipation parameters in the micromagnetics

We aim at determination of the precession and the dissipation parameter (β and α, resp.) in the Landau-Lifshitz (LL) model of micromagnetism

$$\partial_t \mathbf{m} = -\beta \mathbf{m} \times \mathbf{H_{eff}} - \alpha \mathbf{m} \times (\mathbf{m} \times \mathbf{H_{eff}})$$

The LL equation governs the evolution of the magnetization in ferromagnets on nanoscales. Since composite materials can have space-varying magnetic properties, we consider the LL equation with space-varying coefficients α and β, representing the dissipation and the precession.

We define a cost functional f involving the difference between the measured data and the computed solution in an appropriate norm. Further f includes a regularization term; we consider two cases, one with the L^2-regularization and one with the total variation regularization.

A primal-dual approach is used for obtaining an explicit formula for the derivative Df.

Christian Clason (Zentrum mathematic, TU München)
A non-standard numerical method for variational data assimilation for a convection diffusion equation

Data assimilation problems are concerned with determining the initial condition at $t = 0$ in evolution equations from distributed or boundary measurements over a time interval $[0, T_0]$. These arise for example in weather or climate prediction, and are known to be ill-posed problems. The standard approach uses optimal control techniques for minimizing a suitable cost function on a linearized problem together with a regularization method and an optimality system making use of the adjoint state. The state in the time interval $[0, T_1]$, $T_1 > T_0$, is then calculated via a classical initial boundary value problem.

In this talk, we consider a linear convection diffusion equation and compute from distributed observations the state at the final time $t = T_0$, which can serve as an initial condition for the state equation in the time interval $[T_0, T_1]$. This "forward assimilation" problem is well-posed, as can be shown using an observability estimate for the adjoint state equation derived via a Carleman estimate. Its solution can be obtained via a series of null controllability problems for elements of a Hilbert basis of L^2, for which we present an efficient numerical method using proper orthogonal decomposition.

This is joint work with Jean-Pierre Puel (Universitè de Versailles, St. Quentin) and Peter Hepperger.

Christian Clason (Zentrum mathematic, TU München)
The quasi-reversibility method for thermoacoustic tomography in a heterogeneous medium

In this talk we consider thermoacoustic tomography as the inverse problem of determining from lateral Cauchy data the unknown initial conditions in a wave equation with spatially varying coefficients. Using the method of quasi-reversibility, the original ill-posed problem is replaced with a boundary value problem for a fourth order partial differential equation. We find a weak H^2 solution of this problem and show that it is a well-posed elliptic problem. Error estimates and convergence of the approximation follow from observability estimates for the wave equation, derived via a Carleman estimate. We derive a numerical scheme for the solution of the quasi-reversibility problem by a B-spline Galerkin method, for which we also give error estimates. Finally, we present numerical results supporting the robustness of this method for the reconstruction of initial conditions.

This work was done in collaboration with Michael V. Klibanov (University of North Carolina, Charlotte).

Matias Courdurier (University of Washington)
Solving the Interior Problem in Computed Tomography Using a Priori Knowledge

In Computed Tomography (CT) the data measured correspond to the line integrals of an attenuation function. The goal is then to reconstruct the value of the attenuation function from the measurements.

When all the line integrals are measured, there is an inversion formula that recovers the attenuation function in an accurate way. This can change drastically when there truncation of the data set is present. For instance, for the interior problem case, the amount of measurements is not enough to uniquely determine the value of the attenuation function at any point.

Nonetheless, by adding some extra a priori knowledge it might be possible to change this condition.

We will present a result with respect to that. If we add extra knowledge about the support of the attenuation function, and knowledge of the value of the attenuation in a subregion of the object, then the measurements are enough to uniquely determine the attenuation function, and some stability estimates can be obtained.

George Dassios (University of Cambridge)
The scalar magnetic potential in MEG

We present an integral representation of the scalar magnetic potential in terms of the boundary values of the correspoding electric potential for any conductor. Then, we restrict the geometry of the conductor to the ellpisoidal one and we present an analytic consrtuction of the magnetic potential in the form of an expansion in exterior ellipsoidal harmonics.

Ingrid Daubechies (Princeton University)
Sparse wavelet expansions for an inverse problem in Astrophysics

This talk presents joint work with Sandrine Anthoine and Elena Pierpaoli. It concerns the separation of astronomical images into different components: galaxies, galactic dust, cosmic background radiation and stars, based on observations at different light frequencies. We use an ℓ^1-constraint to promote sparse wavelet representation of the galaxy component; the results are compared with a different wavelet-based approach.

Ingrid Daubechies (Princeton University)
Sparsity and Inverse problems

Adding an ℓ^1-constraint or penalization in order to promote sparsity is a well-established custom among statisticians. In finite dimensions, it has been proved recently that, for certain types of matrices A, the inverse problem of recovering sparse vectors x from (noisy versions of) their images Ax can be solved in a stable manner, even if A has a large null space, by means of such ℓ^1-constraints or penalizations. This special class of operators cannot be generalized to spaces that are infinitely-dimensional. Yet even in separable infinite-dimensional Hilbert spaces, ℓ^1-penalization turns out to provide a regularization procedure for ill-posed or ill-conditioned linear inverse problems. After introducing the general framework, the talk will discuss various algorithms that can be used for such ℓ^1-constrained or penalized inverse problems, and point to several applications.

Maarten Dehoop (Purdue University)
Inverse scattering of reflection seismic data in the reverse-time approach

We discuss the inverse scattering of seismic reection data based on the wave equation. We follow an approach known in the seismic literature as reverse-time migration. We derive pseudodifferential operators within such an approach to arrive at a microlocal reconstruction of reflectivity, both for common-source and maximal source-receiver acquisition geometries. The pseudodifferential operators appear to perform two tasks: adapting reverse-time migration or imaging to inverse scattering, and removing certain artifacts. Furthermore, we show some examples with doubly scattered waves.

Christine De Mol (Universite Libre de Bruxelles)
Sparse and smooth solutions for learning and inverse problems

We consider learning and inverse problems formulated in terms of the minimization of a least-squares loss or discrepancy with combined smoothness and sparsity-enforcing penalties. The smoothness penalty is of the usual quadratic type used in classical regularization theory whereas the sparsity-enforcing penalty involves the ℓ^1-norm of the sequence of the solution coefficients on a given basis or frame. The use of both penalties together allows to select sparse blocks of correlated coefficients (variables). We analyze the properties of the regularized solutions derived within such scheme and describe iterative algorithms allowing to compute such solutions. We derive regularization theorems which apply to inverse problems with errors in the data and in the operator as well as probabilistic consistency results which apply to learning theory. Potential fields of applications for these results are also outlined.

Laurent Demanet (Stanford University)
Fourier sketching: sublinear computation foof sparse Fourier expansions

When the Fourier transform of a signal of length N is sparse, computing it should be a o(N) operation since the negligible Fourier coefficients need not be part of the output. Sublinear algorithms for sparse Fourier analysis were introduced recently by Gilbert, Strauss, Zou, and collaborators—but in this talk, I would like to discuss a somewhat different approach to the same problem. Early numerical experiments show definite promise. The success of a new Fourier Sketching algorithm will be linked to the possibility of decoding from judiciously chosen compressed measurements in o(N) time, without even formulating an ell-1 problem.

Oliver Dorn (Universidad Carlos III de Madrid)
Optical and Fluorescence Tomography using a Transport Model in 2D

Optical and Fluorescence Tomography are modelled as an inverse problem for the linear transport equation in 2D. We investigate reconstruction algorithms which are based on an adjoint field technique. We also investigate the use of level sets in these applications.

David Dos Santos Ferreira (Universit Paris 13)
Determining a magnetic Schrodinger operator from partial Cauchy data

In this joint work with Kenig, Sjoestrand and Uhlmann, we show in dimension bigger than 3, that measuring the Dirichlet to Neumann map associated to a Schrodinger equation with magnetic and electric potentials on possibly very small subsets of the boundary suffices to determine the magnetic field and the electric potential.

Anton Duchkov (Purdue University)
Migration velocity analysis using velocity continuation of seismic image gathers

Seismic refection data, in the single scattering or Born approximation, are commonly modelled by a Fourier integral operator (FIO) mapping a medium image (velocity contrast containing reflectors), given a background medium (velocity model), to a data (wavefeld at the surface containing reflections). Migration of seismic reflection data is then described by a FIO adjoint to modelling operator. Usually seismic data space is of greater dimension compared to the model space (the subsurface). Then one can map seismic data into extended image (common-image gathers) of the same dimension. We will consider the class of FIOs the canonical relations of which are graphs, and which are invertible. Thus canonical relations describing propagation of singularities are canonical transformations (and diffeomorphisms).

The notion of velocity continuation can be introduced: the continuation of common-image gathers (CIG) following a path of background media without remigrating the data. Continuation of CIG in background velocity can be exploited in developing a method for determining it (migration velocity analysis): CIG should be flat in particular direction p for true velocity model.

Velocity continuation operators can be viewed as solution operators to pseudodifferential evolution equations (globally). Thus, continuation operators attain the form of propagators. The evolution equation leads to the introduction of a global Hamiltonian and continuation bicharacteristics which describe the propagation of singularities by continuation. Global Hamiltonian provides geometry of velocity continuation. Then reflectors present in CIG can be viewed as 'fronts' evolving with a continuation parameter. For true background velocity the curvature of this 'front' should vanish in particular direction p.

Global evolution equation forms the basis for wave equation velocity continuation of CIG and migration velocity analysis. However, the continuation operator itself typically does not have an explicit form that complicates its numerical implementation (compared to calculating geometry). In order to cope with this issue, we will employ a dyadic parabolic wave packet (curvelet) decomposition of the continuation operator, as it is specially designed to maximally exploit bicharacteristics for solving evolution equations.

Mehran Ebrahimi (University of Waterloo)
Regularization schemes involving self-similarity in imaging inverse problems

In this talk we introduce and analyze a set of regularization expressions defined based on self-similarity of images to address the classical inverse problem of image denoising and the ill-posed inverse problem of single-frame image zooming. The regularization expressions introduced are similar to the ones arising in example-based image enhancement techniques, for which examples are taken from the observed image itself. Traditionally, such expressions can be constructed using Classical fractal image transform or the newly developed Nonlocal-means (NL-means) image denoising filter (A. Buades et al., 2005). We exploit these regularization terms in a global MAP-based formulation, for which we derive analytical and computational solutions. We analytically compare the solution of such MAP-based approach to the results based on the classical methods (e.g., fractal-based denoising and zooming, and NL-means image denoising). Furthermore, the related ill-posed inverse problem of missing fractal codes will be introduced and addressed using various classical regularization techniques.

Harry Eckel (Universität Göttingen)
An idea to couple a BEM and a grid-based method for EIT via an evolutionary algorithm

In a number of applications of impedance tomography - like, for example, in the case of the human thorax - the conductivity has the property to be of high contrast and to present only a few inhomogeneties. In such a situation it seems natural to approximate the conductivity by a piecewise constant function and to treat the inverse EIT problem via a boundary element method (BEM). Compared to the mostly used grid-based methods this reduces the spatial dimension of the problem by one and can deal with a variable size of the inclusions. However these methods need the a-priori information of the number and approximate location of all inclusions which is often not available. For this case we suggest to combine them with a grid-based method which is used to provide an initial guess for the BEM. As grid-based method we try an iterative FEM method as well as the factorization method by Bruhl and Hanke, and the BEM we employ is an extension of an integral equation method proposed by Kress and Rundell. The coupling of the methods is done via an evolutionary algorithm which additionally is used to determine the regularization parameters for the integral equation method.

Herbert Egger (RWTH Aachen)
Y-Scale Regularization

Inverse problems are typically ill-posed in the sense that their solution is unstable with respect to data perturbations, and hence *regularization methods* have to be used for their stable solution. The analysis of such methods is goverend by the mapping properties of the involved operators and smoothness of the data and the solution with respect to the operator. A-priori knowledge on the smoothing properties of the operator can be utilized, e.g., for

- acceleration of iterative regularization methods
- dealing with very high/unbounded noise.

Hilbert Scales provide a framework to analyse mapping properties of operators and relate them to the more intuitive smoothness measure of differentiability. We will utilize a Hilbert Scale over the image space of the operator under consideration and design a parameterized family of modified iterative regularization methods that allow two address both aims mentioned above. We present the main ingredients of the convergence analysis of such Y-scale methods and illustrate the advantages in numerical examples.

Abdellatif El Badia (University of Technology of Compiegne)
Inverse source problem in an advection dispersion reaction system

Part I (work in collaboration with A. Hamdi). We consider the problem of identification of the unknown source $F(x,t) = \lambda(t)\delta(x-S)$ in the following system $\begin{array}{l}(\partial_t - D\partial_{xx} + V\partial_x + R)u(x,t) \\ 0 < x < \ell, \;\; 0 < t < T\end{array}$ the data $[\{v(a,t), \partial_x v(a,t)\}, \{v(b,t), \partial_x v(b,t)\}]$ where a and b are two points of $]0,\ell[$. Moreover, we suppose that one of them is strategic in a sense that will be described later. Assuming that the source F became inactive after the time T^* i.e. $(\lambda(t) = 0$ for $t \geq T^*)$, we prove an identifiability result and propose an identification method.

Part II (work in collaboration with Du Duc Thang). Let us consider the operator

$$L[u] = u_t - D\Delta u + V \cdot \nabla u + Ru, \tag{1}$$

We consider the following problem

$$L[u] = \sum_{k=1}^{N} \gamma_k \rho(x - a_k), \quad x \in \mathbb{R}^2, t > 0, \;\; u(x,0) = 0, \tag{2}$$

where ρ is a given function, which belongs to $\mathcal{S}(\mathbb{R}^2)$. We denote the number of sources by N, the source positions by a_k, $k = 1, \dots, N$ and the intensities γ_k. Assume that we have the measurement of u at some points b_j, $j = 1, \dots, M$, i.e., $u(b_j, t) = d_j(t)$. We propose to determine uniquely the number of source N, the intensities and the source positions a_k with measurements on u at three point b_j.

Matthias Eller (Georgetown University)
Carleman estimates for some first-order systems of partial differential equations

Carleman estimates were developed in order to prove uniqueness for non-hyperbolic Cauchy problems for operators with non-analytic coefficients. More recently they have become powerful tools for many applied problems. The theory for scalar equations is rather complete, however concerning systems of equations the picture is less clear. The only general result pertaining Carleman estimates for systems of equations is due to Calderon.

In this talk we will establish Carleman estimates for certain first order systems. In contrast to previous works our result does not rely on pseudo-differential operators or diagonalization methods which allows for minimal smoothness assumptions on the coefficients. This is of some significance when considering nonlinear problems. Moreover, the explicit nature of the estimate makes the inclusion of boundary terms possible.

Gregory Eskin (UCLA)
Inverse problems for the Schrodinger equations with time-dependant electromagnetic potentials and the Aharanov-Bohm effect

We consider nonstationary Schrodinger equation with time-dependent electromagnetic potentials in space-time domain $D \subset R^{n+1}$ containing obstacles. In general, the domain is multi-connected and the obstacles are moving obstacles. The multi-connectness of the domain leads to the Aharonov-Bohm effect, and the presence of moving obstacles leads to the Aharonov-Bohm effect caused by the electric fluxes, as well by the magnetic fluxes.

We introduce gauge invariant boundary data. The main theorem is that the gauge invariant boundary data uniquely determine the electromagnetic potentials up to a gauge transformation. The fact that the gauge invariant boundary data can distinguish between two not gauge equivalent electromagnetic potentials allows to detect the Aharonov-Bohm effect.

The proof of the main theorem consists of two steps. First, we introduce the broken (reflected) rays in each plane $t = \text{const}$, i.e. rays that undergo finite number of nontangential reflections at the obstacles. Using the geometric optics type solutions we prove that the gauge invariant boundary data uniquely determine the integrals of the magnetic (and subsequently electric) potentials over all broken rays. The second step of the proof is the study of the new branch of X-ray tomography : the tomography of broken rays. We prove for some class of convex and piece-wise smooth obstacles in the plane that the integrals of magnetic potentials over broken rays uniquely determine the magnetic potential up to the gauge transformation (see details in arXiv:math.AP/0611342). In the end of the talk we shall describe results on the related inverse hyperbolic problems (c.f. arXiv:math.AP/0508161v2).

Adel Faridani (Oregon State University)
Sampling Conditions and Numerical Analysis for 3D Helical CT

A major development in 3D computed tomography in recent years has been the emergence of theoretically exact reconstruction algorithms. This talk reports on ongoing investigations with regard to optimal sampling and numerical analysis for a filtered back-projection type algorithm based on Katsevichs exact reconstruction formula for 3D helical computed tomography.

Dario Fasino (Universit di Udine)
Boundary Conditions for nodestructive evaluation based on stationary infrared thermography

Various tomographic methods (based e.g., on X-rays, electrical impedance, ultrasounds, eddy currents, thermal imaging) can be used to investigate damages over the inaccessible surface of a thin conducting plate, in order to prevent critical situations in which, for example, a specimen should not support excessive pressure.

In particular, stationary models in thermal imaging are relevant in both the experimental frameworks of a constant-in-time heat flux $\Phi(x)$ kept on until the system reaches a stationary status, and thermal waves. In the latter case, a periodic heat flux $\Phi(x,t) = \Phi_0(x) + \Phi_1(x)\sin(\frac{2\pi}{\tau}t) + \dots$ gives rise to a periodic temperature profile $u(x,t)$ having the same period τ, apart of a more or less fast deacaying term. Heat equation can be Fourier transformed into a sequence of Helmoltz-type elliptic equations. The equation of order zero, in particular, is Laplaces equation. Thus, at least in theory, solving an inverse problem for Laplaces equation can provide an answer to the main problem of detecting damages from observed thermal data.

Different damage aftereffects are modeled by endowing the Laplaces equation with suitable conditions placed on the inaccessible boundary. Here, we deal with two distinct kinds of boundary properties in thermal models:

(1) The damage does not affect the shape of the specimen, but it leaves effects on its transmissivity properties. This possibility leads to the largely studied problem of recovering coefficients in Robin boundary conditions. Recently, we supposed that the damage gives origin to nonlinearities in the cooling law. We considered uniqueness, stability, and numerical solution of the problem of recovering these nonlinearities from thermal data.

(2) As observed in literature, the effect of cooling is neglectable in many cases. The presence of non-insulation terms in the boundary conditions is in fact quantitatively important only for some materials in particular environment. In these cases, we studied the problem of recovering small perturbations in the shape of the specimen from thermal data when other physical parameters in boundary conditions are known.

Thomas Fidler (University of Innsbruck)
An integral invariant for star-shaped domains

Integral invariants are expected to be useful for shape recognition, but a rigorous analysis of the underlying mathematical framework is missing so far. We focus our attention to the cone area invariant, which measures the area of intersection of a cone with the characteristic function of the object of interest. We present theoretical results concerning the injectivity of the mapping of the shape to its invariant in arbitrary space dimension. Furthermore, we show some numerical results refering to the reconstruction of the original shape based upon its invariant by using an appropriate numerical method.

David Finch (Oregon State University)
Inversion of spherical means and the wave equation

Recently inversion formulas of filtered backprojection type for the problem of recovering a function in a ball from its spherical means over spheres centered on the boundary have been found in all dimensions. These imply inversion formulas for the recovery of the initial data of the free space, constant speed, wave equation for initial data of the form $(f, 0)$ supported in a ball from the trace of the solution on the boundary of the ball. This talk will give a presentation of these results, along with a discussion of their relation to other work and to some open problems.

Matthias Fink (University Denis Diderot)
Time-Reversed Waves and Super-Resolution

The origin of diffraction limit in wave physics, and the way to overcome it, can be completely revisited using the time-reversal mirror concept and the Greens function formalism, without the explicit use of the evanescent wave concept. Through a careful description of the way a time reversal mirror is working, we will first recall that the time-reversed wave, generated by a closed time-reversal mirror, which converges to its source, is always followed by a spatially diverging wave due to energy flux consideration. Because the focal spot results from the interference of these two waves, the time-reversed field (for a monochromatic wave) can always be expressed as the imaginary part of the

Greens function. This statement is very general and is valid for wave propagating in any heterogeneous medium with timereversal symmetry.

In a homogeneous medium, the imaginary part of the Green function oscillates typically on a wavelength scale. To create focal spots much smaller than the wavelength, we will show that a very efficient method is to introduce a random distribution of subwavelength scatterers in the near field of the source. Therefore the spatial dependence of the imaginary part of the Greens function is modified to oscillate on scales much smaller than the wavelength. We have built such media and we experimentally demonstrated focal spots as small as $\lambda/30$ with microwaves time-reversal mirror located in the far field working at a central frequency of 2.4 GHz and with a bandwidth of 250 MHz (see article to be published in Science on 2007 february 16)

We will also discuss another interpretation of this super-resolution effect with the formalism of evanescent waves: in a medium made of random distribution of sub-wavelength scatterers, a time-reversed wave field interacts with the random medium to regenerate not only the propagating but also the evanescent waves required to refocus below the diffraction limit. To conclude this talk we will make a comparison of this new approach for super-resolution, experimentally validated, to the negative index material approach.

Lou Fishman (MDF International)
Some Thoughts on the Inclusion of Multiple Scattering in a Phase-Space-Based Marching Velocity Field Reconstruction Algorithm

Historically, seismic imaging and inversion have been, for the most part, based on a linearization (Born approximation) of the underlying wave equation. Starting with a data set, a "smooth" background velocity component is determined through a velocity analysis, and, subsequently, applied in the linearized (primaries only) construction of a reflectivity or velocity field estimate, often through migration or downward continuation procedures. By far, the most challenging and rate determining step, in proceeding from the data to the final image, is the velocity analysis. Considerable effort has been expended on this pivotal problem in seismic data processing. But why expend all that time and energy on the velocity analysis just to produce a first-order perturbation theory result in the end? Why not focus on developing a full multiple-scattering approach that requires no initial velocity model at all? An important clue for potential success comes from the experiences with the optimization, or model matching, approaches that are prevalent within the greater inverse problems community. While essentially brute force approaches, optimization methods certainly account for the full multiple scattering in their repeated numerical solutions of the direct problem. But even this approach requires a reasonable, smooth initial velocity model, enabling the search algorithm to start in the neighborhood of the global minimum and, subsequently, produce acceptable results. This initial velocity model can be viewed as prior information needed to construct a successful algorithm. The lesson here is that it will almost certainly be necessary to incorporate appropriate prior information into the desired full multiple-scattering algorithm; it just wont be the costly and time consuming initial velocity model. The motivation for the full multiple-scattering algorithm derives from the standard, depth migration, seismic imaging algorithms based on an "approximate imaging condition" that provides a reflectivity estimate; essentially a ratio of the up- and down-going wave fields at a fixed level. However, this is just an approximation to an "exact imaging condition," the exact relationship between the upand down-going wave field components, at a fixed level, through the nonlocal reflection operator, accounting for all of the multiple scattering in the environment. This exact relationship provides the starting point for a classical "layer-stripping". While the reflection operator kernel is a natural

Sergey Fomel (University of Texas at Austin)
Reproducible computational experiments using the Madagascar software package

Because of both practical constraints on computational resources and the inherent ill-posed nature, many of the practically important large-scale inverse problems require experimentation with parameters and algorithms in order to achieve acceptable solutions. A convenient software environment that enables fast experimentation as well as documentation and publishing of experimental results becomes an indispensable tool for a computational scientist. Such an environment is provided by the open-source "Madagascar" software package, developed by an open community and publicly available since June 2006. "Madagascar" re-implements and extends the functionality of SEPlib, a software library developed originally by Jon Claerbout and his students at the Stanford Exploration Project.

In this presentation, I will describe the main design principles of the "Madagascar" project, such as a universal data format and a three-level system of processing modules, data processing flows, and documentation. The system makes use of SCons, a Python-base software construction utility, for managing the information flow and documenting computational experiments. Keeping the experimental results reproducible is important both for robust and maintainable software development and for peer review of scientific results. I will show simple examples of using "Madagascar" for solving practically important inverse problems in seismic imaging and geophysical data analysis.

Massimo Fornasier (Princeton University)
Accelerated iterative thresholding algorithms

Since the work of Donoho and Johnstone, soft and hard thresholding operators have been extensively studied for denoising of digital signals, mainly in a statistical framework. Usually associated to wavelet or curvelet expansions, thresholding allows to eliminate those coefficients which encode noise components. The assumption is that signals are sparse in origin with respect to such expansions and that the effect of noise is essentially to perturb the sparsity structure by introducing non zero coefficients with relatively small magnitude. While a simple and direct thresholding is used for statistical estimation of the relevant components of an explicitly given signal, and to discard those considered disturbance, the computation of the sparse representation of a signal implicitly given as the solution of an operator equation or of an inverse problem requires more sophistication. We refer, for instance, to deconvolution and superresolution problems, image recovery and enhancing, and problems arising in geophysics and brain imaging. In these cases, thresholding has been combined with Landweber iterations to compute the solutions. In this talk we present a unified theory of iterative thresholding algorithms which includes soft, hard, and the so-called firm thresholding operators. In particular, we develop a variational approach of such algorithms which allows for a complete analysis of their convergence properties. As a matter of fact, despite their simplicity which makes them very appealing to users and their enormous impact for applications, iterative thresholding algorithms converges very slowly and might be impracticable in certain situations. By analyzing their typical convergence dynamics we propose acceleration methods based 1. on projected gradient iterations, 2. on alternating subspace corrections (domain decompositions.) Also for both these latter families of algorithms, a variational approach is fundamental in order to correctly analyse the convergence.

Colin Fox (Auckland University)
Bayesian Inference for Geothermal Model Calibration

In geothermal systems, heat flux from underlying magma causes convection of groundwater in the overlying surface layers, with hot rising and cool water descending. The size and shape of the resulting convective plume is determined by the deep heat flux and the shallow geological structures such as major faults, fractured zones and capping formations. Development of a numerical model for predicting the operation of a geothermal field requires parameter values to be obtained by calibrating the model against near-surface data collected in well tests and field exploitation. Our study investigates model calibration, or the inverse geothermal modelling problem, as a problem in statistical inference within a Bayesian framework. Efficiency of sample-based inference is improved using a novel parallel rejection algorithm that utilizes multiple independent compute servers, along with application of the delayed acceptance Metropolis-Hastings algorithm. The methodology is applied to determining the geophysical reservoir parameters near a single well in Fushime, Japan, using measurements of flowing enthalpy and well-head pressure, and to a complete reservoir model for the Mokai field, New Zealand, using measurements of natural-state temperature versus depth.

Hiroshi Fujiwara (Kyoto University)
Identifying discontinuity in real inversion of the Laplace transform with the Tikhonov regularization method

In this presentation, we shall give an example of identifcation of discontinuity of a function with the Tikhonov regularization, in problems of the real inversion of the Laplace transform. The proposed method bases on the theory of reproducing kernel Hilbert space (RKHS) with a suitable norm. We have established the real inversion formula of the Laplace transform using a Fredholm integral equation of the second kind. In the regularization method, we approximate an original function by absolutely continuous functions in the RKHS. We must choose quite small regularization parameters to obtain good approximations, especially the original function has the discontinuity. Though the regularized equations is well-posed in the sense of Hadamard by virtue of the regularization, its discretization scheme is numerically unstable (ill-conditioned) for small regularization parameters. To overcome the instability, we take multiple-precision arithmetic to reduce the influence of the rounding error with high-accurate numerical integration rules.

Romina Gaburro (University of Limerick, Ireland)
Microlocal Analysis of Synthetic Aperture Radar Imaging in the Presence of a Vertical Wall

Many imaging methods involve probing a material with a wave and observing the back-scattered wave. The back-scattered wave measurements are used to compute an image of the internal structure of the material (in a non-desctructive way usually). Many of the conventional methods make the assumption that the wave has scattered just once from the region to be imaged before returning to the sensor to be recorded. The purpose here is to show how this restriction can be partially removed and also how its removal leads to an enhanced image, free of the artifacts often associated with the conventionally reconstructed image.

We consider Synthetic Aperture Radar (SAR) in which backscattered waves are measured from locations along a single flight track of an aircraft and the target is located nearby a reflective vertical wall.

The forward operator associated to this problem is a Fourier Integral Operator (FIO); such operators map singular distributions to other singular distributions. The relationship between the input and output singularities forms what is called a canonical relation. We study this in details; emphasis is given in particular on the case where it is not possible to form a beam with the radar.

Patricia Gaitan (Universit de Provence)
Inverse Problem for the Schrodinger Operator

The question of the identification of a diffusion coefficient c, is studied for the Schrödinger problem in an unbounded strip Ω in $\mathbb{R}^2$. Let $\Omega = \mathbb{R} \times (-\frac{d}{2}, \frac{d}{2})$ be an an unbounded strip of $\mathbb{R}^2$ with a fixed width d. We will consider the Schrödinger equation

(3)

$$\{ \ Hq := i\partial_t q + \nabla \cdot (c(x,y)\nabla q) = 0 \ \text{ in } \ Q = \Omega \times (0,T), \ q(x,y,t) = b(x,y,t) \ \text{ on } \ \Sigma = \partial\Omega \times (0,T),$$

where $c(x,y) \in \mathcal{C}^3(\overline{\Omega})$ and $c(x,y) \geq c_{min} > 0$. Moreover, we assume that c and all its derivatives up to order three are bounded. The aim of this paper is to give a stability and uniqueness result for the coefficient $c(x,y)$. We prove a global Carleman estimate and an energy estimate for the operator H with a boundary term on Γ^+. Then using these estimates and following the method developed by Imanuvilov, Isakov and Yamamoto for the Lamé system, we give a stability and uniqueness result for the diffusion coefficient $c(x,y)$.

We denote by ν the outward unit normal to Ω on $\Gamma = \partial\Omega$. We denote $\Gamma = \Gamma^+ \cup \Gamma^-$, where $\Gamma^+ = \{(x,y) \in \Gamma;\ y = \frac{d}{2}\}$ and $\Gamma^- = \{(x,y) \in \Gamma;\ y = -\frac{d}{2}\}$. Our problem can be stated as follows: Is it possible to determine the coefficient $c(x,y)$ from the measurement of $\partial_\nu(\partial_t q)$ on Γ^+? Let q (resp. $\widetilde{q}$) be a solution of (**??**) associated with (c, b, q_0) (resp. $\widetilde{c}$, b, q_0)) satisfying some regularity properties:

- $\partial_t\widetilde{q}$, $\nabla(\partial_t\widetilde{q})$ and $\Delta(\partial_t\widetilde{q})$ are bounded.
- q_0 is a real valued function in $\mathcal{C}^3(\Omega)$.
- q_0 and all its derivatives up to order three are bounded.

Our main result is

$$|c - \widetilde{c}|^2_{H^1(\Omega)} \leq C|\partial_\nu(\partial_t q) - \partial_\nu(\partial_t \widetilde{q})|^2_{L^2((-T,T)\times\Gamma^+)},$$

where C is a positive constant which depends on (Ω, Γ, T).

Bastian Gebauer (Austrian Academy of Sciences)
Electric potentials with localized divergence properties

In this talk we explore special sequences of electric potentials in impedance tomography that diverge on given subsets of a domain while staying bounded on others. These potentials are closely connected to the Factorization Method and they can be used to prove theoretical identifiability results and to construct non-iterative reconstruction algorithms.

Omar Ghattas (The University of Texas at Austin)
Prospects for Scaling of Seismic Inversion to Petaflops Systems

The U.S., Japanese, and European governments are all pursuing petaflops computing programs, and the first systems capable of a peak petaflops performance will appear sometime in 2008. Problems in the geosciences have been one of the drivers for the development of such systems. In particular, the seismic inverse problem of determining the distribution of earth properties from surface observations of ground motion in large heterogeneous elastic regions often requires petaflops-class computing. The complexity of solution of this inverse problem stems from the need to solve the forward problem repeatedly for a given regularization parameter, the need to solve the inverse problem repeatedly to estimate the best regularization parameter, the need to estimate the variance in the inverted earth model, and ultimately the need to provide a complete characterization of the model uncertainty. Scaling of inversion methods requires both algorithmic (scaling to large problems sizes) and parallel (scaling to large numbers of processors) scalability. In this talk, we examine both parallel efficiency and algorithmic efficiency of several inverse methods and assess the prospects of scalability of seismic inversion to the petascale.

Nathan Gibson (Oregon State University)
Electromagnetic Characterization of Damage in Complex Dielectrics

We present results from our computational efforts to determine defect characteristics via solution of inverse problems which involve Maxwell's equations coupled with mechanisms for attenuation/scattering in dielectrics. These problems are motivated by the need to detect cracks in the sprayed on foam insulation (SOFI) on the Space Shuttle.

Mark S. Gockenbach (Michigan Technical University)
Numerical Analysis of Elliptic Inverse Problems

A number of algorithms have been proposed and analyzed for estimating a coefficient in an elliptic boundary value problem. Most of the analysis has been done for the simple scalar BVP

$$-\nabla \cdot (a\nabla u) = f \text{ in } \Omega,$$
$$a\frac{\partial u}{\partial n} = g \text{ on } \partial\Omega.$$

This talk will briefy discuss the results found in the literature for the scalar problem and then discuss extensions to the problem of estimating Lamé moduli in the system of linear isotropic elasticity.

Raul Gonzalez-Lima (University of So Paulo)
Online transition matrix identification of the state evolution model for the extended Kalman filter in electrical impedance tomography

The electrical impedance tomography objective is to estimate the electrical resistivity distribution in a domain based only on contour electrical potential measurements caused by an imposed electrical current distribution into the contour. In biomedical applications, the random walk model is frequently used as evolution model and, under this conditions, it is observed poor tracking ability of EKF. An analytically developed evolution model is not feasible at the moment. The present work investigates the possibility of identifying the evolution model in parallel to the EKF and updating the evolution modelwith certain periodicity. The evolution model is identified using the history of resistivity distribution obtained by a matrix sensitivity based algorithm. To identify the numerical linear evolution model, it is used the Ibrahim Time Domain Method, normally used to identify the transition matrix on structural dynamics. The investigation was performed by numerical simulations of a resistivity time varying domain with added noise to simulate instrumentation and modelling errors. Numerical difficulties to compute the transition matrix were solved using a Tikhonov regularization. The EKF numerical simulations suggest that the tracking ability is significantly improved.

Markus Grasmair (University of Innsbruck)
On an Inversion Problem for Integral Invariant Signatures

Integral Invariants have been proposed in the fields of shape recognition and classification as robust counterpart to differential invariants. To every point on the boundary of the object of interest a number is assigned, which is defined by integration of a given kernel function over the domain of the object.

In this talk we focus on the circle integral invariant, where the kernel is the characteristic function of a ball. We discuss the question whether the assignment of a shape to the corresponding signature is injective, or in other words, whether a shape is uniquely determined by its signature. This injectivity is crucial in all classification applications.

Closely related is the problem of reconstructing an object from its signature. We present numerical examples of reconstructions in two dimensions.

Allan Greenleaf (University of Rochester)
An FIO calculus for linearized marine seismic imaging

The linearization of the soundspeed to surface data map, F , is a Fourier integral operator (FIO) under fairly general conditions. However, in the presence of caustics for the smooth background soundspeed, the FIO is degenerate in that the associated canonical relation has degenerate projections onto the cotangent space of the Earth and into the cotangent space of the data set. This puts the composition that goes into the formation of the normal operator, F^*F, outside of the standard clean intersection calculus for FIOs. Nolan showed that if the caustics are of the simplest type, namely folds, then for the single-source data set, F is an FIO associated with a folding canonical relation in the sense of Melrose-Taylor. We show that for the (overdetermined) marine seismic data set, F is associated with a canonical relation having a particular form, namely one projection is a submersion with folds and the other is a cross-cap. We then obtain a composition calculus for general FIOs having this structure, which shows that the resulting artifact in the normal operator is $1/2$ derivative smoother than in the single source case. Sobolev estimates then show that it is reasonable to hope for removal of the artifact.This is joint work with Raluca Felea and Malabika Pramanik.

Roland Griesmaier (Johannes Gutenberg-University Mainz)
An asymptotic factorization method for detecting small objects using electromagnetic scattering

We consider the inverse problem of localizing a collection of finitely many small perfectly conducting objects within an unbounded homogeneous background medium using near-field measurements of time-harmonic electromagnetic fields. Therefore we first investigate the direct scattering problem in detail and rigorously derive an asymptotic expansion of the scattered field in terms of the incident field, the centers of the inhomogeneities and their geometry, as the size of the inhomogeneities tends to zero. Similar formulas have recently been derived formally by Ammari et al. and they have subsequently been successfully applied to reconstruct the centers of inclusions using a MUSIC-type method. Inspired by the factorization method we also use the asymptotic formula as the basis of a direct (i.e. noniterative) reconstruction algorithm closely related to linear sampling methods and also to MUSIC-type methods. The viability of this method is documented by numerical examples.

Fernando Guevara Vasquez (Stanford University)
Selective illumination of extended targets in array imaging

We present an algorithm that illuminates the edges or the interior of an extended target by choosing particular subspaces of the array response matrix. In the Fraunhofer diffraction regime, we characterize these subspaces in terms of the singular functions of a frequency and space restricting operator, which are also called generalized prolate spheroidal wave functions. Preliminary results of this analysis will be presented to explain the behavior of the algorithm.

Grant Gullberg (E.O. Lawrence Berkelely National Lab)
The Challenge of Uniqueness in the Application of Dynamic SPECT

Dynamic single photon emission computed tomography (SPECT) imaging involves studying the kinetics of biochemical processes in living organisms. This entails following the uptake of radiopharmaceuticals, its potential metabolism or catabolism, and the eventual washout of tagged products from organs of interest. The greatest challenge for dynamic SPECT imaging is to measure the blood tracer concentration as a function of time where input to the organ of interest often changes faster than the systems ability to obtain consistent tomographic projections. For years dynamic imaging has been realized with positron emission tomography (PET). It has been used to study physiological processes to better understand organ function in health and disease because of a geometric detector sensitivity that allows for rapid measurement of consistent projections. Dynamic sequences of fully 3D reconstructions can be obtained from which time activity curves are generated for the purpose of estimating kinetic parameters of multi-compartment pharmacokinetic models. The development of SPECT clinical systems has moved away from providing sufficient fast acquisition of fully 3D reconstructed dynamic sequences. Time activity curves of blood input and organ uptake and washout or even kinetic model parameters must be estimated directly from projection measurements. Even though this involves the challenge of determining unique solutions to large inverse problems, the effort has lead to the realization that this is the correct way to process SPECT and even PET dynamic data because the estimation of parameters directly from projections provides more efficient estimates of parameters than those estimated from time activity curves generated from reconstructed regions of interest.

Eldad Haber (Emory University)
Adaptive multilevel refinement for parameter estimation problems

In this work we develop a finite volume adaptive grid refinement method for the solution of distributed parameter estimation problems with almost discontinuous coefficients. We discuss discretization on locally refined grids, as well as optimization and refinement criteria. An OcTree data structure is utilized. We show that local refinement can significantly reduce the computational effort of solving the problem, and that the resulting reconstructions can significantly improve resolution, even for noisy data and diffusive forward problems.

Markus Haltmeier (University Innsbruck)
Limited Angle Photoacoustic Tomography with Line detector

Photoacoustic (or thermoacoustic) tomography is an emerging hybrid imaging method for non-invasive medical diagnosis and fully three-dimensional visualization of biological probes. In this talk we assume that an array of line detectors is used to record the acoustical data. This leads to the mathematical problem of inverting the circular Radon transform (or equivalently reconstructing a function from certain circular means). Recently exact inversion formulas have been found for inverting the circular Radon transform from full data, that is in the case where the set of centers is a closed curve enclosing the unknown function. However, in many practical applications, such as in breast cancer detection with Photoacoustic Tomography, the set of centers does not enclose the unknown function. Theoretically, some features of the object can be recovered stably but so far no stable direct algorithm for inverting such data is known. In this talk we discuss and compare regularization methods for inverting limited angle data.

Horst Heck (TU Darmstadt)
Reconstruction of obstacles immersed in an incompressible fluid

We consider the reconstruction of obstacles inside a bounded domain filled with an incompressible fluid. The flow of the fluid is assumed to be described by the stationary Stokes equation. The measurements are modelled by the associated Dirichlet-to-Neumann map which maps given Dirichlet data to the Cauchy forces of the fluid at the boundary. Our method relies on special complex geometrical optics solutions for the stationary Stokes equation with a variable viscosity.

This is a joint work with Gunther Uhlmann (University of Washington) and Jenn-Nan Wang (National Taiwan University)

Jenni Heino (Helsinki University of Technology)
Computational modelling of cellular level metabolism

The quest for understanding cellular level metabolic processes stems from the fundamental role of metabolism in many physiological and diseased conditions. Understanding the metabolic processes behind different conditions can ultimately help, e.g., to prevent or find cures for metabolic related diseases or conditions, such as diabetes.

Computational models for cellular level metabolism can give important insight in understanding the metabolic processes. Cellular level metabolic models typically contain a large number of parameters, whereas the data is usually scarce and may have large variance. The inverse problem is often identifying the large set of parameters and/or the state of the system using the scarce data and available prior information.

In this talk, some models and computational challenges for cellular level metabolism are outlined and a practical approach for modelling by developing an integrated simulation and research tool is introduced.

The work has been done in collaboration with Erkki Somersalo and Knarik Tunyan, Helsinki University of Technology, and Daniela Calvetti, Case Western Reserve University.

Tapio Helin (Helsinki University of Technology)
A stochastic interpretation of the Mumford-Shah functional

In 1989 Mumford and Shah proposed their celebrated minimization method for image segmentation. The method combines shape and functional minimization thus making the computational problem challenging. In this talk we discuss the connections between the Mumford-Shah functional and the Bayesian approach in statistical inverse problems.

Radu Herbei (Ohio State University)
Quasi-3D Statistical Inversion of Oceanographic Tracer Data

The application we are presenting involves estimating water velocities and diffusion coefficients in a 2 km deep region in the South Atlantic Ocean. Partial and sparse measurements of tracer concentrations (salinity, oxygen, etc.) are available. The data are filtered to eliminate outliers, then interpolated to the nearest point on a regular lattice and restricted to thin neutral density layers. The connection between velocities, diffusion coefficients, boundary conditions and tracer concentrations is made via a 3D advection-diffusion equation and a geostrophic flow model. A robust solution to this inverse problem can be obtained by introducing prior information on the parameters (velocities, diffusion coefficients, boundary values) and modeling the measurement error. The (unnormalized) posterior density of the parameters conditionally on the data is summarized using Markov chain Monte Carlo techniques. We reconstruct the tracer fields as well, thus, for regions where no data was available, concentrations are now estimated in a manner that is consistent with physical principles. This approach is extended to a model with multiple active layers interconnected via thermal wind equations.

Felix Herrmann (University of British Columbia)
Seismic inversion through operator overloading

Inverse problems in (exploration) seismology are known for their large to very large scale. For instance, certain sparsity-promoting inversion techniques involve vectors that easily exceed $2^3 0$ unknowns while seismic imaging involves the construction and application of matrix-free discretized operators where single matrix-vector evaluations may require hours, days or even weeks on large compute clusters. For these reasons, software development in this field has remained the domain of highly technical codes programmed in low-level languages with little eye for easy development, code reuse and integration with (nonlinear) programs that solve inverse problems.

Following ideas from the Symes' Rice Vector Library and Bartlett's C++ object-oriented interface, Thyra, and Reduction/Transformation operators (both part of the Trilinos software package), we developed a software-development environment based on overloading. This environment provides a pathway from in-core prototype development to out-of-core and MPI 'production' code with a high level of code reuse. This code reuse is accomplished by integrating the out-of-core and MPI functionality into the dynamic object-oriented programming language Python. This integration is implemented through operator overloading and allows for the development of a coordinate-free solver framework that (i) promotes code reuse; (ii) analyses the statements in an abstract syntax tree and (iii) generates executable statements.

In the current implementation, we developed an interface to generate executable statements for the out-of-core unix-pipe based (seismic) processing package RSF-Madagascar (rsf.sf.net). The modular design allows for interfaces to other seismic processing packages and to in-core Python packages such as numpy.

So far, the implementation overloads linear operators and element-wise reduction / transformation operators. We are planning extensions towards nonlinear operators and integration with existing (parallel) solver frameworks such as Trilinos.

Felix Herrmann (University of British Columbia)
Stable Seismic Data Recovery

In this talk, directional frames, known as curvelets, are used to recover seismic data and images from noisy and incomplete data. Sparsity and invariance properties of curvelets are exploited to formulate the recovery by a ℓ_1-norm promoting program. It is shown that our data recovery approach is closely linked to the recent theory of "compressive sensing" and can be seen as a first step towards a nonlinear sampling theory for wavefields.

The second problem that will be discussed concerns the recovery of the amplitudes of seismic images in clutter. There, the invariance of curvelets is used to approximately invert the Gramm operator of seismic imaging. In the high-frequency limit, this Gramm matrix corresponds to a pseudo-differential operator, which is near diagonal in the curvelet domain.

Thorsten Hohage (University of Goettingen)
Inverse Problems with Random Noise

We study the convergence of regularized Newton methods applied to nonlinear operator equations in Hilbert spaces if the data are perturbed by random noise. We show that under certain conditions it is possible to achieve the minimax rates of the corresponding linearized problem if the smoothness of the solution is known. If the smoothness is unknown and the stopping index is determined by Lepskiĭś balancing principle, we show that the rates remain the same up to a logarithmic factor due to adaptation. The performance and the statistical properties of the proposed method are illustrated by Monte-Carlo simulations.

Lior Horesh (Emory University)
Learning dictionaries for sparse representation

The choice of regularisation functional has been a subject of active research for the last few decades, going from the basic energy term $\lambda\|\underline{m}\|_2^2$ of Standard Tikhonov (ST) regularisation, through smoothness term as in Generalised Tikhonov (GT) $\lambda\|L\underline{m}\|_2^2$, and then advanced to more robust measures, such as Total Variation $\lambda\|\underline{m}\|_1$ in ℓ_1 norm, Wavelet Sparsity $\lambda\|W\underline{m}\|_p^p$ in ℓ_p norm ($p \leq 1$) or Huber-Markov. The main drawback of these functionals is that some ad-hoc assumptions as for the behaviour of the solution are taken. Solutions derived from such regularisation functional guessing approach are intrinsically subjective to their arbitrary choice and therefore prone to be distorted from the true model pursued. An alternative approach is to learn the regularisation term from given authentic examples. This recent approach employs sparse representation of the regularisation term $\lambda\|\underline{u}\|_0^0$ for $\underline{m} = D\underline{u}$, where D is an overcomplete dictionary of basis functions. The underlaying assumption in this case is that the true solution is describable by a small number of parameters (principle of parsimony). Thus, the ℓ_0 norm, which effectively counts the number of non-zeros entries in $\underline{u}$, would favour solutions in which $\underline{u}$ is sparse. In this framework the regularisation functional is constructed implicitly, liberating the solution from any artificial and undesirable restrictions of any specific Hilbert space associated with the choice of an explicit functional, albeit allowing more effective and efficient restriction of the solution space using trust-worthy considerations which were acquired from true examples. The choice of overcomplete dictionary is unfortunately a NP hard problem. Several combinatoric approaches have been proposed for this task in the recent years. Here we propose an innovative constraint optimisation-based approach for updating the dictionary of a sparse-represented regularised inverse problem. The application of this approach for image deblurring is presented and compared with results from state of the art regularisation methods which were available so far.

Nuutti Hyvonen (Helsinki University of Technology)
An implementation of the factorization method within the complete electrode model of electrical impedance tomography

In electrical impedance tomography, one tries to recover the spatial conductivity distribution inside a body from boundary measurements of current and voltage. In many practically important situations, the object has known background conductivity but it is contaminated by inhomogeneities. The factorization method of Andreas Kirsch provides a tool for locating such inclusions. In earlier work, it has been shown, both theoretically and numerically, that the inhomogeneities can be characterized by the factorization technique if the input current can be controlled and the potential can be measured everywhere on the object boundary. However, in real-world electrode applications, one can only control the net currents through certain surface patches and measure the corresponding potentials on the electrodes. In this work, we introduce a factorization-based algorithm within the complete electrode model of electrical impedance tomography and demonstrate its functionality through two-dimensional numerical experiments. Special attention is paid to the efficient numerical implementation of the algorithm and to the characterization of special types of inclusions.

Nuutti Hyvonen (Helsinki University of Technology)
Locating transparent cavities in optical absorption and scattering tomography

The aim of optical absorption and scattering tomography is to reconstruct the optical properties inside a physical body, e.g. a neonatal head, by illuminating it with near-infrared light and measuring the out coming flux of photons on the object boundary. Because brain consists of strongly scattering tissue with imbedded cavities filled by weakly scattering cerebrospinal fluid, propagation of near-infrared photons in the human head can be treated by combining the diffusion approximation of the radiative transfer equation with geometrical optics to obtain the radiosity-diffusion forward model of optical tomography. Currently, a disadvantage with the radiosity-diffusion model is that the locations of the transparent cavities must be known in advance in order to be able to reconstruct the physiologically interesting quantities, i.e., the absorption and the scatter in the strongly scattering brain tissue. In this work, we introduce two methods for locating the transparent cavities through the boundary measurements of optical tomography assuming that the background optical properties of the strongly scattering tissue are known. The first one is an application of the factorization method of Andreas Kirsch and the second one is a Newton type algorithm based on the output least squares formulation of the inverse problem. The functionality of the methods is demonstrated by numerical experiments.

Takanori Ide (Tokyo metropolitan university)
Detection of inclusions from localized boundary measurements in the electrical conductivity problem

Suppose given physical body in dimension two, and that the electrical conductivity distribution inside the body consists of conductive inclusions in a known background. We propose reconstruction formula for the location of inclusions from localized boundary measurements based on hyperbolic geometry. And we demonstrate the numerical experiments for our proposal algorithm.

David Isaacson (RPI)
Electrical Impedance Tomography and Spectroscopy

Electrical impedance tomography systems apply currents to electrodes on a bodies surface and measure the resulting voltages. From these measurements reconstructions of the electrical conductivity and permittivity inside the body are made and displayed. When the measurements are made at multiple frequencies the reconstructed conductivities and permittivities regarded as functions of frequency are called the impedance spectra. We describe how we measure and reconstruct impedance spectra. We will present movies and images showing how the impedance spectra may be used to diagnose breast cancer.

Kazizat Iskakov (KazNPU)
Optimization method for solving two dimensional inverse problem for hyperbolic equation

Consider two dimensional inverse problem for hyperbolic equation $u_{tt} = \Delta_{x,y}u - q(x,y)u$.

According projection method **[?]** consider the system of integral equations

$$\mathbf{v}(x,t) = \frac{1}{2}\Big[\mathbf{f}(t+x)+\mathbf{f}(t-x)\Big]+\frac{1}{2}\int\limits_{0}^{x}\int\limits_{t-x+\xi}^{t+x-\xi}(N+\widehat{Q})\mathbf{v}(\xi,\tau)\,d\tau\,d\xi, \tag{1}$$

$$\mathbf{q}(x) = \mathbf{f}(x) + \int\limits_{0}^{x}\int\limits_{-x+\xi}^{x-\xi}(N+\widehat{Q})\mathbf{v}(\xi,\tau)\,d\tau\,d\xi, \quad x \in (0,T). \tag{2}$$

Where $\mathbf{v}$, $\mathbf{f}$, $\mathbf{q}$ – vectors $(2M+1)$, N, Q – matrices $(2M+1)\times(2M+1)$.

Direct problem. *Find* $\mathbf{v} \in L_2(\Delta(T))$ *by* $\mathbf{f} \in L_2(T)$, $\mathbf{q} \in L_2(T)$ *satisfying (1).*

Inverse problem. *Find* $\mathbf{q} \in L_2(T)$ *by* $\mathbf{f} \in L_2(T)$ *satisfying (2). (In (2) function* $\mathbf{v}(x,t) = \mathbf{v}(x,t;\mathbf{q})$ *is determined by* $\mathbf{q}(x)$ *from (1)).*

We suggest that $\mathbf{q} \in L_2(T)$, if $q_{(i)}(x) \in L_2(0,T)$ for all $|i| \le M$ and $\mathbf{v} \in L_2(\Delta(T))$ if $v_{(i)}(x,t) \in L_2(\Delta_*(T,0))$, $|i| \le M$.

We define norms

$$\|\mathbf{q}\|^2_{L_2(T)} = \int_0^T \Big(\sum_{|i|\le M} q^2_{(i)}(x) \Big)\, dx, \ \|\mathbf{v}\|^2_{L_2(\Delta(T))} = \int_{\Delta_*(T,0)} \Big(\sum_{|i|\le M} v^2_{(i)}(x,t) \Big)\, dt\, dx$$

Let $\|\mathbf{q}\|_{L_2(T)} \le K_2$, $\quad \|\mathbf{f}\|_{L_2(T)} \le Q_2$ are determined. We denote

$$\Omega_2(M,T,K_2) == \big\{ \mathbf{q} \mid q_{(j)}(x) \in L_2[0,T],\ j = \overline{-M,M},\ \|\mathbf{q}\|_{L_2(T)} \le K_2 \big\}.$$

Let $\mathbf{p}(x) \in \Omega_2(M,T,K_2)$ and

$$\boldsymbol{\eta}(x) = \mathbf{p}(x) - \int_0^x \int_{-x+\xi}^{x-\xi} (N + \widehat{P})\mathbf{v}(\xi,\tau)\, d\tau\, d\xi - \mathbf{f}(x), \quad x \in (0,T).$$

Consider functional of new type

$$J[\mathbf{p}] = \int_0^T \sum_{|n|\le M} [\eta_{(n)}]^2(x)\, dx.$$

We obtained a strong convergence rate of the steepest descent method

$$\|\mathbf{p}^{(n+1)} - \mathbf{q}\|^2_{L_2(T)} \le C_6 J[\mathbf{p}^{(0)}] \exp\Big\{ -\frac{n}{4C_4C_5} \Big\}.$$

Where $C_4,\ C_5,\ C_6$ are constants of $M,\ T,\ \|\mathbf{q}\|^2_{L_2(T)},\ \|\mathbf{f}\|_{L_2(T)}$.

Leila Issa (Rice University)
Imaging in cluttered waveguides

We consider an inverse problem for the wave equation in noisy acoustic waveguides. The question is how to locate sound sources or scatterers given measurements of the time traces of the acoustic pressure at a remote array of transducers. The sound speed in the waveguide has rapid fluctuations which are not known to detail and are modeled as random processes. The main goal of the study is to understand the effect of these fluctuations on the imaging process and to develop statistically stable imaging strategies.

Olha Ivanyshyn (Georg-August University of Goettingen)
Inverse Scattering for Planar Cracks via Nonlinear Integral Equations

We present a Newton-type method for reconstructing planar sound-soft or perfectly conducting cracks from far-field measurements for one time-harmonic scattered with plane wave incidence.

Our approach arises from a method suggested by Kress and Rundell (Kress/Rundell:2005) for the inverse boundary value problem for the Laplace equation. It was extended to inverse scattering problems for sound-soft obstacles (Ivanyshyn/Kress:2005) and for sound-hard cracks (Lee:2006). In both cases it was shown that the method gives accurate reconstructions with reasonable stability against noisy data.

The approach is based on a pair of nonlinear and ill-posed integral equations for the unknown boundary. The integral equations are solved by linearization, i.e., by regularized Newton iterations. Numerical reconstructions illustrate the feasibility of the method.

Marcin Janicki (Technical University of Lodz)
Real Time Temperature Estimation of Heat Sources in Integrated Circuits with Remote Temperature Sensors

Temperature is an important factor affecting both electronic circuit operation and its life-time. Therefore, certain applications require continuous temperature monitoring during their operation so as to protect circuits from destruction. Such circuits should be equipped with temperature sensors placed directly where the heat is generated. However, quite often this is not allowed due to certain design constraints. Then, circuit temperature has to be monitored using sensors located away from the heat sources. The paper presents certain considerations on the possibilities and fundamental limitations of integrated circuit temperature estimation based on remote circuit measurements. The considerations presented in the paper are based on the simulations of a test structure with four heat sources of known location and size, which is similar to the real ones. In the simulations, for a given heat source sizes and position 25 sensor locations were considered as shown in the left figure. For this structure the heat equation was solved using the 3D Greens function method. First, given the position of heat sources, the optimal locations of sensors were found using the steady state solution. In the simulation different number of temperature sensors was considered and various cooling conditions applied. Obviously all the best solutions always contained the sensors located in the heat sources. However, when the number of sensors was limited only to those located outside the sources, it turned out that the best remote sensor locations are always on the edges of the structure, as pictured for 8 sensors in the left figure with black circles. Next, the dynamic solutions were taken into consideration. The simulations proved that with poor cooling the temperature of a silicon chip is fairly uniform and remote sensor temperatures are lower only by a few degrees than the temperature of the heat source. Quite the opposite, in typical cooling conditions occurring in power applications, the sensor temperature might be lower by more than 50 K, even a few millimetres from the heat source. This suggests that the estimation of hot spot temperature from remote sensor measurements might be an extremely ill-posed problem. On the other hand, in good cooling conditions already after 100 ms the temperature rise in the heat source exceeds one third of its steady state value, which might cause serious problems in the detection of unexpected short circuits before the maximum allowed temperature is exceeded. Finally, the paper discusses the problem of real time heat source temperature estimation in the presence of noise corrupting sensor responses. The computer generated noisy input data was filtered using digital filters implementing the function specification algorithm derived from the Becks method. Exemplary results of such estimation are presented in the right figure, where the noisy estimate (light line) was filtered out (black lines) and compared with the original signal.

As can be seen in the figure, owing to the application of the digital filter it was possible to improve significantly the quality of the obtained estimates.

Xiao-Yi Ji (Texas Tech University)
Frechét-differentiation of functions of operators with application to testing the equality of covariance operators

It is well-known that the sample covariance operator converges in distribution in the Hilbert space of Hilbert-Schmidt operators, and that this result entails the asymptotic distribution of simple eigenvalues and corresponding eigenvectors.

Several estimators and test statistics for the analysis of functional data require the asymptotic distribution of eigenvalues and eigenvectors of certain functions of the sampl covariance operator. To obtain such a result, apparently the asymptotic distribution of such a function of the sample covariance operator is a prerequisite. In this paper we discuss the Fréchet-derivative of functions of operators and an ensuing delta-method to solve this problem.

The results are applied to obtain the asymptotic distribution of a test statistic for testing the equality of two covariance operators.

B. Tomas Johansson (School of Mathematics)
Determining the temperature from the heat equation with mixed boundary data in corner domains

A solvability result in a weighted Sobolev space for the heat equation with time-dependent conductivity, and with mixed boundary conditions in plane corner domains, is presented. Regularity of the solution is discussed. This solvability result opens the possibility of using iterative regularizing methods for the reconstruction of the temperature in non-smooth inhomogeneous and non-isotropic bodies from Cauchy data.

Geurt Jongbloed (Delft University of Technology)
Density estimation in the Current Status model

Many interesting statistical models involve data that are hidden in some sense. Data can be censored, corrupted by noise or only random fractions of them could be observed. In such situations, there is a hidden- and observation space. Estimating (aspects of) the distribution of random quantities in the hidden space based on data from the observation space is a statistical inverse problem. In this presentation we discus the problem of estimating a density of a hidden variable in the current status (censoring) model.

Consider a positive random variable X with (unknown) distribution function F (think of it as time of onset of a disease) and independent of that another random variable T (think of it as inspection time). In the current status model, one only observes T and an indicator variable $\{X \leq T\}$. In words: one observes the inspection time T and the 'current status' at T of the patient (did the disease already set on or not). Item of interest is the distribution of the random variable X. The Nonparametric Maximum Likelihood estimator (NPMLE) of the distribution function F of X in this model, based on n i.i.d. copies of the observables, is well studied and understood. This estimator is a step function and as such non-smooth.

Under the assumption that F has a density f w.r.t Lebesgue measure, the NPMLE is therefore not a natural estimator. We consider two alternative estimators, a maximum smoothed likelihood estimator and a smoothed maximum likelihood estimator, that take smoothness of F into account. For those we present characterizations and asymptotic properties.

Sung Chan Jun (Los Alamos National Laboratory)
Source inversion technique using probabilistic Bayesian inference: MEG/EEG/fMRI imaging

Source inversion techniques have been investigated in various areas such as geophysics, biomedical imaging, remote sensing, and so on. Source inversion has the inherent ill-posedness problem. Investigators have been commonly making efforts in developing the methodologies to avoid the effect of the ill-posedness, but recently proposed probabilistic Bayesian inference analysis has opened a new eye in dealing ill-posedness. It does not make any attempt against ill-posedness, but accepts its inherence. Regardless of how a given problem is ill-posed and complicated, under the Bayesian frame the likelihood distribution function (forward modeling) and the priori distribution (any priori data and information) are easily combined to release the posterior distribution. Through a sampling technique, likely solutions are sampled from the posterior probability distribution. Then solutions are used to yield a reasonable solution confidence region.

In biomedical brain imaging, several different brain imaging modalities have been developed and used for brain disease diagnosis and neuroscience research. In general, each imaging modality has its own advantage and disadvantage, thus investigators have been recenlty developing strategies combining multi-modalities in a most effective way. The Bayesian inference analysis can be one of conceptually simple and easy tools for this purpose. In this work, we introduce the Bayesian inference analysis which is applied for spatiotemporal biomedical imaging - MEG/EEG/fMRI imaging. We focus on efforts to develop combined analysis on MEG/fMRI or MEG/EEG, and some related issues on this effort are discussed.

Sergey Kabanikhin (Sobolev Institute of Mathematics)
Dirichlet-to-Neumann map and direct numerical methods in inverse multidimensional hyperbolic problems

We consider dynamical type of inverse problems in which the additional information is given by the trace of the direct problem solution on a (usually time-like) surface of the domain. This kind of inverse problems were originally formulated and investigated by M. M. Lavrentiev and V. G. Romanov (1966).

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

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

The first group of methods, namely, Volterra operator equations, Newton-Kantorovich, Landweber iteration and optimization produce the iterative algorithms in which one should solve the corresponding direct (forward) problem and adjoint (or linear inverse) problem on every step of the iterative process. On the contrary, the Gelfand-Levitan method, the method of boundary control, the finite-difference scheme inversion and sometimes linearization method do not use the multiple direct problem solution and allow one to find the solution in a specific point of the medium. Therefore we will refer to these methods as the "direct" methods. In the present talk we will discuss theoretical and numerical background of Gelfand- Levitan, Dirichlet-to-Neumann map and boundary control methods. We will formulate and prove theorems of convergence, conditional stability and other properties of the mentioned above methods.

Sergey Kabanikhin (Sobolev Institute of Mathematics)
Gel'fand-Levitan-Krein equation and Boundary Control method

We consider a problem of determining the coecient (density of the medium) in multidimensional inverse acoustic problems when the sources and the receivers are located at the plane boundary of the medium. Nonlinear multidimensional inverse acoustic problem is reduced to the system of linear integral equations (multidimensional analog of Gel'fand-Levitan-Krein equation. The main idea of boundary control method is to reduce the nonlinear inverse problems to the system of linear algebraic equations. We prove the unique existence of the solution of the boundary control problem and investigate the problem of choice the sequence of sources in boundary control method. We apply SVD analysis to Gel'fand-Levitan-Krein equation and Boundary Control method for constructing stable algorithms of solving two-dimensional inverse acoustic problem.

Jari Kaipio (University of Kuopio)
Estimation Of Fluid Flow In Unsaturated Porous Medium

We consider the estimation of electrically conductive fluid flow in porous media with unknown material parameter distribution. The inversion problem is formulated as a state estimation problem. The approach is based on an evolution-observation model and is solved using an extended Kalman filter algorithm. The example we consider involves the imaging of time-varying distributions of water saturation in porous media using time-lapse electrical resistance tomography (ERT). The complete electrode model with Archies law relating saturations to electrical conductivity is used as the observation model. The evolution model we employ is a simplified (approximate) model for simulating flow through partially saturated porous media. Since the material parameters are not known, the evolution model is not completely specified and a statistical model for the disrepancy has to be constructed. This model can be realized using the nonstationary extension of the approximation error approach.

Barbara Kaltenbacher (University of Stuttgart)
Determination of cracks in piezoelectric media by Newton-multilevel methods

The identification of cracks in piezoelectric ceramics from boundary measurements is a both practically highly relevant and mathematically challenging problem. The resulting inverse problems are highly nonlinear and ill-posed. Hence, for their numerical solution, we propose to apply a combination of a regularizing multilevel discretization scheme with Newtons method that can be show to yield convergence and convergence rates under less restrictive conditions on the nonlinearity than other iterative regularization methods for nonlinear problems. Numerical tests with synthetic data illustrate the performance of the proposed methodology.

Barbara Kaltenbacher (University of Stuttgart)

Uniqueness for a Paramater Identification Problem for a Nonlinear Parabolic Equation with Application in Population Dynamics and Magnetics

In this talk we demonstrate the use of Carleman estimates to prove identifiability of a coefficient function in a nonlinear parabolic PDE from initial and boundary data. Here, the coefficient depends on the spatial derivative of the PDE solution and appears in the principal part of the differential operator. Our result equally applies to problems where the coefficient depends on values of the PDE solution and the differential operator is in non-divergence form. Both situations appear in several applications. We here illustrate applicability of our uniqueness result for parameter identification problems in population dynamics and in magnetics. Computational experiments obtained by a method based on a multiharmonic expansion of the PDE solution illustrate the theoretical results.

Hyeonbae Kang (Seoul National University)
Current Trends in Biomedical Imaging

Hyeonbae Kang (Seoul National University)
Three methods of internal corrosion detection

Authors : H. Ammari, H. Kang, E. Kim, H. Lee, M. Lim, K. Louati, and M. Vogelius
We will explain various algorithms to detect internal corrosive parts. These algorithms are based on three different physical phenomena: electrostatic, vibration test (guided wave), and ultrasonic, and are designed through rigorous asymptotic analysis under the assumption that the size of the corrosive parts are small. Viability of these methods will be demonstrated with results of numerical simulations. This talk will be base on three papers by three different combination of above mentioned authors.

Alain Kassab (University of Central Florida)
Singular-Superposition Method for the Inverse Geometric Problem - applications in heat transfer and elasticity

A method is presented for the efficient solution of the inverse geometric problem applied to detection of subsurface cavities and flaws using additional information provided by thermographic or mechanical measurements. A hybrid method, consisting of the superposition of clusters of sources/sinks in thermal applications or point forces or loads in mechanical applications either of which is coupled to a boundary element field solution of the forward problem. The singularities are adjusted to satisfy the measured quantities and a search is subsequently undertaken to determine the flaw(s) or cavity(ies) location(s). The numerical scheme avoids re-meshing of the interior geometry as it evolves in the process of solving the inverse problem iteratively to detect the subsurface flaw(s) or cavity(ies). The hybrid approach markedly reduces the computational burden involved in solving the inverse problem and presents a promising technique for practical 3D applications. We present examples both in heat transfer and elasticity.

Arnold Kim (University of California, Merced)
Reconstructing a thin absorbing obstacle in a half space of tissue

We solve direct and inverse obstacle scattering problems in a half space composed of a uniform absorbing and scattering medium. Scattering is sharply forward-peaked, so we use the modified Fokker-Planck approximation to the radiative transport equation. The obstacle is an absorbing inhomogeneity that is thin with respect to depth. Using the first

Born approximation, we derive a method to recover the depth and shape of the absorbing obstacle. This method requires only continuous plane wave illumination at two incident angles and a detector with a fixed numerical aperture. First we recover the depth of the obstacle through solution of a simple nonlinear least-squares problem. Using that depth, we compute a point spread function explicitly. We use that point spread function in a standard deconvolution algorithm to reconstruct the shape of the obstacle. Numerical results show the utility of this method even in the presence of measurement noise.

Sungwhan Kim (Hanbat National University)

Trans-admittance scanner (TAS) is a device for breast cancer diagnosis based on numerous experimental findings that complex conductivities of breast tumors significantly differ from those of surrounding normal tissues. In TAS, we apply a sinusoidal voltage through a hand-held electrode and place a scanning probe with zero voltage against the breast skin to make current travel through the breast. The scanning probe has an array of electrodes to measure exit currents (Neumann data) that provide a map of trans-admittance data over the breast surface. The inverse problem of TAS is to detect a suspicious abnormality underneath the breast skin from the measured Neumann data. Previous anomaly detection methods used a difference between measured Neumann data and reference Neumann data in the absence of anomaly. However, in practice, the reference data is not available and itś computation is not possible since the inhomogeneous complex conductivity of the background is unknown. To deal with this problem, we develop a multi-frequency TAS, in which a frequency difference of trans-admittance data measured at a certain moment is used for anomaly detection. We provide a mathematical framework of this multi-frequency TAS model and its feasibility.

Stefan Kindermann (University of Linz)
A relaxation algorithm for solving inverse interface problems

The scope of this work is the field of inverse problems, where the unknown is the boundary of a set. A well-known way to approach such problems is e.g. by the level-set method. In this talk we propose an alternative which is based on Tikhonov regularization. Instead of working with a level-set function we formulate a Tikhonov functional in the space of characteristic functions, which leads to a difficult minimization problem over the set of characteristic functions. We propose a new method for finding a minimizer of this optimization problem - or at least a critical point - by combining recent results from regularization theory and image processing.

The method of surrogate functionals can be used to find a sequence of simpler optimization problems, which can be solved by the method of exact relaxation. This leads to an iterative algorithm, where in each step a Rudin-Osher-Fatemi-(ROF)-functional has to be minimized, which solution is then pro jected onto the set of characteristic functions by simple thresholding. We discuss convergence questions of this algorithm and give numerical results for a simple deblurring operator.

Stefan Kindermann (University of Linz)
Dynamic programming principle for static and dynamic inverse problems

Dynamic inverse problem are problems, where the solution, the data and/or the operator depend on time. We investigate a Tikhonov-type regularization method for linear static and dynamic inverse problems, where the regularization term involves the time-derivative of the regularized solution. The minimizer of this problem is computed using Bellman's principle of dynamic programming. In this way we obtain a Hamilton-Jacobi equation for the value function. This equation can be solved in the time-discrete case by a Riccati equation and a backward and forward iteration. In this way we find an iterative way to compute a regularized solution. For this method, it can be shown using spectral theory and filter function, that it gives a convergent regularization.

Anna Kirpichnikova (The University of Edinburgh)
Inverse boundary spectral problem for Riemannian polyhedra

We consider an admissible Riemannian polyhedron with piece-wise smooth boundary. The associated Laplacian defines the boundary spectral data as the set of eigenvalues and restrictions to the boundary of the corresponding eigenfunctions. We prove that the boundary spectral data prescribed on an open subset of the polyhedron boundary determine the admissible Riemannian polyhedron uniquely. This is a joint work with Professor Kurylev.

Esther Klann (Radon Institute for Computational and Applied Mathematics)
A Mumford-Shah level-set approach for the inversion and segmentation of SPECT data

In this talk we present a level-set approach for the reconstruction of an activity function f and a density function μ from SPECT data (Single Photon Emission Computerized Tomography) modeled by the attenuated Radon transform

$$y(s,\omega) = A(f,\mu) = \int_{t\in\mathbb{R}} f(s\omega + t\omega^{\perp}) \exp\Big(- \int_{\tau=t}^{\infty} \mu(s\omega + \tau\omega^{\perp}) \mathrm{d}\tau \Big) \mathrm{d}t \ .$$

For the medical application at hand, we consider it reasonable to restrict the reconstructions to activity functions f and density functions μ which are constant with respect to a partition of the body. Hence, we determine a pair of piecewise constant functions (f,μ) from possibly noisy SPECT data. Simultaneously, a segmentation of the reconstructed density and activity is obtained. The segmenting contours and the corresponding density and activity functions are found as minimizers of a Mumford-Shah like functional over the set of admissible contours and – for a fixed pair of contours – over the space of piecewise constant density and activity functions which may be discontinuous across the contour. Shape sensitivity analysis is used to find a descent direction for the cost functional which leads to an update formula for the contour in the level-set framework.

Michael Klibanov (University of North Carolina at Charlotte)
Some Inverse Problems for Partial Differential Equations

We will consider the following topics:

1. An inverse problem of the recovery of the initial condition in the parabolic equation $u_t = L(x,t,D)u + f(x,t)$ from the Dirichlet and Neumann boundary data . Here $L(x,t,D)$ is a general elliptic operator of the second order. Logarithmic stability estimate will be presented for the case when $xinOmega$, where $Omega$ is a bounded domain. This is an extension of the previously known result for case of the self adjoint operator $L(x,D)$ with t-independent co efficients, which was obtained by the logarithmic convexity method. While the first result is for the finite domain, the second stability estimate is for an i nfinite domain. In this case a new Carleman estimate is derived.

2. A coefficient inverse problem for the non-stationary transport equation. We prove uniqueness result for the case when the absorption coefficient is recover ed from boundary measurements at the time interval $(0, T)$. The main difficulty here is that one needs to properly extend the solution of the transport equation $(-T, T)$ in such a way that boundary integrals over $\{t = 0\}$ in the Carleman estimate would cancel out.

3. Numerical results for the inverse problem of the recovery of the initial condition of a hyperbolic equation from the Dirichlet and Neumann boundary data. We present an analog of the quasi-reversibility method of R. Lattes and J.-L. Lions, prove its convergence and demonstrate numerical results.

4. A globally convergent convexification algorithm for some coefficient inverse problems. The algorithm will be presented along with numerical results.

Michael Klibanov (University of North Carolina at Charlotte)
Carleman estimates and inverse problems: theory and numerical methods

We will present several versions of the so-called "convexification" method for coefficient inverse problems. This is a globally convergent method. In addition, we will present a numerical method for the determination of the initial condition in a hyperbolic equation.

Michael Klibanov (University of North Carolina at Charlotte)
Some Numerical Methods for Hyperbolic Inverse Problems

Development of numerical methods for coefficient inverse problems is one of important tasks, because of the applied nature of these problems. In this talk numerical methods for two inverse problems for hyperbolic Partial Differential Equations will be presented. The first one is for the recovery of a coefficient in the principal part of the operator (joint with J. Xin). This one is a globally convergent method. The second one is for the recovery of an initial condition of the hyperbolic equation (joint with C. Clason). Carleman estimates play a substantial role in both algorithms. Indeed, Carleman Weight Functions are used directly in the numerical scheme in the first, and convergence of the second is proven using Carleman estimates. Applied examples will be presented for imaging of land mines and thermoelastic tomography.

Kim Knudsen (Aalborg University)
The Calderón problem with partial measurements

In this talk we will discuss recent progress on the inverse conductivity problem, which is the mathematical problem behind electrical impedance tomography. We will show that for the three-dimensional problem measurements of the Dirichlet-to-Neumann map on particular subsets of the boundary uniquely determine a non-smooth conductivity. Moreover, we will discuss the unique determination of a non-smooth magnetic field from partial measurements of the associated Dirichlet-to-Neumann map.

Ville Kolehmainen (University of Kuopio)
Sedimentation monitoring using EIT

Sedimentation monitoring provides information about the properties of a sedimentation process based on non-invasive measurements. The information obtained from sedimentation monitoring can be used in the control and optimization of industrial sedimentation processes. In this talk, we introduce a novel computational method for sedimentation monitoring using electrical impedance tomography (EIT). The method is based on shape estimation and state estimation formulation of the EIT problem. We parameterize the sedimentation using the locations of the sedimentation phase interfaces and conductivities of the phase layers. The state estimation problem is solved using the extended Kalman filter algorithm. The performance of the method is evaluated using simulated and experimental data.

Ville Kolehmainen (University of Kuopio)
Approximation Errors and Model Reduction in Optical Tomography

Model reduction is often required in optical diffusion tomography (ODT), typically due to limited available computation time or computer memory. In practice, this often means that we are bound to use sparse meshes in the model for the forward problem. Conversely, if we are given more and more accurate measurements, we have to employ increasingly accurate forward problem solvers in order to exploit the information in the measurements. In this talk we apply the approximation error theory to ODT. We show that if the approximation errors are estimated and employed, it is possible to use mesh densities that would be unacceptable with a conventional measurement model.

Rainer Kress (University of Goettingen)
Integral equations for inverse problems in corrosion detection

We consider the inverse problem to recover a part Γ_c of the boundary of a simply connected planar domain D from a pair of Cauchy data of a harmonic function u in D on the remaining part $\partial D \setminus \Gamma_c$ when u satisfies a homogeneous impedance boundary condition on Γ_c. Our approach extends a method that has been suggested by Kress and Rundell (2005) for recovering the interior boundary curve of a doubly connected planar domain from a pair of Cauchy data on the exterior boundary curve and is based on a system of nonlinear integral equations. As a byproduct, these integral equations can also be used for the problem to extend incomplete Cauchy data and to solve the inverse problem to recover an impedance profile on a known boundary curve. We present the mathematical foundation of the method and illustrate its feasibility by numerical examples.

Venky Krishnan (University of Washington)
A Support Theorem For The Geodesic Ray Transform On Real-Analytic Riemannian Manifolds

We consider the geodesic ray transform on a compact simple Riemannian manifold with boundary and with a real-analytic Riemannian metric. Using analytic microlocal analysis, we prove a support theorem for this transform in the spirit of Helgasons support theorem for the Radon transform.

Shiro Kubo (OsakaUniversity)
Passive Electric Potential CT Method for Crack Identification

The present authors proposed the passive electric potential CT (computed tomography) method for the identification of defects and cracks in a structural member subjected to mechanical load. In this method piezoelectric film is pasted on a body to be inspected and the electric potential distribution on the piezoelectric film is obtained without applying electric current. The electric potential distribution obtained passively is used for the identification cracks and defects. In this study the method is applied to the identification of plural cracks and defects. An inverse analysis scheme based on the least residual method is applied, in which square sum of residuals is evaluated between the measured electric potential distributions and those computed by using the finite element method. Akaike information criterion (AIC) was used to estimate the number of cracks. The location and size of these cracks are quantitatively estimated by the present method.

Amy Kuceyeski (Case Western Reserve University)
The Liver: Spatial Distribution at Steady State

A spatially distributed model of the liver is proposed that describes the metabolic concentrations and reaction fluxes in the tissue and blood domains. The blood domain equations account for convection, axial dispersion, and blood/tissue transport. The tissue equations account for key metabolic reactions as well as blood/tissue transport. This model deals with spatial distribution via a railway construction, where different stations (tissue compartments) along the blood flow route are modeled by a metabolic pathway network. As the blood flows, the concentrations of the species transported into the tissue by the blood change according to the mass balance equations. This implies that transports vary in space, hence it is necessary to include a differential equation of second order. Discretizing the differential equation generates as many variables as points used in estimation. Therefore, the number of parameters required for model identification is quite large. A recently developed method of statistical Flux Balance Analyis is used to estimate these parameters. This approach is especially useful in this case, as it allows the use of a smoothness prior to account for the continuity of the spatially continuous parameters. Under a Bayesian framework, Gibbs and adaptive sampling algorithms are implemented in order to explore the posterior probability densities of the metabolic fluxes in the tissue, blood concentrations, and transports. The large number of parameters required the utilization of different adaptive sampling techniques, such as Adaptive Hit and Run (AHR) and Adaptive Metropolis Hastings (AM). We compare these algorithms for speed, accuracy and convergence.

Philipp Kuegler (University of Linz / RICAM)
Online parameter identification

Online parameter identification becomes necessary whenever model parameters are needed in order to support decisions that have to be taken during the operation of the real system. Based on ideas from adaptive control and regularization of inverse problems we suggest an online method that works both for ODEs and time-dependent PDEs. It allows for partial state observations and does neither require a linear parameterization nor data differentiation or filtering. Numerical examples in context of aircraft control are presented.

Leonid Kunyansky (University of Arizona)
A series solution and a fast algorithm for the inversion of the spherical mean Radon transform

An explicit series solution is proposed for the inversion of the spherical mean Radon transform. Such an inversion is required in problems of thermo- and photo- acoustic tomography. Closed-form inversion formulae are currently known only for the case when the centers of the integration spheres lie on a sphere surrounding the support of the unknown function, or on certain unbounded surfaces. Our approach results in an explicit series solution for bounded measuring surfaces enclosing regions for which the eigenfunctions of the Dirichlet Lapla- cian are explicitly known. Such are the surfaces of a cube, finite cylinder, half-sphere, etc. The simplest measurement surface is that of a cube. For the latter case we present a fast reconstruction algorithm that reconsrtucts 3-D images thousands times faster than the backprojection-type methods.

Leonid Kunyansky (University of Arizona)
Explicit inversion formulas for the inversion of the spherical mean Radon transform

We derive explicit formulas for the reconstruction of a function from its integrals over a family of spheres, or for the inversion of the spherical mean Radon transform. Such formulas are important for problems of thermo- and photo-acoustic tomography. A closed-form inversion formula of a filtration backprojection type is found for the case when the centers of the integration spheres lie on a sphere in $\mathbb{R}^n$ surrounding the support of the unknown function.

Steven Kusiak (New Frontier Advisors, LLC)
Identification and Characterization of a Moving Source in a General Parabolic Differential Equation

We discuss an inverse source problem for a general parabolic differential equation in $\mathbb{R}^n \times \mathbb{R}$ with variable coefficients and a source whose strength and support may vary with time. We demonstrate that a knowledge of the solution on any bounded open set M in $\mathbb{R}^n$ located away from the source for any fixed time t determines the so-called "carrier support" [as originally defined and presented in, Notions of support for far fields, John Sylvester, Inverse Problems, 2006] (a nontrivial subset of the support of the true source) at that coincident time. Additionally, we provide a reconstruction algorithm which can locate the time-varying position of the carrier support of the assumed unknown source with extremely few discrete (possibly nonuniform) measurements taken on such an open set over a wide range of regulartity classes of the source.

Lastly, we provide a few numerical examples which illustrate the efficacy and robustness of this location and tracking method.

Heung Fai Lam (City University of Hong Kong)
Crack detection of beam-type structures following the Bayesian system identification framework

This paper puts forward a method for the detection of crack locations and extents on a structural member utilizing measured dynamic responses following the Bayesian probabilistic framework. In the proposed crack detection method a beam with different number of cracks is modeled using different classes of models. The Bayesian model class selection method is then applied to select the most plausible class of models in order to identify the number of cracks on the structural member. The objective of the proposed method is not to pinpoint the crack locations and extents but to calculate the posterior (updated) probability density function (PDF) of crack parameters (i.e., crack locations and extents). The method allows for the uncertainties introduced by measurement noise and modeling error to be handled explicitly. This paper presents not only the theoretical formulation of the proposed method but also numerical and experimental verifications. In the numerical case studies, noisy data generated by a Bernoulli-Euler beam with semi-rigid connections is used to demonstrate the procedures of the proposed method. The method is finally verified by measured dynamic responses of a cantilever beam utilizing a laser Doppler vibrometer.

Arnaud Lange (IFP)
Genetic-based Characterization of Fractured Reservoirs from Interpreted Well Tests

The presence of fractures at various scales affects the flow dynamics within a reservoir, thus casting uncertainty on the assessment of the field productivity and reserves. Methodologies and tools are available (i) to construct geologically-realistic models of the fault/fracture network (ii) to turn these models into simplified conceptual models usable for field-scale simulations of multi-phase production methods. However a critical intermediate step remains that of validating the geometry of the geological fault/fracture network and characterizing it in terms of flow properties. This characterization step is usually performed by calibrating available field data, e.g. well tests, with simulated data. A 3D Discrete Fracture Network (DFN) simulator has been developed, enabling one to simulate single-phase flow in DFN models and to compute equivalent fracture flow properties. A genetic algorithm has been developed and coupled with the 3D DFN flow simulator in order to perform the simultaneous calibration of well tests data. Thus fracture properties are characterized such that their flow properties are consistent with the well tests data. As a first step, the well tests data considered for calibration result from interpreted well tests i.e. equivalent transmissivities Kh, with K the equivalent permeability that takes into account fracture flow properties, and h the reservoir thickness over which the well test has been interpreted. The genetic algorithm is described and applications are presented on a geologically-realistic fractured reservoir model having three facies, up to three fracture sets and seven wells. The characterized fracture properties are the mean length, mean conductivity, orientation dispersion factors, and facies-dependent properties such as the average spacing and the bed-crossing probability. The effectiveness of the genetic algorithm to characterize physically meaningful and data-consistent fracture properties is discussed.

Matti Lassas (Helsinki University of Technology)
A modified time reversal method and inverse problems for wave equation

A novel method to solve inverse problems for the wave equation is introduced. The method is a combination of the boundary control method and an iterative time reversal scheme, leading to adaptive imaging of coefficient functions of the wave equation using focusing waves in unknown medium. The approach is computationally effective since the iteration lets the medium do most of the processing of the data. The iterative time reversal scheme also gives an algorithm for approximating a given wave in a subset of the domain without knowing the coefficients of the wave equation. These results are obtained in collaboration with Kenrick Bingham, Yaroslav Kurylev, and Samuli Siltanen.

Also, we will disucss how the energy of a wave can be focused near a single point in an unknown medium. These results are done in collaboration with Matias Dahl and Anna Kirpichnikova.

Matti Lassas (Helsinki University of Technology)
Invisibility and Inverse problems

There has recently been considerable interest in the possibility, both theoretical and practical, of invisibility of objects to different types of waves. We construct several examples of cloaking enclosures covered with anisotropic materials. These examples have a close connection to earlier works carried out for the case of static Maxwell's equations (at zero frequency), a case that is very important in electrical impedance tomography (EIT). These results have also a close connection to counter examples for inverse problem. For instance, consider the Calderon problem, that is, whether the Dirichlet-to-Neumann map determines uniquely the conductivity. The problem has a positive answer in all dimensions $n \geq 2$ if the conductivity is isotropic (under suitable regularity hypothesis) and in 2D, it also known for anisotropic conductivities. However, in all of these results it is assumed that the conductivity is bounded both below and above by strictly positive constants. If this condition is violated, one can cover any object with a properly chosen anisotropic material so that the covered object appears in all boundary measurement similar to a domain with constant conductivity. Clearly, this kind of counter example gives us theoretical instructions how to cover an object so that it appears "invisible" in zero frequency measurements. In this talk we consider similar kind of result for all frequencies.

We review the results on the counter examples based on singular transformations that push isotropic electromagnetic parameters forward into singular, anisotropic ones. We define the notion of finite energy solutions of Maxwell's equations for such singular electromagnetic parameters, and study the behavior of the solutions on the entire domain, including the cloaked region and its boundary. Analyzing the behavior of such solutions inside the cloaked region, we show that, depending on the chosen construction, there appear new "hidden" boundary conditions at the surface separating the cloaked and uncloaked regions. We also consider the effect on invisibility of active devices inside the cloaked region, interpreted as collections of sources and sinks or internal currents. When these boundary conditions are overdetermined, we see that Maxwell's equation do not have finite energy solutions for the generic internal currents. We will consider in detail the existence of the finite energy solutions when cloaking a ball or an infinite cylinder. When cloaking an infinite cylinder, we show that the finite energy solutions solutions exist if the coating material is lined from inside with a surface satisfying the soft and hard (SHS) boundary condition. Surprisingly, without such a lining finite energy solutions may not exists even if there are no internal sources.

Armin Lechleiter (University of Karlsruhe)
Factorization and Perturbation

The factorization method provides an explicit characterization of the shape of an inclusion in impedance tomography or of a scatterer in inverse scattering problems. In practice the data required for this characterization is never at hand due to finite dimensional perturbed measurements. Nevertheless, perturbation theory explains why the method works when only approximate data is at hand. Moreover, it shows that regularization of the method's criterion is crucial. As an application, the insights provided by perturbation analysis are used to set up a factorization method for the complete electrode model in impedance tomography.

Hyundae Lee ()
A Method of Biological Tissues Elasticity Reconstruction Using Magnetic Resonance Elastography Measurements

Magnetic resonance elastography (MRE) is an approach to measuring material properties using external vibration in which the internal displacement measurements are made with magnetic resonance. A variety of simple methods have been designed to recover mechanical properties by inverting the displacement data. Currently, the remaining problems with all of these methods are that in general the homogeneous Helmholtz equation is used and therefore it fails at interfaces between tissues of different properties. The purpose of this talk is to propose a new method for reconstructing both the location, the shape and the shear modulus of a small anomaly with elastic parameters different from the background ones using internal displacement measurements. (joint work with H. Ammari, P. Garapon, and H. Kang).

Antonio Leitao (Federal Univ of St Catarina)
Identification of a discontinuous coefficient in semiconductor equations

In this talk we consider inverse problems related to stationary drift-diffusion equations modeling semiconductor devices. In this context we analyze several identification problems corresponding to different types of measurements, where the parameter to be reconstructed is an inhomogeneity in the PDE model, the so-called em doping profile.

The precise implantation of the doping profile is crucial for the desired performance of semiconductor devices. In many applications, there is substantial interest in replacing expensive laboratory testing by numerical simulation and non-destructive testing, in order to minimize manufacturing costs of semiconductors as well as for quality control. The identification of the doping profile from indirect measurements is called an inverse doping profile problem.

Daniel Lesnic (University of Leeds)
Restoring Boundary Conditions In Heat Conduction

In many physical problems the measurements of the temperature and the heat flux can experience practical difficulties and in some cases the relation between the temperature and the heat flux is unattainable. Physical examples include the measurement of the temperature and heat flux at a highly heated hostile boundary, the difficulty in determination of temperature over the surface of a space vehicle re-entering the atmosphere, etc. This study describes the restoration of boundary conditions in transient heat conduction problems. In the formulation, the boundary conditions are represented by linear relations between the temperature and the heat flux, together with an initial condition of the temperature. Within this context, inverse problems which require finding the spacewise or timewise dependent am- bient temperature appearing in the boundary conditions from additional terminal, integral or point observations at the boundary will be investigated. Analogous inverse problems, however nonlinear, which require finding the spacewise or timewise dependent heat transfer coefficient will also be addressed. Numerical results based on the boundary element method will be presented and discussed.

Shingyu Leung (University of California, Irvine)
Transmission Traveltime Tomography Based on Paraxial Liouville Equations and Level Set Formulations

We propose a new formulation for traveltime tomography based on paraxial Liouville equations and level set formulations. This new formulation allows us to account for multivalued traveltimes and multipathing systematically in the tomography problem. To obtain efficient implementations, we use the adjoint state technique and the method of gradient descent. Starting from some initial guess, we minimize a nonlinear energy functional by a Newton-type method. The required gradient is computed by solving one forward and one adjoint problem of paraxial Liouville equations. Then the velocity model is updated iteratively by solving a Helmholtz equation with the computed gradient as the right-hand side. Numerical examples with and without added noise demonstrate that the new formulation is effective and accurate. To our knowledge this is the first Eulerian approach to taking into account all arrivals systematically in traveltime tomography.

Xiaosheng Li (University of Washington)
Determination of viscosity in the stationary Navier-Stokes equations

In this work we consider the unique determination of the viscosity in an incompressible fluid. Assume that a bounded domain is filled with an incompressible fluid and the velocity vector field satisfies the stationary Navier-Stokes equations with a variable viscosity. We show that the viscosity function can be determined from the knowledge of the boundary data. This is a joint work with J.-N. Wang.

Mikyoung Lim (Ecole Polytechnique)
Reconstructing Small Perturbations of Scatterers from Electric or Acoustic Far-Field Measurements

We consider the problem of determining the boundary perturbations of an object from far-field electric or acoustic measurements. Assuming that the unknown object boundary is a small perturbation of a circle, we develop a linearized relation between the far-field data that result from fixed Dirichlet boundary conditions, entering as parameters, and the shape of the object, entering as variables. This relation is used to find the Fourier coefficients of the perturbation of the shape and makes use of an expansion of the Dirichlet-to-Neumann operator.

Fa-Hsuan Lin (Athinoula A. Martinos Center for Biomedical Imaging)
Optimization of high spatiotemporal resolution brain imaging using combined MEG, MRI, and fMRI

Magnetoencephologhraphy (MEG) is a non-invasive tool to investigate human brain function with a high temporal resolution of milliseconds by measuring neuromagnetic fields. MEG is closely related to electroencephalography (EEG), which measures the electric potential distributions generated by the same sources. MEG is selectively sensitive to source currents that are tangential with respect to the surface of the head whereas EEG detects both the tangential and radial source components. Localization of the sources with these methods is complicated by the non-uniqueness of the electromagnetic inverse problem. To render the solution unique several source models with different constraints have been proposed.

A common MEG source modeling approach is to assume the extent of activation is small and, consequently, the measured fields can be accounted for by modeling the source by a set of equivalent current dipoles (ECDs). If multiple sources are simultaneously active, reliable estimation of the source parameters becomes complicated due to the nonlinear relationship between the source locations and the measured signals. While global optimization algorithms have been tailored to accomplish this task [3], the most feasible solutions combine optimization algorithms with partly heuristic interactive approaches, motivated by prior physiological and anatomical information. In addition, the dipole maybe an oversimplification as a model for spatially extended source activity.

To overcome these difficulties, several distributed current solutions have been proposed. A widely employed distributed source localization approach in MEG is based on the ℓ_2-norm prior, resulting in diffuse minimum-norm estimates (MNE). More focal estimates can be obtained by using an ℓ_1-norm prior; the corresponding minimum-norm solution is often called the minimum-current estimate (MCE). Nevertheless, distributed source modeling is challenging in terms of optimizing parameters for source estimation. Specifically, anatomical information from high resolution MRI can be used to constraint the source localization with improved accuracy. The biases of distributed source modeling toward superficial source locations (close to the MEG sensors) can be potentially alleviated using appropriate depth weighting. We also investigate the cross-talk/point-spread function of the MEG inverse determined by a regularization parameter, which is usually related to signal-to-noise ratio (SNR). Furthermore, we extend the incorporation of functional MRI weighting to spectral analysis in order to improve the spatial localization accuracy of oscillatory activity recorded by MEG.

Dirk Lorenz (University of Bremen)
On the convergence speed of iterative methods for linear inverse problems with sparsity constraints

In this talk we report on different iterative algorithms for the minimization of Tikhonov type functionals which involve sparsity constraints in form of ℓ^p-penalties.

One part is devoted to generalized gradient methods and their connection the well known iterative shrinkage methods. We establish convergence rates of $O(n^{-1/2})$ and $O(\lambda^n)$ for $p = 1$ and $1 < p \leq 2$ respectively.

Another part shows the applicability of semismooth Newton methods to the non-smooth problem with $p = 1$. This results in a locally superlinear convergent algorithm.

Numerical experiments are given and illustrate the established convergence rates.

Ignace Loris (Vrije Universiteit Brussel)
Tomographic inverson with wavelets and ℓ_1-norm penalization

We propose the use of ℓ_1 regularization in a wavelet basis for the solution of linearized seismic tomography problems $Am = d$, allowing for the possibility of sharp discontinuities superimposed on a smoothly varying background. An iterative method is used to find a sparse solution m that contains no more fine-scale structure than is necessary to fit the data d to within its assigned errors. We also discuss possible ways to accelerate the convergence of this algorithm.

Alfred K. Louis (Saarland University)
Dynamic Inverse Problems: Efficient Algorithms and Approximate Inverse

We consider dynamic problems, where the investigated object is allowed to change during the measurement. Hence we regularize both the spatial and the temporal behaviour of the solution. In a first step we show how two different regularization terms can be coupled in a Tikhonov regularization approach such that an efficient solution for underdetermined problems is possible. Especially we consider temporal smoothness of the object. We apply the results to tomography problems and to current density reconstructions.

Finally we study this approach as special case of the approximate inverse regularization method.

Russell Luke (University of Delaware)
A MUSIC Algorithm for Crack Identification

We develop a sampling method for the inverse scattering of time-harmonic plane waves by open arcs. We use the characterization of the scatterer in terms of the spectral data of the scattering matrix to construct a MUSIC-type indicator function for the location of the open arc. The methodology is analogous to recent results for scattering from bounded obstacles with Dirichlet boundary conditions. Numerical examples show that the method is feasible and yields a fast visualization technique for the unknown arc. The method can be interpreted in terms of the construction of fields that do not scatter from the arcs, which opens the door to the design of wavefronts that avoid certain known features while targeting others.

Russell Luke (University of Delaware)
On the Construction of Nonscattering Fields

There are many methods for identifying the shape and location of scatterers from far field data. We take the view that the connections between algorithms are more illuminating than their differences, particularly with regard to the Linear Sampling and Factorization Methods, the Point Source Method and the MUSIC algorithm. Using the first two techniques we show that, for a scatterer with Dirichlet boundary conditions, there is a nontrivial incident field that does not generate a scattered field. This incident field, written as an expansion of eigenfunctions of the far field operator, is used in the MUSIC algorithm to image the shape and location of the obstacle as those points z where the incident field is orthogonal to the far field pattern due to a point source located at z. This has two intriguing applications, one for inverse scattering and the other for signal design. Numerical examples demonstrate these ideas.

Dariusz Madej (Motorola)
Inverse problems in bar code decoding

The presentation paper addresses inverse problems relative to bar code decoding. Deblurring and de-noising of a bi-level signal yielded by scanning 1-D bar codes by a flying-spot laser scanner poses an ill-defined problem, yet it is fundamental to increasing reading performance of a scanner and to advances in device miniaturization. Three different approaches will be discussed, all of which rely on a-priori knowledge based heuristic models; in particular methods using HMM and wavelet maxima for de-noising, and edge interaction model for de-blurring. Such approach will be compared to a L2 norm minimization approach suggested by Santosa and Esodoglu. Decoding 2D bar codes scanned by an imaging scanner presents different set of obstacles. We will focus on a challenge posed by a low resolution of imaging sensor resulting in bar code image were few pixels (less than 2) represent a bar code element; this is related to "super resolution". Decoding bar code placed in curved surface is yet another challenge is. Both problems may be solved by finding a proper mapping between image and 2D matrix representing ideal bar code.

Benny Malengier (Ghent University)

Inverse determination of interdiffusion coefficients in Si-Al-Fe alloys

Diffusion of silicon and aluminium in steel in an important topic in electrical steels. In a macro-model approach, the relevant diffusion equations are , with $i = 1$ (Si), 2 (Al),

$$\frac{\partial C_i^3(x,t)}{\partial t} = \frac{\partial}{\partial x}\left(D_{i1}^3 \left(C_1^3, C_2^3\right) \frac{\partial C_1^3(x,t)}{\partial x} + D_{i2}^3 \left(C_1^3, C_2^3\right) \frac{\partial C_2^3(x,t)}{\partial x} \right),$$

where $0 \le x \le L$, $0 \le t < \infty$, and the superscript 3 indicates the dependent element (Fe). Appropriate boundary conditions are imposed.

We show how to determine practically the four interdiffusion coefficients D_{ij}^3, $i, j = 1, 2$, from experimental measurements of concentration profiles at discrete timesteps, thus avoiding separate interdiffusion determining experiments. An unbiased approach is chosen, comparing a Levenberg-Marquardt type of approach with a costate (adjoint) approach.

Fabio Marcuzzi (Universit di Padova)
Efficient reconstruction of corrosion profiles by infrared thermography

Pulsed Infrared Thermography becomes practical in detecting hidden corrosion in those cases where induced temperature signals are high enough, even if they exist for short periods of time. The principle of operation is based on analyzing spatial-temporal phenomena which occur in corroded sites subjected to stimulated heat diffusion.

The 1D approach assumes that transient thermal events occur independently in sound and defect areas, therefore, defects are to be very large so that the boundary heat diffusion effect can be neglected in the defect center. In such a case an analytical approach is possible. It has been shown [**?**] that the relative material loss (i.e. the ratio between the residual thickness in the corroded spot and the thickness of the defect-free area) is a function of the temperatures over the defect and the sound area.

When dealing with *small defects*, the lateral heat diffusion is no longer negligible and must be taken into account (2D and 3D cases). In this talk we consider a Finite Element model embedded in a parameter estimation procedure to solve the inverse heat transfer problem. In the numerical model, the corrosion profile is approximated by a function T_θ, piecewise constant, with subdivision step h_θ. We consider particularly situations in which the corrosion profile may have high gradients, as it happens e.g. in problems where there is a localized deep corrosion. It is important to be able to estimate the local depth of the corrosion. It turns out that to represent the corrosion profile accurately by a piecewise-constant approximation it is necessary to use an h_θ quite small, at least locally. Without substantial limitations in the approach, we will consider a 2D model problem. Indeed, in presence of an heating source of radius $R >> h_\theta$, the response due to the corrosion at a subinterval of T_θ tends to overlap with neighboring responses The ill-conditioning of the estimation problem grows when h_θ diminishes, and becomes critical for the profiles here considered. In this case, it is not possible to leave out some parameters from the estimation process, since there is no a-priori distinction upon their relative importance. Nor it is surely convenient to add a regularization term in the problem formulation, since the only possible a-priori estimates for the parameters value is zero. Instead, we propose to embed a principal component analysis in the estimation algorithm.

A second issue arise because a small uniform h_θ corresponds to a large number N_θ of subintervals and, therefore, of parameters for the estimation problem. This fact brings at prohibitive computing times for a real-time diagnostic instrument, especially in a 3D problem setting. We propose an adaptive subdivison of the profile, based on indicators obtained after iterative comparisons between the experimental measurements and model predictions, i.e. *a-posteriori*. Such indicators can be obtained from the residuals given by the Kalman Filter. This is often used in statistical *fault detection* algorithms precisely for this purpose. The distributed nature of the parameters and of the state-variables in the reference FEM model used in the Kalman Filter make it possible to locally subdivide T_θ according to the indicators.

We show some results obtained from laboratory experiments with metal samples.

Youssef Marzouk (Sandia National Laboratories)
Dimensionality reduction and polynomial chaos acceleration of Bayesian inverse problems

The Bayesian approach to inverse problems provides a foundation for inference from noisy data and uncertain forward models, a natural mechanism for regularization in the form of prior information, and a quantitative assessment of uncertainty in the inverse solution. With computationally intensive forward models such as PDEs, however, the cost of repeated likelihood evaluations may render a Bayesian approach prohibitive. This problem is compounded by high dimensionality, as when the unknown is a spatiotemporal field. We address these difficulties in the case of Gaussian process priors: first, by using a Karhunen-Lo‘ve (KL) expansion to express the inverse solution as a joint distribution over the KL mode strengths; then by using a Galerkin/polynomial chaos construction to efficiently propagate prior uncertainty through the forward model. The result is a lower-dimensional surrogate posterior which may be explored at negligible cost. We demonstrate this approach on transient diffusion equations with unknown inhomogeneous diffusivities.

Anna Maria Massone (CNR-INFM)
Imaging Spectroscopy of hard x-ray sources in solar flares using regularized analysis of source visibilities

A new method for the reconstruction of electron maps at different energies from X-ray solar data is described. The method is based on the analysis of visibilities, which are samples of the Fourier transform of the flux source in the Sun and which have been first introduced in the processing of radio-astronomical data. In this approach a regularized inversion for the synthesis of electron visibility spectra is applied and imaging techniques are utilized for the reconstruction of two-dimensional electron flux maps. The effectiveness of the method is shown in the analysis of X-ray data detected by the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI), launched by NASA in 2002 with the specific intent of investigating the physical processes occuring during solar flares.

Anna L Mazzucato (Pennsylvania State University)
On uniqueness in the boundary inverse problem for anisotropic elastodynamics

We study the unique determination of material parameters in anisotropic elastic media from dynamic displacement-traction measurements made at the boundary. We consider in particular transversely isotropic media with ellipsoidal slowness surfaces.

Maeve McCarthy (Murray State University)
Parameter Identification in a Parabolic System Modeling Chemotaxis

Chemotaxis is the process by which cells aggregate under the force of a chemical attractant. The cell and chemoattractant concentrations are governed by a coupled system of parabolic partial differential equations. We establish identifiability of the nonlinear chemotactic parameter. A least-squares approach with Tikhonov regularization is used to find the chemotactic parameter. Numerical results are presented.

Joyce McLaughlin (Rensselaer Polytechnic Institute)
Imaging Shear Stiffness in Tissue from Dynamic Wave Propagation Data

We discuss crawling wave sonoelasticity (experiments by K. Parker at the University of Rochester), supersonic imaging (experiments by M. Fink at ESPCI in Paris) and Magnetic Resonance Elastography (experiments by D. Ehman at Mayo Clinic), the algorithms we develop and images we create for the identification of cancerous inclusions.

Valdemar Melicher (Ghent University)
Source identification in low-frequency electromagnetism

We analyze a source identification problem for the steady-state Maxwell's equation

$$\beta \mathbf{E} + \nabla \times (\mu^{-1} \nabla \times \mathbf{E}) = \mathbf{J} in \Omega,$$

where β is a time-scaled conductivity, $\mathbf{E}$ stands for the electric field and $\mathbf{J}$ is the unknown source term. The tangential components of the magnetic and the electric field are measured on the boundary of the Lipschitz polyhedron Ω. We have to deal with a low-regularity of Maxwell's system for such a domain. A primal-dual approach is employed to tackle the problem.

Ivan Mizera (University of Alberta)
Regularized estimation of probability density: likelihoods, penalties, and algorithms

We review the evolution of regularization approaches to probability density estimation—starting from classical formulations involving penalized maximum likelihood in conjunction with L^2 penalties, later modified to shaped-constrained prescriptions and proposals with L^1, total-variation based penalties, and most recently to dual formulations, leading to alternative likelihood concepts in connection with maximum entropy/minimum divergence paradigm. We discuss various aspects regarding this intriguing array of new possibilities: computational aspects (using achievements of contemporary mathematical programming), multidimensional potential, and flexibility in various applied contexts—in particular in estimating probability densities under shape constraints.

Joint work with Roger Koenker.

Shahram Mohanna (The University of Sistan and Baluchestan)
Critical ill-posed problems in Three-Dimensional Electrical Impedance Tomography (3D EIT) of vessels that have a metallic structure

The difficulties of solving forward and inverse problems in conducting boundary domains would be explored. In such applications, the metal wall measurement strategy is employed. This technique uses the three-terminal measuring method, in which the tomography measurements are taken with reference to the grounded wall of the vessel. This creates two problems; firstly, the boundary voltage measurements taken from the farthest electrodes are very low. Secondly, the small nodal potentials across the entire domain cause a significant decrease in the sensitivity of the tomography system with respect to conductivity changes. Therefore, 3D EIT image reconstruction problem would be critically ill-posed.

Shari Moskow (University of Florida)
Scattering and resonances of thin dielectric structures

In this work we consider both wave scattering and the computation of resonance values of a thin structure with large refraction index. The Helmholtz equation with a variable coefficient models the wave phenomena. The scatterer is assumed to have a high (possibly periodic) index of refraction while at the same time it is very small in one of the dimensions. We show that if the index scales as $O(1/h)$, where h is the thickness of the scatterer, then approximate solutions, based on perturbation analysis can be obtained. For the scattering problem the approximate solution consists of a leading order term plus a corrector, each of which solves an integral equation in two dimensions for a three dimensional problem. We provide error analysis on the approximation. The approximate method can be viewed as an efficient computational approach since it can potentially greatly simplify scattering calculations. For the resonance problem, we examine the perturbation approach as a means to calculate resonance modes. Applications in mind are for the modeling and optimal design of photonic bad gap materials.

David Moulton (Los Alamos National Laboratory)
Multilevel approximations in sample-based inversion from the Dirichlet-to-Neumann map.

In 2005, Christen and Fox introduced a delayed acceptance Metropolis-Hastings (DAMH) algorithm that improved computational efficiency in sample-based imaging of electrical conductivity (EIT). This work used a linear approximation to the forward map in the first step of the algorithm. In this paper, we develop an alternative approximation for use in DAMH, namely a multilevel approximation developed from the hierarchy of coarse-scale models obtained by variational coarsening. This approach builds on two important strengths of robust multigrid solvers. First, the cost of a fine-scale solution of the forward map scales linearly with the degrees of freedom, and hence, it is provides better efficiency for algorithms performing sample-based inference. Second, the homogenization implicit in robust variational multigrid methods gives better solutions at coarse scales than homogenization by averaging of coefficients. We report results from a stylized example in electrical impedance imaging where data is a noisy and incomplete measurement of the Dirichlet-to-Neumann map.

Jennifer Mueller (Colorado State University)
Reconstructions of experimental and simulated discontinuous conductivities by the D-bar method for EIT

In this talk the theoretical implications of applying the D-bar algorithm based on A. Nachman's constructive uniqueness proof for the inverse conductivity problem [Ann. of Math. 143, 1996]) to nonsmooth conductivity distributions will be explained, and aspects of numerical implementation will be presented. Reconstructions of human and simulated data will be displayed. Furthermore, a connection between the D-bar method and Calderon's linearization method will be revealed.

Axel Munk (Georg-August Universität Göttingen)
Large Jump Estimation in Inverse Problems - Distributional Results

We adress the problem of estimating a jump function in the context of an inverse regression problem $Y_i = Kf(x_i) + \epsilon_i$, $i = 1, \cdots, n$, where K is a known (linear) integral operator and $f : [0,1] \longrightarrow \mathbb{R}$ is the unknown function to be estimated. The x_i are (regular, possib ly random) design points. It turns out that here a $\sqrt{n}$-rate of convergence is generic and minimax, provided the kernel of K is bounded and continuous. In fact, the jump locations together with the jump sizes are asymptotically multivariate normal. To this end we require an identifiabilty condition related to the theory of radial basis functions on the kernel K, which turns out to be crucial for recovering jump functions in nosiy inverse problems.

Asymptotic normality can be used to construct confidence bands for jump functions or for a piecewise linear regression function in multiphase regression.

We stress that our analysis for jump spaces is completely different to the situation where the underlying function space is of some smoothing type, such as a Sobolev space, where the spectral behaviour of K determines the asymptotics [**?**]. We show that for jump spaces the localisation behaviour of the kernel determines the rate of convergence, rather than the spectral behaviour. In this sense a bounded integral kernel is most difficult. We obtain, e.g. for singular kernels with decay of the singularity of the order $|x|^{-\alpha}$, $\alpha \in [1/2, 1)$ the minimax rate (which is attained by the *Jplse*) as $n^{-1/\min(2,(3-2\alpha))}$.

Motivated by a problem from material science, we extend this to estimation problems with certain nonlinear operators. More specifically we show similar results for the class of generalized Hammerstein equations of the type

$$K_\varphi(f)(\cdot) \quad = \quad \int K(x,\cdot)\varphi \circ f(x)dx,$$

for some φ injective, C^1. It is an open and challenging problem how general nonlinear problems can be treated.

James Nagy (Emory University)
Numerical Methods for Coupled Super-Resolution

The process of combining, via mathematical software tools, a set of low resolution images into a single high resolution image is often referred to as super-resolution. Algorithms for super-resolution involve two key steps: registration and reconstruction. Most approaches decouple these steps, solving each independently. This can be effective if there are very simple, linear displacements between the low resolution images. However, for more complex, nonlinear, nonuniform transformations, estimating the displacements can be very difficult, leading to severe inaccuracies in the reconstructed high resolution image. In this talk we present a mathematical framework and optimization algorithms that can be used to jointly estimate these quantities. Efficient implementation details are considered, and numerical experiments are provided to illustrate the effectiveness of our approach.

This is joint work with Julianne Chung and Eldad Haber.

Andreas Neubauer (University of Linz)
Solution of Ill-Posed Problems via Adaptive Grid Regularization

When studying (linear or nonlinear) ill-posed problems

$$F(x) = y, \qquad F : D(F)(\subset X) \to Y,$$

where usually only noisy measurements y^δ of y with $\|y^\delta - y\| \leq \delta$ are given, Y is a Hilbert space and X, is a Banach space, it is well known by now that standard regularization methods are not appropriate for ill-posed problems with discontinuous solutions, since they have a smoothing effect on regularized solutions.

If one expects discontinuous solutions, special care has to be taken in choosing the regularization method. Bounded variation regularization has turned out to be an effective method when dealing with such problems. An other approach is regularization for graph and surface representations. Based on these ideas, the author recently developed a new method, namely *adaptive grid regularization*, an iterative method, where local grid refinement techniques are combined with adaption of the regularizing norm after each iteration.

The method has already been successfully applied to linear integral equations in 1D and 2D as well as to 1D parameter estimation problems. The numerical results show that this method is an efficient and fast tool to identify discontinuities of solutions of ill-posed problems.

In this talk, we present a convergence analysis for the adaptive grid regularization method combined with Tikhonov regularization and new numerical results for the problem of identifying a temperature dependent heat conductivity from a single boundary measurement:

$$-\mathrm{div}(a(u)\nabla u) = f \text{ in } \Omega$$

$$a(u)\frac{\partial u}{\partial n} = h \text{ on } \Gamma = \partial\Omega$$

Here Ω is an open bounded convex subset of $\mathbb{R}^d$ $(d = 1, 2, 3)$ with Lipschitz boundary Γ, $f \in L^2(\Omega), h \in L^2(\Gamma)$, and the parameter a satisfies the conditions

$$0 < \underline{a} < a < \bar{a} < \infty \text{ and}$$

a is continuous in all but at most countably many points.

Frederic Noo (University of Utah)
Two-dimensional SPECT imaging with truncated projections

This work investigates extensions to SPECT of results that have been recently published for the inversion of the Radon transform from incomplete (truncated) projections. We assume that the activity function to be reconstructed lies in a convex region of uniform attenuation, so that the SPECT data may be described using the exponential Radon transform. Under this assumption, we first present a new unicity theorem based on the concept of differentiated-backprojection and Plemelj's formula for Hilbert transforms. Of course, this unicity theorem is of limited use in practice because unicity does not imply stability, i.e., unicity does not imply accurate reconstruction can be achieved from real data. However, using our theory, we are also able to discuss stability in a particular geometry. More specically, we will present a method that allows accurate reconstruction of some regions-of-interest from truncated SPECT projections. Our results are signicant for

SPECT imaging, as they could allow more accurate reconstruction by focussing the data acquisition on the rays that are most relevant for the region-of-interest.

Assad Oberai (Rensselaer Polytechnic Institute)
Nonlinear Elasticity Imaging

Mechanical properties of soft tissue can change with tissue pathology. For example, it is observed that the elastic (shear) modulus of malignant breast masses is typically an order of magnitude higher than the background of normal soft tissue. In addition with increasing applied strain their stiffness increases more rapidly than the background.

Elasticity imaging makes use of conventional imaging techniques such as ultrasound imaging, MRI and PET to generate images of mechanical properties. This is made possible by (1) imaging the tissue with a conventional imaging technique in an undeformed state, (2) deforming the tissue and imaging it once again, (3) registering the underformed and deformed images to estimate the displacement field and (4) reconstructing the spatial variation of mechanical properties from the displacement field by assuming an appropriate mechanical model and then evaluating the parameters in this model by solving an inverse problem.

In this talk I will describe a new algorithm for solving the inverse elasticity problem when the tissue is modeled as a hyperelastic material undergoing quasi-static finite deformation. The problem is posed as the minimization of a cost function representing the difference between the measured and predicted displacement fields. The cost function is minimized with respect to the spatial distribution of material properties using a gradient based optimization approach. The gradient is calculated efficiently using the adjoint method and a continuation strategy in the material properties.

I will present numerical examples (1) with synthetic data that demonstrate the feasibility and efficiency of the proposed algorithm, and (2) with clinical data the demonstrate its usefulness in the diagnosis of breast cancer.

Rossana Occhipinti (Case Western Reserve University)
Bayesian Model Selection for Brain Metabolism

The inverse problem of estimating metabolic fluxes for brain metabolism is important, among other things, to test the validity of different hypotheses that have been proposed in the literature. The question of how the neuron is supported during neural activity has recently received a lot of attention and two main hypotheses have emerged. The classical hypothesis supports the primacy of glucose as main fuel for active neurons while the astrocyte-neuron lactate shuttle hypothesis (ANLSH) supports the lactate as preferred substrate by neurons. In this talk we will describe a five compartment model of brain metabolism which considers, in addition to the blood compartment, the cytosol and mitochondria of both astrocyte and neuron, including detailed metabolic pathways. We use a recently developed methodology to perform flux balance analysis (FBA) and to test whether one of these hypotheses is more in agreement with measured data. We recast the estimation problem in the form of Bayesian statistical inference and by a Markov Chain Monte Carlo (MCMC) sampling method we estimate simultaneously all the reaction fluxes and transport rates at steady state, under different levels of neural activity. The analysis of the histograms of the posterior distributions provides a useful tool for assessing the validity of different hypotheses and to detect preferred metabolic pathways that are in agrement with experimental data.

Xiaochuan Pan (University of Chicago)
Image Reconstruction in Diffraction Tomography

Diffraction tomography (DT) is an imaging modality that can be viewed as a generalization of X-ray computed tomography for use with diffracting wavefields. In DT, a probing wavefield such as an ultrasound or coherent x-ray wavefield, illuminates an ob ject, and the scattered wavefield is measured. From the measured wavefield data, one seeks to reconstruct an image that depicts the spatial distribu- tion of the object's complex-valued refractive index. In this talk, the imaging models of DT will be described under different physical conditions. Based-upon the imaging models, examples of DT-image reconstruction will be discussed. In particular, the discussion will focus on how to develop (numerically) stable algorithms, how to exploit data redundancy for controlling image noise, and how to reconstruct images from reduced-scan data. It is not uncommon that only sparsely sampled DT data are available in practice. Therefore, it is of practical merit to investigate accurate image reconstruction from sparse DT data. This talk will also briefly cover some recent results on image reconstruction from highly sparse DT data.

Sergiy Pereverzyev (Johann Radon Institute for Computational and Applied Mathematics (RICAM), Austrian Academy of Sciences)
Adaptive Regularization Algorithms In Learning Theory

We investigate the problem of an adaptive parameter choice for regularization learning algorithms. In the theory of ill-posed problems there is a long history of choosing regularization parameters in optimal way without a priori knowledge of a smoothness of the element of interest. But known parameter choice rules cannot be applied directly in Learning Theory. The point is that these rules are based on the estimation of the stability of regularization algorithms measured in the norm of the space where unknown element of interest should be recovered. But in the context of Learning Theory this norm is determined by an unknown probability measure, and is not accessible. In the talk we are going to present a new parameter choice strategy consisting in adaptive regularization performed simultaneously in a Hypothesis space and in a space equipped with an empirical norm. Both these spaces are accessible and a new parameter choice rule called the balancing principle can be used there. Then a parameter for the regularization in the inaccessible space is chosen as the minimal among the parameters selected for above mentioned accessible spaces. We prove that under rather mild assumptions such strategy guarantees an optimal order of the risk. Our analysis covers the capacity independent learning algorithms, but some capacity dependent results can be also obtained in a similar way.

Sergiy Pereverzyev (Junior) (Technische Universitt Kaiserslautern)
Approximate Solution of Nonlinear Inverse Problems by Fixed-Point Iteration

Nonlinear inverse problems, represented by the operator equations, are usually approximately solved by the Newton method that requires Frechet derivative of the forward operator. The frequent disadvantage of this method is difficult construction of the derivative and its expensive evaluation. In this talk we present the iterative scheme based on rewriting the operator equation as a fixed-point equation. In such a scheme only evaluation of the forward operator is required. We study behavior of the scheme for noisy data and propose two stopping strategies. For illustration we use an inverse problem appearing in spectral pyrometry.

Michele Piana (Universita di Verona)
A new formulation of the linear sampling method: spatial resolution and post-processing

A new formulation of the linear sampling method is described, which requires the regularized solution of a single functional equation set in the direct sum of L^2 spaces. This new approach presents the following notable advantages: it is computationally more effective than the traditional implementation, since time consuming samplings of the Tikhonov minimum problem and of the generalized discrepancy equation are avoided; it allows a quantitative estimate of the spatial resolution achievable by the method; it facilitates a post-processing procedure for the optimal selection of the scatterer profile by means of edge-detection techniques. The formulation is described in a two-dimensional framework and in the case of obstacle scattering although generalizations to three dimensions and penetrable inhomogeneities are straightforward.

Mark Pickering (University of New South Wales)
Robust Super-Resolution Mosaicing of Compressed Images

Image mosaicing is the process of increasing the visual field of view of a camera by combining several partial views of a scene into a single broad view. The term super-resolution imaging is often used to describe the fusion of multiple low-resolution images to produce a single high-resolution image. The combination of image mosaicing and super-resolution imaging, i.e. super-resolution mosaicing, is a powerful means of representing all the information of multiple overlapping images to obtain a high resolution broad view of a scene. In most current image acquisition systems, images are routinely compressed prior to transmission and storage. In this talk, we present a robust super-resolution mosaicing algorithm which can be applied to compressed images. The algorithm operates on the quantized transform coefficients available in the compressed bitstream so that super-resolution reconstruction can be implemented directly in the transform domain.

Martin Pieper (Institute for Mumerical an Applied Mathematics)
Nonlinear integral equations for an inverse electromagnetic scattering problem

In 2005, Kress and Rundell developed a new method to solve an inverse boundary value problem for Laplace equation. They showed, that the inverse problem is equivalent to a system of nonlinear integral equations, which is solved iteratively. This idea was carried over to inverse acoustic scattering problems by Ivanyshyn and Kress. With some modifications, the main parts of their work can be used to show, that the inverse electromagnetic scattering problem is also equivalent to a system of nonlinear integral equations. Avoiding the usage of the hypersingular electric dipole operator leads to a system of two equations. The first one is the well posed magnetic field equation, whereas the second one is severely ill posed. In the talk, after presenting the main parts of the equivalence proof, we show in detail how to solve iteratively the corresponding system of integral equations: With an initial guess to the boundary, we first solve the magnetic field equation for the unknown density. For this, we have developed a spectral method, which is based on Wienert's and Graham and Sloan's work on acoustic scattering. After that we solve a linearised version of the second equation to get a new approximation to the unknown scatterer and iterate this procedure.

Edward Pike (King's College)
An update of Hopkins analysis of the optical disc player using singular system theory

In this paper we describe a new approach to the analysis of scanning optical imaging systems which uses singular function expansions, rather than Fourier optics, to update the well-known low-aperture treatment of Hopkins of 1974 for arbitrary numerical apertures. This new approach can also be used to update the widely used theory of optical transfer functions for general imaging systems.

Hanna Katriina Pikkarainen (Austrian Academy of Sciences)
State estimation approach to nonstationary inverse problems

We examine nonstationary inverse problems in which the time evolution of the unknown quantity is modelled by a stochastic partial differential equation. We consider the problem as a state estimation problem. The time discrete state evolution equation is exact since the solution is given by an analytic semigroup. For the practical reasons the space discretization of the time discrete state estimation system must be performed. However, space discretization causes an error and inverse problems are known to be very intolerant to both measurement errors and errors in models. We analyse the discretization error so that the statistics of the discretization error can be taken into account in the estimation. We are interested in the related filtering problem. A suitable filtering method is presented. We also verify the method using numerical simulation.

Vittorio Pizzella (University of Chieti)
Integrating MEG/EEG with fMRI

The possibility of integrating functional data from magnetoencephalografic (MEG) measurements and functional Magnetic Resonance Imaging (fMRI) offers new insight on brain organization. In fact, MEG and fMRI integration can provide accurate identification of active brain areas as well as a precise identification of the timing of brain response. Recently our group has performed a series of experiments with the aim at characterizing the functional organization of the human somatosensory system (SSS) with respect to selective electric stimulation of different body districts (somatotopy), as well as to painful vs. non-painful stimulation. A combined MEG and fMRI approach yielded interesting results which permitted to identify a specific somatotopic organization not only in the primary and secondary cortices, but also in other cortical areas, such as anterior cyngulate and SMA. Additionally, a clear differentiation of SII with respect to painful vs. non-painful stimulation was observed, although the area activated by painful stimuli did not feature somatotopy. Another study aimed at understanding how the human brain reacts to sounds coming from different spatial directions and the hierarchical processes involved in this analysis.

Olivier Poisson (latp, universite de Provence)
Uniqueness for discontinuous coefficients in an inverse problem for the heat equation

Let $\subset^n$ be a bounded connected open set that satisfies a natural geometric condition. Let $_0$ and $_1$ be two non-empty open subsets of such that $_0 \subset\subset$ and $_1 = \setminus\bar{}_0$. We denote by $S = \bar{}_0 \cap \bar{}_1$ the interface. We consider the heat equation with a discontinuous diffusion coefficient c at the interface S:

$$\begin{aligned} \partial_t y - \nabla \cdot (c \nabla y) &= 0 && \text{in } (0,T)\times \\ y(t,x) &= h(t,x) && \text{in } (0,T)\times\delta \\ y(0,x) &= y_0 && \text{in} \end{aligned}$$

We assume that the diffusion coefficient c is smooth in each domain $_j$ and that we can measure both the normal flux $\partial_n \partial_t y$ on $\gamma \subset \partial$ on the time interval (t_0, T) and y in at time $T' \in (t_0, T)$.

But we do not know the interface S which is an unknown in this inverse problem.

We shall prove uniqueness for S and the diffusion coefficient c with only one given boundary condition.

Oleg Poliannikov (Massachusetts Institute of Technology)
Focusing of time reversed random coda

In this talk, we consider a problem of refocusing of acoustic energy on a passive target. This is important in applications such as noninvasive destruction of a kidney stone located inside a patient. We show that a standard solution that involves illumination of the target with a pulse followed by back-propagation of the coherent reflection does not result in tight refocusing. We propose instead to make use of the super-resolution property of acoustic time reversal in a random medium by placing a patient on a layered medium, activating the target with a pulse and back-propagating the random reflections generated by the layered medium. This process results in refocusing of energy on the target with a resolution superior to that of the back-propagated front. We present a theoretical setup and numerical simulations in support of the proposed method.

Amyn Poonawala (University of California, Santa Cruz)
Mask Design for Resolution Enhancement: An Inverse Problem in Optical Microlithography

Optical microlithography, a technique similar to photographic printing, is used for transferring circuit patterns onto silicon wafers. The above process introduces distortions arising from optical limits and non-linear resist effects, leading to poor pattern fidelity and yield loss. The input to the above system is a photo-mask (or reticle), which can be controlled (or engineered) such that it cancels out (or compensates for) the process losses to come. This forms the basis of optical proximity correction (OPC) and phase shift masks (PSM), two commonly employed resolution enhancement techniques (RETs) for patterning very small features (close to the optical limit). In this talk, we discuss a novel inverse lithography technology (ILT) framework to synthesize OPC and PSM for high-fidelity patterning of random logic 2-D features. ILT attempts to synthesize the input mask which leads to the desired output wafer pattern by inverting the mathematical forward model from mask to wafer. Our framework employs a pixel-based mask parameterization, continuous function formulation, and analytic gradient-based optimization techniques to synthesize the masks. We also introduce a regularization framework to control the tone and complexity of the synthesized masks, and inculcate other user-defined properties. The results indicate automatic generation and placement of assist bars, which are very popular in the semiconductor industry. We conclude by briefly discussing ILT-based mask design for double exposure lithography systems, which are deemed as key technology enablers for the future.

Roland Potthast (University of Reading)
Wave splitting for multiple obstacle reconstruction

We study wave splitting procedures for acoustic or electromagnetic scattering problems. The idea of these procedures is to split some scattered field into a sum of fields coming from different spatial regions such that this information can be used either for inversion algorithms or for active noise control.

Splitting algorithms can be based on general boundary layer potential representation or Green's representation formula. We will prove the unique decomposition of scattered wave outside the specified reference domain G and the unique decomposition of far-field pattern with respect to different reference domain G. Further, we employ the splitting technique for field reconstruction for a scatterer with two or more separate components, by combining it with the point source method for wave recovery. Using the decomposition of scattered wave as well as its far-field pattern, the wave splitting procedure proposed in this paper gives an efficient way to the computation of scattered wave near the obstacle, from which the multiple obstacles which cause the far-field pattern can be reconstructed separately. This considerably extends the range of the decomposition methods in the area of inverse scattering. Finally, we will provide numerical examples to prove the feasibility of the splitting method.

Roland Potthast (University of Reading)
On the convergence of the no response test

The no response test is a new scheme in inverse problems for partial differential equations which was recently proposed by Luke and the author in the framework of inverse acoustic scattering problems. The main idea of the scheme is to construct special probing waves which are small on some test domain. Then, the response for these waves is constructed. If the response is small, the unknown object is assumed to be a subset of the test domain. The response is constructed from *one*, *several* or *many* particular solution of the problem under consideration.

We investigate the *convergence* of the no response test for the reconstruction information about inclusions D from the Cauchy values of solutions to the Helmholtz equation on an outer surface $\partial\Omega$ with $\overline{D} \subset \Omega$. We show that the one-wave no response test provides a criterion to test the analytic extensibility of a field. In particular, we investigate the construction of approximations for the set of singular points $N(u)$ of the total fields u from one given pair of Cauchy data. Thus, the no response test solves a particular version of the classical *Cauchy problem*. Also, if an infinite number of fields is given, we prove that a *multi-field version* of the no response test reconstructs the unknown inclusion D.

Simon Prince (University College London)
Estimating spatial and temporal factors in optical diffusion tomography

We apply state space estimation techniques to the time-varying reconstruction problem in optical tomography. We develop a stochastic model for describing the evolution of quasi-sinusoidal medical signals such as the heartbeat, assuming these are represented as a known frequency with randomly varying amplitude and phase. We use the extended Kalman filter in combination with spatial regularization techniques to reconstruct images from highly underdetermined time-series data. We also investigate unsupervised learning of spatial correlations using a modified factor analysis model. We present reconstructions of simulated data and of real data recorded from the human motor cortex. It is argued that the application of these spatial and temporal techniques improves the fidelity of reconstruction in optical tomography.

Sampsa Pursiainen (Hensinki University of Technology)
Effective EEG/MEG forward simulation through hp-FEM

Electro/Magnetoencephalography (EEG/MEG) is an non-invasive imaging modality in which a primary current density generated by the neural activity in the brain is to be reconstructed from external electric potential/ magnetic field measurements. This work focuses on effective and accurate simulation of the EEG/MEG forward model through the hp-version of the finite element method (hp-FEM). The goal is to show that the use of the hp-FEM in discretization of the electric potential can lead to better reconstructions as compared to the use of the classical h-FEM. An hp-FEM type forward simulation is described and implemented, and the related implementation issues are discussed. These issues include, for example, generation of sparse finite element meshes for realistic geometries through the use of different element types, and finding appropriate finite element enrichment techniques for specific mesh refinements. Suitable inversion methods to be used in the presence of accurate forward simulation are also considered.

Jianliang Qian (Wichita State University)
An Adjoint State Method For Three-dimensional Transmission Traveltime Tomography Using First-Arrivals

Traditional transmission travel-time tomography hinges on ray tracing techniques. We propose a PDE-based Eulerian approach to travel-time tomography so that we can avoid the cumbersome ray-tracing. We start from the eikonal equation, define a mismatching functional and derive the gradient of the nonlinear functional by an adjoint state method. The resulting forward and adjoint problems can be efficiently solved by using the fast sweeping method; a limited memory BFGS method is used to drive the mismatching functional to zero with quadratic convergence. 2-D, 3-D numerical results and Marmousi synthetic velocity model demonstrate the robustness and the accuracy of the method.

Joe Qranfal (Simon Fraser University)
Regularized Kalman Algorithm For Dynamic Spect Reconstruction

Single photon emission computed tomography (SPECT) is a nuclear medicine imaging technique that is extensively used for clinical diagnosis. Classical SPECT reconstruction algorithms assume that the activity does not vary in time. This is not always true in practice. For instance, when we study Teboroxime cardiac images, the activity changes in time. Thus arises the need of exploring dynamic SPECT. We explore a Kalman reconstruction approach with spatial regularization to estimate the time varying activity. While other methods assume a priori knowledge about the activity behavior, Kalman assumes little. We formulate a state-space model of this ill-posed inverse problem which we solve using the optimal Kalman filter and smoother. Numerical results are provided.

Eric Todd Quinto (Tuffts University)
Local tomography in electron microscopy

Tomographic techniques, in which samples are viewed from multiple directions, are used in electron microscopy. Often, the molecules are all different (rather than copies of one single molecule in different orientations), and one wants to image the individual molecules. Therefore, any algorithm for this problem must reconstruct each molecule independently. The problem is local because the electron beam is only wide enough to penetrate a small part of the object. Furthermore, the data are limited angle since the object cannot be rotated through a full 180°. For these reasons, some data are missing, and inversion is unstable. The author will explain how singularities can be added (similar to the added singularities in cone-beam CT). The author will present a refined local algorithm and reconstructions (pictures) using his algorithm.

Rachell, Lizabeth (Rensselaer Polytechnic University)
Uniqueness of the travel time for any disjoint mode in anistotropic elastic media

We study general anisotropic elastic media that have a disjoint wave mode, that is, elastic media with the property that one sheet of the slowness surface never intersects the others. We extend results from mi crolocal analysis to describe the propagation of singularities for the disjoint mode. Applying these results to the study of the dynamic inverse problem, we show that displacement-traction surface measurements uniquely determine the travel time between boundary points for the disjoint mode. We conclude that two of the five elastic parameters describing transversely isotropic elastodynamics with ellipsoidal slowness s urfaces and a disjoint mode are partially determined by surface measurements. (Joint with Anna Mazzucato.)

James Ralston (UCLA)
Inverse Spectral Problems in Rectangular Domains

This is a report on joint work with Gregory Eskin. We consider the Schrödinger operator $-\Delta + q$ in domains of the form $D = \{x \in R^n : \ 0 \leq x_i \leq a_i, \ i = 1, .., n\}$ with either Dirichlet or Neumann boundary conditions on the faces of D, and study the constraints on q imposed by fixing the spectrum of $-\Delta + q$ with these boundary conditions. We work in the space of potentials, q, which become real-analytic on R^n when they are extended evenly across the coordinate planes and then periodically. Our results have the corollary that there are no continuous isospectral deformations for these operators within that class of potentials when the a_jś are rationally independent.

This work is based on new formulas for the trace of the wave group in this setting. It is an extension of the proof of similar results for periodic boundary conditions (Eskin-Ralston-Trubowitz, CPAM **37**). The wave trace with Dirichlet or Neumann boundary conditions is significantly different from the trace for periodic boundary conditions, but the new terms in the trace "telescopeïn a way which simplifies their contribution to the singularities of the trace. The resulting formulas reveal close relations between these traces and the periodic trace, and they are also make it possible to compute the singularities in the trace in a way that identifies contributions with the underlying geometry. In addition to the inverse spectral results these formulas lead to asymptotic expansions for the traces of the wave and heat kernels on rectangular domains.

Ronny Ramlau (Johann Radon Institute)
Regularization of Inverse Problems using sparsity constraints — Analysis and Applications

In this talk we consider the regularization of nonlinear operator equations $F(x) = y$. Assuming that the solution of the equation has a sparse expansion with respect to a preassigned frame or basis, we want to develop methods that also enforce a sparse reconstruction. This is usually not the case if e.g. Tikhonov regularization with a quadratic Hilbert space penalty term is used. Instead, we propose the use of a weighted ℓ_p norm, which allows for $p < 2$ sparse reconstructions. For $1 \leq p < 2$ we will propose iterative minimization strategies for the minimization of the Tikhonov functional by so called *Surrogate functionals*. We will also provide regularization parameter rules and give convergence and convergence rate results. Finally, some numerical results from medical imaging and for the inpainting problem will be presented.

Maaria Rantala (PaloDEx Group)
Wavelet-based reconstruction for limited angle X-ray tomography

The aim of X-ray tomography is to reconstruct an unknown physical body from a collection of projection images. If the projection images are only available from a limited angle of view, the reconstruction problem is an ill-posed inverse problem. Statistical inversion allows regularized solution of the limited angle tomography problem by complementing the measurement data by a priori information. In this work, the unknown attenuation distribution inside the body is represented as a wavelet expansion, and a Besov space prior distribution together with positivity constraint is used. The wavelet expansion is thresholded to reduce the dimension of the computational problem. Feasibility of the method is demonstrated by numerical examples using in vitro data from dental radiology.

Holger Rauhut (University of Vienna)
Algorithms for inverse problems with joint sparsity constraints

Signals and images can often be well-approximated by sparse representations in terms of a suitable basis or frame, i.e., many coefficients of the expansion vanish. A recent direction in inverse problems uses this preknowledge about the signal (image, function) to be recovered and poses sparsity constraints on the regularized solution. This is modeled by a functional that includes a weighted ℓ_1-norm of the frame coefficients. It was shown by Daubechies, Defrise and DeMol that a minimizer of this functional can be computed by a soft-tresholded Landweber iteration.

The above setting can be generalized to vector-valued functions (signals), where the vector components possess sparse representations with a common sparsity pattern, i.e., the non-zero coefficients are at the same location in each component. A typical example are color images, where each color channel has a sparse representation in terms of wavelets, say, and additionally the relevant coefficients are at the same locations due to common edges in all channels. Such joint sparsity assumptions can be modeled in a functional by using weighted ℓ_1 norms of componentwise ℓ_q norms of frame coefficients. In generalization of the approach by Daubechies, Defrise and DeMol, solutions of linear inverse problems with such joint sparsity regularization constraints can again be computed by soft thresholded Landweber algorithms.

Suitable weights appearing in the weighted ℓ_1-norm can be chosen adaptively by constructing a functional both in the frame coefficients and the weights, which has to be minimized. Hereby, the weights can be interpreted as indicators of the sparsity pattern. The resulting functional has some connections to hard and firm thresholding.

Two algorithms for the minimization of this functional are discussed:

- alternating between a minimization with respect to the frame coefficients and the weights;
- damped hard or firm thresholded Landweber iterations.

Both algorithms converge.
Numerical experiments in color image restoration are presented.

Kui Ren (Columbia University)
Numerical reconstructions with large data sets in optical tomography

One of the major recent advances in optical tomography is the ability to obtain large data set through the use of CCD cameras. Analytical reconstructions in simple geometry show that the use of such large data sets can potentially improve the quality of reconstruction significantly. It is, however, extremely challenging to use such large data sets in most model-based numerical reconstruction algorithms because of the overwhelming computational cost involved.

We will present some numerical reconstruction algorithms that allows us to use extremely large data sets while keeping the computational cost reasonable. The essential idea behind those methods is the efficient usage of fast direct solvers. The methods we will present depend on the forward model chosen for light propagation in tissues. We can deal with both diffusion and transport type of models. Numerical examples with synthetic data will be shown to demonstrate the performance of the methods.

Rosemary Renaut (Arizona State University)
Analysis and Development of Algorithms for Regularization Parameters in the Solution of Linear Parameter Estimation Problems

Solution of the regularized least squares problem for linear parameter estimation requires the use of regularization parameters. Typical approaches for finding an appropriate parameter choice involve methods such as the L-curve and cross-correlation methods. Recently, a new technique was introduced by Mead (2007) in which the weights on the parameter misfits are found by solving an optimization problem, for which it can be shown that the penalty functional follows a χ^2 distribution with n degrees of freedom, where n is the dimension of the data space. Here, our focus is on the impact of the formulation of this optimization problem for determing best possible confidence intervals on the parameter estimates, given the covariance structure on the data. The given optimization problem is reformulated to become more feasible. Experiments to show the validity of the new model, and theoretical results will be presented.

Daniel Renzi (Rensselaer Polytechnic Institute)
Recovering the shear wave speed parameters in an anisotropic medium

In an isotropic medium, one technique for shear wave speed recovery in transient elastography is level set based inversion of arrival times. Using this technique one first finds the arrival times of a shear wave using a cross-correlation procedure, and then determines the shear wave speed by using level sets of the arrival times to solve the inverse Eikonal equation. In many kinds of tissue, especially tissue with fibers like muscle, the wave speed depends quite heavily on direction. The method described above can only find speed orthogonal to the wave front. We will present results on a related technique that uses multiple transient elastography experiments to determine all the parameters that govern the directionally dependant shear wave speed. In this talk, we will use a nearly incompressible transversely anisotropic model. This medium supports two shear waves, the SH wave and the QS wave. We will consider the following inverse problem: Given arrival times of the QS wave calculate the shear wave parameters governing anisotropy. We first show that using only one set of arrival times, there is no unique solution. We then describe a technique using multiple arrival times to calculate the shear wave speed parameters. Next we will describe how we will use this with supersonic imaging experiments devised by experimenters in the laboratory of Mathias Fink. Last, we will give reconstruction examples using synthetic data in 2 and 3 dimensions.

Jorge Ripoll (FORTH)
Challenges and Applications of Optical Tomography in Microscopy

Very recently, optical tomography setups for microscopy are being developed to image low scattering specimens, mainly triggered by the work of J. Sharpe et al (Science 2002). These setups offer many advantages over traditional 2D microscopy allowing 3D visualization of both fluorescence and absorption endogenous or exogenous contrast. However, several new challenges in the inverse problem appear when using such setups, mainly due to the change of position within the focal plane while rotating, and the point source-like emission of fluorophores. In this talk these new challenges will be analyzed and results in-vivo presented, outlining its potential as a quantitative in-vivo microscopy technique.

Fernando Alves Rochinha (Federal University of Rio de Janeiro)
Total Variation Regularization Applied To Damage Identificaton

It is needless to emphasize the importance of damage detection techniques and health monitoring in aerospace, civil and mechanical engineering. It is essential to determine the safety and reliability of their systems and structures. Based on experimental modal analysis and signal processing techniques, monitoring and interpreting changes on structural dynamic measurements can be considered as a quite promising approach for damage identification and health monitoring. Here, a time domain damage identification method, combining a continuum damage modeling and an optimal control formulation is introduced. It builds on the same damage parameterization that has been used before by the authors and it can be also considered a model updating, but represents a non-modal detection technique.It is assumed that there is set of experimental data available, probably noisy, which can be used as the basic information for the estimation of the parameters . The idea is to minimize a suitable error function which consists of the norm of the difference between the measured data and the data obtained from the system model for the same input excitation. Due to the presence of noise and the ill-posedeness of the proposed formulation, a regularized formulation is required. Here, due to the existence of sharp gradients in the vicinity of damaged regions, Total Variation regularization is adopted.

Luca Rondi (Università degli Studi di Trieste)
Stability and instability for the determination of unknown isothermal surfaces

We consider the stability issue for an inverse parabolic problem arising from nondestructive evaluation by thermal imaging. We wish to determine an unknown portion of the boundary of a thermic conducting body by prescribing initial and boundary values of the temperature and by measuring the corresponding thermal flux on an accessible and known portion of the boundary. The unknown part of the boundary to be determined is assumed to be an isothermal surface.

We characterize the stability of this problem by coupling stability results with an instability analysis. Relationships with essentially optimal temperature profiles to be prescribed at the boundary might also be discussed.

This is joint work with Michele Di Cristo and Sergio Vessella.

Luca Rondi (Università degli Studi di Trieste)
Stable determination of polyhedra by a single far-field measurement

We discuss optimal stability estimates for the determination of a finite number of sound-soft polyhedral scatterers in $\mathbb{R}^3$ by a single far-field measurement. The admissible multiple polyhedral scatterers satisfy minimal a priori assumptions of Lipschitz type and may include at the same time obstacles, screens and even more complicated scatterers. We characterize any multiple polyhedral scatterer by a size parameter h which is related to the minimal size of the cells of its boundary.

We present two different kinds of results. First, we show that, provided the error ε on the far-field measurement is small enough with respect to h, then the corresponding error, in the Hausdorff distance, on the multiple polyhedral scatterer can be controlled by an explicit function of ε which approaches zero, as $\varepsilon \to 0^+$, in an essentially optimal, although logarithmic, way. Then, we show how to improve this stability estimate, provided we restrict our attention to polyhedra and ε is even smaller with respect to h. In this case we obtain an explicit estimate essentially of Hölder type.

Luca Rondi (Università degli Studi di Trieste)
A Variational Approach to the Reconstruction of Cracks by Boundary Data

We consider a conducting body which presents some (unknown) perfectly insulating defects, such as cracks or cavities, for instance. We aim to reconstruct the defects by performing measurements of current and voltage type on a (known and accessible) part of the boundary of the conductor. A crucial step in this reconstruction is the determination of the electrostatic potential u inside the conductor, by the electrostatic boundary measurements performed. Or, in other words, the determination of the harmonic function u by its (measured) Cauchy data on a known and accessible part of the boundary.

Since the defects are unknown, we state such a determination problem as a free-discontinuity problem for the electrostatic potential in the framework of special functions of bounded variation. The corresponding variational formulation consists of the minimization of a suitable functional which depends only on the (possibly noisy) boundary data. The functional takes into account the error in the measurements and contains as a regularizing term the so-called Mumford-Shah functional.

Partha Routh (ConocoPhillips)
Source Estimation from Pre-Stack Seismic Data using Nonlinear Bounded Minimization Technique

Source signature estimation is an important problem in seismic data processing and inversion. Inaccurate estimation of the source function leads to incorrect estimates of Earth parameters. In exploration seismics, one common approach is to estimate the source independently of the Earth parameters. These processing-oriented techniques usually make assumptions about wavelet phase and/or the statistics of reflectivity. In this paper we utilize differential (non-parallel) moveout over offset in prestack gathers to estimate the source function (Minkoff et. al, 1997). Our choice of prior information favors oscillatory wavelets and spiky reflectivity traces when input data constraints are weak. The inversion operates on input data having no moveout correction. Therefore wavelet stretch related to moveout correction, which typically degrades bandwidth and resolution, is not an issue. We propose a nonlinear inversion method that minimizes a mixed-norm objective function subject to fitting the L2 norm of the data. A full-Newton interior point method accommodates our bounds on reflectivity and the mixed norms on model parameters. Field data and synthetic data examples illustrate that the inversion methodology effectively deconvolves the source contribution, and at the same time estimates reflectivity with high resolution. We jointly recover mixed-phase wavelets and AVA parameters to within a scale factor. Moreover, the inverted intercept and gradient traces estimated along with wavelets exhibit much greater time resolution than, say, stacked data. We attribute this resolution in part to the inherent designature of the inversion.

Niall Ryan (University of Limerick)
High-frequency anisotopic elastic inversion

We consider data from an ensemble of experiments which measure scattered mode-converted elastic waves. The resulting forward modelling operator maps singularities in the elastic Hooke's tensor and the density field into high-frequency scattered elastic waves. The number of experiments in the ensemble is arranged to match the number of independent components in the Hooke's tensor plus one, so that we have a formally determined problem. We show what information can be extracted (by way of an inversion algorithm) using quasi- P-P, P-SH, P-SV mode converted waves.

Rayan Saab (UBC)
Source Separation Via Iterative Thresholding in Some Transform Domain

In this talk, we present a source separation scheme which makes use of the sparsity of underlying sources in a possibly overcomplete transform domain, such as the curvelet transform, to perform separation from noisy linear mixtures. The proposed algorithm uses the output of a preliminary step that provides crude predictions of the sources. We start with a Bayesian interpretation of the problem and show that the signal components, i.e., the sources, can be separated by solving an optimization problem. In particular, the algorithm converges to a minimizer of the cost function via iterative thresholding. Finally, we shall apply the algorithm in the setting of primary/multiple separation in seismic signal processing and in the setting of noisy blind source separation for speech signals.

Paul Sacks (Iowa State University)
Singular inverse spectral problems

We consider inverse spectral problems associated with the singular Sturm-Liouville equation

$$\phi'' + \left(\lambda - V(x) - \frac{\ell(\ell+1)}{x^2}\right)\phi = 0 \qquad 0 < x < 1$$

$\ell = 0, 1, 2 \ldots,$ which is obtained by separation of variables in the 3-D radial Schrodinger equation. A common feature in many approaches is the use of special (almost) isospectral transformations, by means of which a reduction to a similar problem in the classical $\ell = 0$ case is possible. In this talk I will focus on the development of computational techniques suggested by these ideas.

Mikko Salo (University of Helsinki)
Stability for solutions of wave equations

Given a wave equation with nonsmooth metric, we consider the stable dependence of the solution on the metric. In particular, we show that the solution depends uniformly continuously on the metric in the $C^{1,1}$ class, when the Cauchy data is in a range of Sobolev spaces. The proof is constructive and uses the wave packet approach to hyperbolic equations.

The result is motivated by an inverse problem in seismic imaging, where one wishes to determine the interior structure of Earth from acoustic measurements made on the surface.

Fadil Santosa (University of Minnesota)
An inverse problem arising in photolithography

Photolithography is a key process in the manufacturing of chips. In this presentation, we will start with an introduction to the subwavelength projection photolithography. The basic problem is that of optimal design. It involves creating masks through which light is projected to produce a desired intensity pattern. This problem is an example where the forward problem, as well as the the parametrization of the unknown, thus the inverse problem, are best formulated using the level set approach. We show how this can be done and demonstrate our approach in numerical examples.

Otmar Scherzer (University Innsbruck)
Kaczmarz methods for the solution of nonlinear ill-posed equations

We present novel iterative regularization techniques for the solution of systems of nonlinear ill–posed operator equations. The basic idea consists in considering separately each equation of this system and incorporating a loping strategy. We show well-posedness, stability and convergence. Moreover, we present three applications, an inverse problem related to thermoacoustic tomography, a nonlinear inverse problem for semiconductor equations, and a nonlinear problem in Schlieren tomography. The novel algorithms show robustness, stability, computational efficiency and high accuracy.

Otmar Scherzer (University Innsbruck)
Taut-String for High Dimensional Data

We study the problem of density estimation with total variation minimization. The basic ingredient is an equivalence relation between the taut-string algorithm and total variation minimization. Moreover, we show scale-space properties of total variation minimization which allows to explain the taut-string algorithm as a two-step algorithm. This explanation allows to generalize the algorithm to higher dimension, using Voronoi-Diagrams and filtering of pre-processed data. Moreover, we discuss various other filtering techniques.

John Schotland (University of Pennsylvania)

Inverse Scattering and Nanoscale Optical Imaging

This talk will review recent work on inverse scattering problems for wave fields with evanescent components. Applications to three-dimensional optical imaging with sub-wavelength resolution will be described.

John Schotland (University of Pennsylvania)
Optical Tomography with Lare Data Sets

This talk will review recent work on the development of fast image reconstruction algorithms for optical tomography with diffuse light. Numerical simulations and experimental data from model systems will be used to illustrate the results.

Jin Keun Seo (Yonsei university)
Electrical Impedance Tomography and Magnetic Resonance EIT

Magnetic Resonance Electrical Impedance Tomography (MREIT) is a new medical imaging technique combining Electrical Impedance Tomography (EIT) and Magnetic Resonance Imaging (MRI). Noting that EIT suffers from the ill-posed nature of the corresponding inverse problem, we introduce MREIT which utilizes internal information on the one component of the induced magnetic field in addition to the boundary current-voltage measurements to produce three-dimensional images of conductivity and current density distributions.

Since 2000, imaging techniques in MREIT have been advanced rapidly and now are at the stage of animal experiments. In both EIT and MREIT, we inject currents through electrodes placed on the surface of a subject. While EIT is limited by the boundary measurements of current-voltage data, MREIT utilizes the internal magnetic flux density data obtained using a Magnetic Resonance Imaging (MRI) scanner. This is the main reason why MREIT could eliminate the ill-posedness of EIT. The disadvantages of MREIT over EIT may include the lack of portability, potentially long imaging time and requirement of an expensive MRI scanner.

In this talk, we begin with reviewing EIT in order to provide the rationale of pursuing MREIT research that requires an expensive MRI scanner. Then, recent progress in MREIT providing conductivity and current density images with a high spatial resolution and accuracy will be presented including mathematical theory, algorithms, and experimental methods. With numerous potential applications in mind, some future researches in MREIT and EIT will be proposed.

Sergey Shcherbinin (The University of British Columbia)
An Investigation of an Accuracy of Iterative Reconstructions in Quantitative SPECT

There is a well recognized clinical demand for imaging procedures that would provide quantitative information about the processes inside living organisms. In nuclear medicine (SPECT, in particular) tracer molecules labeled with a radioactive isotope are injected into the patient body, and radioactive emissions from this isotope are recorded at several locations around the patient. The diagnosis is based on the analysis of an image which is reconstructed from these data (projections). To provide clinicians with quantitative information, the complex inverse problem needs to be solved with a maximum possible accuracy. From the mathematical perspective, this corresponds to the restoration of a true 3D volumetric distribution of the tracer from the set of 2D detected data. The mathematical description of this problem leads to an under-determined system of algebraic equations with an extremely large matrix (system matrix). The coefficients of both matrix and right-hand side reflect the complex ways in which the emitted photons are interacting with the body and are recorded by the detector. The goal of this study is to estimate the mathematical accuracy of the iterative ordered subsets expectation maximization (OSEM) method in different realistic oncological situations. Numerical model imitating thyroid phantom was created to reproduce some of the clinical cases from the Internal Radiotherapy Dosimetry study. Monte-Carlo simulations and analytical projectors were used to create noisy and noiseless sets of projections, respectively. The quantitative capability of the method was evaluated by performing a comparative analysis of true and reconstructed distributions. The influence of physical conditions of the study (the activity distribution inside the true image; the number of projections; incorporation of photon attenuation, scatter, and distance-dependent resolution loss into the system matrix) and algorithmic parameters (number of sub-sets and iterations, initial guess) on the solution accuracy and the convergence behavior was studied.

Martin Schweiger (University College London)
Jacobian-free Newton-Krylov reconstruction of model parameters in optical tomography

Optical tomography (OT) seeks to recover the optical parameters of absorption and scattering of bilogical tissue from boundary measurements of infrared light transmission. The problem is nonlinear and in general requires an iterative model-based approach that optimises the model parameters by minimising the data error.

Due to scattering, OT, despite its name, can not be reduced to a series of 2-D slice reconstructions such as X-ray computed tomography. Instead, a full 3-D reconstruction of the entire volume is required, leading to a solution space of high dimension n. For second-order Newton-type optimisation strategies, such problems are often intractable due to the size of the $n \times n$ Hessian matrix. We have previously presented a Newton-Krylov approach that avoided the explicit computation and storage of the Hessian matrix. However, this method still required the explicit storage of the first-order derivative of dimension $m \times n$, where m is the dimension of the data space. In many practical problems, data are acquired at high spatial resolution, e.g. by the use of a CCD detector array. In such systems m can be of a similar magnitude to n, and the storage of the Jacobian also becomes impossible.

We present an extension to the previously presented algorithm that provides an implicit representation of the Frechet derivative and adjoint Frechet derivative of the forward problem and thereby avoids the explicit storage of the Jacobian. Reconstructions from simulated 2D and 3D data sets will be presented to show that this new method reduces memory storage costs significantly for large-scale reconstruction problems, and is computationally efficient in cases that contain a large number of detectors.

Raya Shindmes (Emory University)
Influence of Geometric Modelling Errors on EIT Inverse solutions using MRI-based Patient Specific Meshes of the Human Head

Recent advances in the modelling field include finer and more accurate representation of the domain of interest. For domains of complex geometry, as in medical applications, analytical solutions are not applicable and numerical methods are advisable. Among these methods, the Finite Element method, which offers high flexibility, is most broadly used. However, this approach requires the generation of Finite Element meshes, which for complex structures as the human head, was a labour intensive task which required the services of CAD expert. There is a nontrivial correlation between the accuracy of the geometric representation for the forward model and the inverse solution. Previous studies demonstrated that the impact of small changes in the geometry predominates any possible physiological conductivity change within the volume for absolute data. The purpose of this work was to quantify the reconstruction error using prototype human head model vs patient specific one. A generic method for generation of Finite Element meshes based on anatomical images was developed. EIT simulated data was generated and then inverse solutions were computed for both model types. The proposed method is generic and therefore could be advantageous for other modelling techniques.

Maxim Shishlenin (Russian Academy of Science)
Numerical analysis of methods for solving inverse acoustic problems

The one-dimensional inverse acoustic problems are considered. We apply the finite-difference scheme inversion, optimization methods (method of the steepest descent, Landweber iterations, conjugate gradients methods), Gel'fand-Levitan-Krein method and boundary control method for solving inverse acoustic problem. The discrete problem statements are considered. The theoretical and numerical results will be presented and discussed.

Samuli Siltanen (Tampere University of Technology)
Direct reconstruction of discontinuous conductivities using Beltrami equation

The uniqueness theorem for general conductivities by Astala and Pivrinta [Ann.Math.163(2006)] has a constructive proof. A practical EIT algorithm based on this theory is discussed. Complex geometrical optics solutions for the Beltrami equation play a key role in the proof. Numerical computation of those solutions is demonstrated.

Frederik J Simons (Princeton University)
On the recovery of potential field anomalies on the surface of a sphere from incomplete and noisy data taken at an altitude above their source

The estimation of potential fields such as the gravitational or magnetic potential at the surface of a spherical planet from noisy observations taken at an altitude over an incomplete portion of the globe is a classic example of an ill-posed inverse problem. We show that this potential-field estimation problem has deep-seated connections to Slepian's spatiospectral localization problem which seeks bandlimited spherical functions whose energy is optimally concentrated in some closed portion of the unit sphere. This allows us to formulate an alternative solution to the traditional damped least-squares spherical harmonic approach in geodesy, whereby the source field is now expanded in a truncated Slepian function basis set. We discuss the relative performance of both methods with regard to standard statistical measures such as bias, variance and mean squared error, and pay special attention to the algorithmic efficiency of computing the Slepian functions on the region complementary to the axisymmetric polar gap characteristic of satellite surveys. The ease, speed, and accuracy of our method make the use of spherical Slepian functions in earth and planetary geodesy practical.

Eva Sincich (Austrian Academy of Sciences)
Lipschitz stability for the inverse Robin problem

We are concerned with a problem arising in corrosion detection. We consider the stability issue for the inverse problem of determining a Robin coefficient on the inaccessible portion of the boundary by the electrostatic measurements performed on the accessible one. We prove a Lipschitz stability estimate under the further a-priori assumption of a scalar Robin coefficient.

Mourad Sini (RICAM)
Determination of complex obstacles from scattering data

The scattering by an obstacle $D \subset R^n$ with mixed boundary conditions can be considered as a prototype model for the radar detection of complex obstacles with coated and non-coated parts of its boundary. The complex obstacle is characterized by its shape, the type of boundary conditions imposed on the its surface and the boundary values of the impedance coefficient.

In this talk, we are concerned with the identification of these complex obstacles from the scattering data for the acoustic problem. We present the following results:
• We construct some indicator functions for this inverse problem using the far-field pattern directly, without the necessity to transform the far-field to the near field. Based on the careful singularity analysis, we establish point-wise formulas which can be used to reconstruct the shape of the obstacle and give explicitly the values of the surface impedance as a function of the far fields. In addition, these formulas enable us to distinguish and recognize the coated and the non-coated parts of the obstacle. This analysis is given for arbitrary dimension n.
• In the 2D case, we give numerical tests based on these formulas which show that both the boundary shape and the surface impedance in the coated part of boundary can be reconstructed accurately. Our reconstruction scheme reveals that the coated part of the obstacle is less visible than the non-coated one, which corresponds to the physical fact that the coated boundary absorbs some part of the scattered wave. This is known as the *coating effect*. This is of importance in the design of non-detectable obstacles.
• The stability issue for the complex obstacles will be also treated.

Ralph Sinkus ()
MR-Elastography: A unique tool to non-invasively measure the complex shearmodulus of tissue - application to breast, liver, Alzheimer's disease and rheology

Palpation has ever since been most important to screen for pathological abnormalities, especially in the area of breast cancer detection. MR-Elastography offers a unique technique to assess non-invasively the complex shear modulus of biological tissue. The basic concept is to illuminate the region of interest with mono-chromatic low-frequency mechanical waves and image the propagation of those waves via phase-locked motion-sensitized MR-sequences. The advantage over ultrasound-based approaches is that MR allows to measure the 3D displacement vector of the wave field within a volume. Thus, reconstruction of the complex shear modulus G* can be done in an unbiased way: remnants of the compressional wave field are eliminiated via application of the curl operator to the complex-valued displacement field yielding a Helmholz type of equation. Inversion is done locally using third-order derivatives of the 3D displacement field. Results are presented for breast cancer and a 20increase in specificity is demonstrated when adding viscoelastic information to classical data provided by the established MR-mammography.

The application to liver shows that the degree of fibrosis can be staged via the complex shear modulus having an enormous impact on the treatment of hepatitis C. Initial results for Alzheimers disease in mice show that the anisotropic mechanical properties decrease in the corpus callossum (white matter) due to the presence of the disease. This finding correlates to findings done with diffusion tensor MRI imaging the mobility of water molecules. Finally, we investigated the dispersion properties of the complex shear modulus in tissue. A power-law behavior for G^* as a function of frequency is found. A possible explanation is the underlying fractal vascular system representing an enormous mismatch in acoustic impedance for the mechanical wave.

Arkadiusz Sitek (Harvard Medical School and Brigham and Women's Hospital)
Taut-String for High Dimensional Data

We study the problem of density estimation with total variation minimization. The basic ingredient is an equivalence relation between the taut-string algorithm and total variation minimization. Moreover, we show scale-space properties of total variation minimization which allows to explain the taut-string algorithm as a two-step algorithm. This explanation allows to generalize the algorithm to higher dimension, using Voronoi-Diagrams and filtering of pre-processed data. Moreover, we discuss various other filtering techniques.

Marian Slodicka (Ghent University)
Recovery of missing boundary data for magnetic field in eddy-current problems: An iterative approach

We consider a linear steady-state eddy-current problem for a magnetic field in a bounded domain. The boundary consists of two parts: reachable with prescribed Cauchy data and unreachable with no data on it. We design an iterative (Landweber type) algorithm for solution of this problem. At each iteration step two auxiliary mixed well-posed boundary value problems are solved. The analysis of temporary problems is performed in suitable function spaces. This creates the basis for the convergence argument.

Steve Smale (Toyota Technology Institute at Chicago)
Learning Theory and Sampling

Learning Theory relevant to inverse problems will be discussed.

Alexandra Smirnova (Georgia State University)
Large Iteratively Regularized Gauss-Newton Method with Parameter Decomposition

In this talk, we establish theoretical convergence results for Iteratively Regularized Gauss Newton (IRGN) method combined with a generalized Tikhonov regularization. The generalized Tikhnov regularization using a seminorm generated by a linear operator is motivated by the decomposition of the parameter space into diffusion coefficient D and absorption coefficient μ for the exponentially ill-posed inverse problem in optical tomography. We validate our theoretical results using simulations for a one dimensional version of the optical tomography inverse problem. We conclude that the new method contributes greater flexibility for implementations of IRGN solutions of ill-posed inverse problems in which differing scales in physical space hinder standard IRGN inversions.

Erkki Somersalo (Helsinki University of Technology)
Recovery of shapes, hypermodels and Bayesian learning

The talk deals with the recovery of shapes, or blocky objects, from indirect observations such as noisy blurred versions of an image or tomographic projection data. It is shown that Bayesian hypermodels can be used to derive effective algorithms for the recovery.

Alberto Sorrentino (Universit di Genova)
Solving the magnetoencephalography inverse problem with particle filters.

The magnetoencephalography (MEG) inverse problem requires to recover the time-varying neural current distribution which is responsible for the measured magnetic fields. If the neural generators are assumed to be point-wise currents, the problem is strongly non-linear. It has been recently suggested that the class of sequential Monte Carlo methods known as particle filters may provide effective algorithms for solving such a problem with minimum a priori assumptions.

Our group is currently working at developing particle filters for MEG. Here we present a brief review of the good theoretical properties of the method; we show that it allows dynamically estimating from the data (i) the number of active sources, (ii) the source parameters and (iii) the reliability of the source parameters; we discuss some applications to both synthetic and real MEG data, and some comparison with other MEG source estimation methods.

Roberto Souto (Uni. Federal do Rio Grande do Sul)
Advances on Chlorophyll concentration reconstruction from multispectral radiances

An inverse hydrologic optics problem is solved in order to reconstruct gaussian vertical profiles of Chlorophyll concentration from synthetic water-leaving radiance experimental measurements in the ocean water. The inverse problem is formulated as an optimization problem and iteratively solved by the meta-heuristics Ant Colony Optimization, using the radiative transfer equation as direct model. An ob jective function is given by the square difference between computed and experimental radiances at every iteration. In a typical inversion, hundreds of iterations may be required and therefore the choice of an algorithm that is suitable for parallelization is an important issue. It was included a new intrinsic regularization scheme that pre-selects candidate solutions at every iteration based on their smoothness, quantified by the 2nd order Tikhonov norm. Besides the smoothness, an additional information is also used to compute the inverse solution: the concavity of the Chlorophyll profile that is verified by means of its second derivative. Since only curves with negative concavity are expected, a penalty is assigned to profiles with positive concavity. Tipically, good estimations were obtained only for the upper part of the curve with poor agreement below the depth that corresponds to the peak. Therefore, a new two-step strategy is proposed for this kind of profiles: in step-1, estimation is performed for the whole profile and then, in step-2, the reconstruction is performed only for the deeper part of the curve, and the values obtained in the first step for the upper part are frozen. In other words, step-2 is a new inverse problem, but simpler and with a lower dimension than the original problem.

Filip Sroubek (Institute of Information Theory and Automation)
Simultaneous Superresolution and Blind Deconvolution

In many real applications, blur in input low-resolution images is a nuisance, which prevents traditional superresolution methods from working correctly. Only integer resolution enhancement factors, such as two or three, are often considered, but non-integer factors between one and two are also important in real cases. We introduce a method to superresolution and deconvolution, which assumes no prior information about the shape of degradation blurs and which is properly defined for any rational (fractional) resolution factor. The method minimizes a regularized energy function with respect to the high-resolution image and blurs, where regularization is carried out in both the image and blur domains. The blur regularization is based on a generalized multichannel blind deconvolution constraint. Experiments on real data illustrate robustness to noise and other advantages of the method.

Plamen Stefanov (Purdue University)
Local lens rigidity for a class of non-simple manifolds

Let (M, g) be a compact Riemannian manifold with boundary. We study the geodesic ray transform I_Γ of tensor fields over geodesics in an open subset Γ for a class of metrics g that may have conjugate points. Some non-conjugacy assumptions are still imposed. We review some recent results obtained jointly with Gunther Uhlmann. Under the assumptions that $N^*\Gamma$ covers T^*M, and some topological conditions, we show that I_Γ is injective on solenoidal tensors for generic metrics in this class, including the real analytic ones. We also obtain a stability estimate and apply those results to the non-linear lens rigidity problem.

Plamen Stefanov (Purdue University)
Recovering anisotropic metrics from travel times

We will review the recent results by the presenter and Gunther Uhlmann on the lens and boundary rigidity problem from the point of view of recovery of an anisotropic metric (not conformal to the Euclidean one).

Gerald Steiner (Graz University of Technology)
A Bayesian filtering approach for inclusion detection with ultrasound reflection tomography

Ultrasound is frequently used in nondestructive material testing due to its high sensitivity to inhomogeneities like cracks and gas inclusions. Tomographic approaches have the potential to attain higher resolution in terms of defect location and shape compared to conventional B-mode imaging. However, when commonplace reconstruction algorithms are used, the limited number of transducers available in realistic measurement setups leads to blurring and the presence of artifacts in the reconstructed image. This paper presents a novel reconstruction algorithm for ultrasound reflection tomography of binary material distributions. A key component is the Bayesian filtering approach employing a parameterized model of material defects. It allows the incorporation of prior knowledge about the reconstruction problem. Blurring and artifacts are inherently eliminated, allowing for more reliable and accurate reconstruction results.

Chris Stolk (University of Twente)
Amplitudes in seismic migration

We discuss seismic migration theory based on the Born approximation. Denote by F the linearized forward map, that maps the mediumperturbation α (reflectivity) to linearized seismic data d. Under certain conditions the singularities of α can be reconstructed by migration methods based on ray calculations. This can be explained as follows. The normal operator $N = F^*F$ is pseudodifferential, with symbol that depends on ray-theoretic quantities, and that can be computed. A 'true-amplitudemigration method is then given by $N^{-1}F^*$. In wave-equation migration the rays are not explicitly computed, so the question is whether the factor N^{-1}, which acts as an amplitude factor and filter, can still be taken into account correctly, without computing the rays. In this talk we discuss different amplitude effects, due to aperture and geometrical optics in a variable coefficient medium, and ways of inverting for them.

Toshio Suzuki and Shiro Kubo (Osaka University)
Active Use of Piezoelectric Film for Identification of Cracks

The passive electric potential CT (computed tomography) method was proposed for detecting and identifying cracks in structure members subjected to mechanical load. In this method piezoelectric film was pasted on the cracked member to be inspected. The electric potential distribution on the piezoelectric film was obtained without applying electric current. The passively obtained distribution was used for the identification of cracks. The piezoelectric film can be used as an actuator and transducer for the ultrasonic inspection. In this paper the active use of the piezoelectric film for crack detection was examined. A smart layer which works both as the sensor for the passive electric potential CT method and as ultrasonic transducer was developed. Experiments demonstrated the applicability of the layer for the detection of cracks.

John Sylvester (University of Washington)
Non-radiating Sources, Transmission Eigenvalues, and the Born Approximation

A non-radiating source radiates no far field. A transmission eigenvalue is a wavenumber at which a scattering operator (for the Helmholtz equation an an inhomogeneous medium) has a nontrivial kernel. We discuss the relationship between the two and give some results concerning existence and non-existence of transmission eigenvalues, both for the scattering operator and its Born approximation.

William Symes (Rice University)
A tale of two tomographies: traveltime and waveform

Traveltime tomography, in its reflection variant, is widely used to create velocity models for industrial seismic imaging. This process requires that seismic events be identified and their arrival times measured. While modern practice largely automates event picking, the possibility remains that some important events are missed, or that unimportant events (associated perhaps to irrelevant propagation velocities) are picked, or that signal components carrying important velocity information are not identified as events, hence missed altogether. Alternative methods of velocity estimation based directly on the ("waveform") data have also been developed, though many of these are primarily interactive and subjective. In this talk, I will show how various forms of objective waveform tomography can be related directly to traveltime tomography, at the level of algorithmic components. In particular, waveform tomography formulated via explicit use of high-frequency asymptotics uses the same traveltime computations as does traveltime tomography. I will review progress in designing a waveform tomography algorithm using the Qian-Leung traveltime tomography package. If time permits, I will illustrate some important numerical issues, and their implications, using a simpler algorithm based on a layered medium approximation. The principal implication is that reduction in numerical artifacts demands explicit computation of pseudodifferential operator actions.

William Symes (Rice University)
The inverse problem of seismic velocities

Waveform (output least squares) inversion of seismic reflection data can reconstruct remarkably detailed models of subsurface structure, and take into account essentially any physics of seismic wave propagation that can be modeled. However the waveform inversion objective has many spurious local minima, hence convergence of descent methods (mandatory because of problem size) to useful Earth models requires accurate initial estimates of long-scale velocity structure. Accordingly, the seismic industry has developed a collection of apparently unrelated *migration velocity analysis* methods, capable of correcting substantially erroneous initial estimates of Earth structure. Appropriate choice of objective turns migration velocity analysis into an optimization problem, for which Newton-like methods exhibit little tendency to stagnate at nonglobal minima. The main theme of this talk is the intimate relation between these two approaches to seismic velocity estimateion: migration velocity analysis is a solution method for a *partially linearized* waveform inversion problem, based on *extension* of the underlying mapping from Earth structure to data.

William Symes (Rice University)
Software for Time-dependent Inverse Problems

Time-dependent simulations share several common features which can be exploited in constructing optimization applications to solve inverse (and similar) problems. Mapping between internal and external representations of parameters (coefficients, right hand side,...) and of data, coupling of time steps for basic simulation with derivative and adjoint derivative time steps, and prediction of multiple data outputs from the same set of parameters (multiexperiments) play similar abstract roles in all such problems. This talk describes a software framework encoding all of these common features in a library of C++ classes, and defining minimal interfaces for the software components unique to each application. The Timestepping Simulation for Optimization ("TSOpt") package groups simulation modules together with those defining partial derivatives with respect to parameters, adjoints of these, etc., as Operator objects as defined in the Rice Vector Library ("RVL"). Optimization algorithms written in terms of the RVL interfaces can be linked directly to simulators written in TSOpt to form solution algorithms for inverse problems. TSOpt incorporates optimal checkpointing, which minimizes the time/memory complexity of adjoint state computations, and parallelizes at both loop level (individual simulations) and task level (multisimulations). The talk will describe the conceptual structure of the library and its user interface, and demonstrate the use of TSOpt to solve an inverse problem from reflection seismology.

Germain Tanoh (IRMACS, Simon Fraser University)
Proximal Reconstruction Methods For Dynamic Inverse Problems In Emission Tomography

In dynamic SPECT tomography we study the dynamics of physiological processes and biochemical functions of living organism. The mathematical formulation gives rise to a large scale dynamic inverse problem. We describe a new regularization method for computing a spatio-temporal smooth solution. Using Bregman proximity operators we analyze a splitting algorithm. The problem is solved in two steps. First we perform a spatial regularization step; following by a temporal regularization step. We establish convergence results and smoothing properties of this alternating regularization method, and show that it is able to reconstruct the time varying activity distributions. Preliminary numerical results are provided.

Mickael Tanter (Inserm (National Institute for Medical Research))
Time Reversal in Ultrasound Medical Applications

In this paper, we review some of the main applications investigated during the past decade. An iterative implementation of the time-reversal process allows tracking gall-stones in real time during lithotripsy treatments. In this application domain, a smart exploitation of the reverberations in solid waveguides permits the focusing of high amplitude ultrasonic shock waves with a small number of transducers. Finally, because time reversal is able to correct the strong distortions induced by the skull bone on ultrasonic propagation, this adaptive focusing technique is very promising for ultrasonic hyperthermia brain therapy and even high resolution brain echography. An overview of the applications of time reversal in the field of biomedical imaging will be presented. Finally, it will be shown how it is possible by using ultrafast frame rates in ultrasonic imaging to image the viscoelastic properties of soft tissues for cancer diagnosis.

Kazumi Tanuma (Gunma University)
Perturbation formulas for phase velocity and polarization of Rayleigh waves in prestressed anisotropic media

Rayleigh waves are elastic surface waves which propagate along the traction-free surface with the phase velocity in the subsonic range, and whose amplitude decays exponentially with depth below that surface. Such waves serve as a useful tool in nondestructive characterization of materials. The problem there is what material information we could obtain if we could measure accurately Rayleigh waves propagating in any direction on the traction-free surface.

Herein we consider Rayleigh waves propagating along the traction-free surface of a macroscopically homogeneous, anisotropic, prestressed half-space. Assuming that the deviation of the prestressed anisotropic medium from a comparative 'unperturbed', unstressed and isotropic state be small, we investigate the perturbation of the phase velocity and of the polarization of Rayleigh waves caused by the anisotropic part $\mathbb{A} = (a_{ijkl}), (i,j,k,l = 1,2,3)$ of the incremental elasticity tensor and by the initial stress $\mathring{T} = \mathring{T}_{ij}, (i,j = 1,2,3)$. Here, we do not put any restriction on the symmetries of $\mathbb{A}$ and $\mathring{T}$ except for the physically natural conditions $a_{ijkl} = a_{klij} = a_{jikl}$ and $\mathring{T}_{ij} = \mathring{T}_{ji}$, so that $\mathbb{A}$ has 21 independent components.Two physical quantities are determined by the polarization of Rayleigh waves. One is the polarization ratio, which is the ratio of the maximum longitudinal component to the maximum normal component of the displacements of the Rayleigh waves at the surface, and the other is the phase shift, which is the shift in phase between the longitudinal component and the normal component of the displacements.

In this talk we present perturbation formulas for the phase velocity, the polarization ratio and the phase shift, which are correct to first order in the components of $\mathbb{A}$ and $\mathring{T}$. For definiteness, we choose a Cartesian coordinate system such that the material half-space occupies the region $x_3 \leq 0$, whereas the 1- and 2-axis are arbitrarily chosen. (Then $\mathring{T}_{i3} = 0$ for $i = 1,2,3$, and hence $\mathring{T}$ has 3 independent components.) The following consequences immediately follow from the perturbation formulas:

1. Only four components $a_{2222}, a_{2233}, a_{3333}$ and a_{2323} of $\mathbb{A}$ and one component $\mathring{T}_{22}$ of $\mathring{T}$ can affect the first-order perturbation of the phase velocity of Rayleigh waves propagating in the direction of the 2-axis on the surface $x_3 = 0$.
2. Only the same components of $\mathbb{A}$ as the above but no component of $\mathring{T}$ can affect the first-order perturbation of the polarization ratio of such Rayleigh waves.
3. Only two components a_{2223} and a_{3323} of $\mathbb{A}$ and no component of $\mathring{T}$ can affect the first-order perturbation of the phase shift of such Rayleigh waves.

We discuss the problem of determining $\mathbb{A}$ and $\mathring{T}$ by making measurements of perturbation of Rayleigh waves which propagate in any direction on the traction-free surface. We show that, to first order of $\mathbb{A}$ and $\mathring{T}$, the totality of phase velocities of Rayleigh waves propagating in all the directions on the traction-free surface carries information only on 13 components of $\mathbb{A}$ and on all the 3 components of $\mathring{T}$. On the other hand, it can be proved that the totality of the phase shifts of those Rayleigh waves carries information only on the remaining 8 components of $\mathbb{A}$.

Fons Ten Kroode (Shell EP research)
Amundsen inversion - an alternative for surface related multiple elimination?

In seismic data acquisition a signal is emitted by a source and recorded at a multitude of receivers. In the recorded reflection data one distinguishes between primaries, waves which have reflected once in the sub- surface and multiples, waves which have reflected more than once in the subsurface. The most important multiples are surface related, namely those which have bounced against the surface of the earth at least once. Multiples cause a serious problem for the imaging of seismic data, as present day seismic imaging algorithms are based on linearized theory and therefore correct for primaries only. Therefore, one needs to remove or rather attenuate multiple reflections in the data before constructing an image of the subsurface. There are many methods to attenuate surface related multiples in seismic data. Among them there is a class of methods which is purely data driven. It goes by the acronym of SRME, Surface Related Multiple Elimination. Starting from the Rayleigh reciprocity theorem, one derives an algorithm to predict multiples from (deghosted) reflection data. The predicted multiples are subsequently subtracted from the data by an adaptive procedure based on minimizing energy in the residual. The latter step is the weak link: the minimum energy criterion is known to be wrong in case of interference between primaries and multiples and it is quite easy to damage primary reflection information by being too aggressive in the adaptive subtraction. Starting from the Rayleigh reciprocity relation again, L. Amundsen formulated a different way to extract primaries from seismic data. His algorithm is assuming that one has independent measurements of pressure and vertical particle velocity and takes the form of an inverse problem: one extracts primaries by multiplying upgoing waves by the inverse of downgoing waves. This presentation will explain the theory behind these two approaches for multiple elimination and highlight their strengths and weaknesses. We will illustrate the new Amundsen method by examples on ocean bottom cable data and sketch a way towards application on towed streamer data.

Celine Theys (Laboratoire Universitaire Astrophysique de Nice)
Restoration of astrophysical images, statistical influence of the camera

Restoration of astrophysical images is a classical applied inverse problem. The astronomical object is first blurred by the Point Spread Function of the instrument-atmosphere set. The resulting convolved image is corrupted by a Poissonian noise due to low light intensity, then, a Gaussian white noise is added during the electronic read-out operation by the Charge Coupled Device (CCD) camera. For such data, the so-called Richardson Lucy algorithm or, more recently, a regularised version of it is used to restore the object from the data, both neglect the read-out noise. Very recent technology proposes to acquire astrophysic data with Low Light Level CCD (L3CCD) cameras in order to avoid the read-out noise due to the classical CCD acquisition. The physical process leading to the data has been previously described by a "Poisson Gamma" density. We propose to discuss the model and to derive an iterative algorithm for the deconvolution of such data. Some simulation results are given on synthetic astrophysic data pointing out the interest of using L3CCD cameras for acquisition of very low intensity images.

Alex Timonov (University of South Carolina Upstate)
A Numerical Study Of Some Globally Convergent Algorithms For Solving Non-Overdetermined Coefficient Inverse Problems

Some globally convergent algorithms for the numerical solution of non-overdetermined coefficient inverse problems are studied. Two methods are used to construct such algorithms. In the convexification method developed by the author together with M. V. Klibanov, the Carleman weight functions associated with Carleman estimates of the second-order differential operator are utilized to provide the global convergence of numerical solutions to the solution of an original inverse problem. The resulting convexification algorithms exploit either the methods of nonlinear constrained optimization or successive approximations. The results of numerical experiments with the inverse problems of magnetotelluric sounding and microwave imaging are demonstrated. It is concluded that although the convexification algorithms allow for the stable reconstruction of coefficients, they do not provide the high spatial and contrast resolution, especially in high dimensions. The main reason is that the convexification method is based on a sufficiently rough approximation of the integro-differential operator in an auxiliary Cauchy problem by truncating an improper integral and projecting the solution of this problem onto a finite-dimensional space. As a result, both the accuracy and convergence rates are affected, sometimes severely. Such deficiencies motivate further studies. In an on-going research project pursued in collaboration with A. Nachman and A. Tamasan, another approach is developed. The key idea is to transform an original inverse problem to an initial value problem for a parametric family of the first-order ordinary differential equations. Unlike the convexification method, in this approach, the exact operator generated by the initial value problem is used when constructing globally convergent successive approximations utilizing Picards method. To provide a more accurate numerical treatment of improper integrals, the initial value problem is formulated for the increment function with respect to a given background medium, and it is solved together with the forward when computing a successive approximation. The first results of numerical experiments with a 1D model inverse problem of acoustic imaging are reported to demonstrate the computational feasibility and effectiveness of this approach.

Carl Toews (University of Minnesota)
Position Registration from Voltage Measurements

We are interested in determining the position of an electrode within a bounded region B. Across this region we apply three orthogonal voltage potentials, and for each field collect a data point corresponding to a voltage measurement at the probe. Were the fields linear, the positions of the probe could be read directly from the voltage data. Unfortunately, the unknown conductivity of the medium surrounding B induces non-linearities, and the problem becomes an inverse problem for which the objective is to determine the probe positions and the field distortions.

To approach this task, we model each field as linear plus a perturbation term that has a low order expansion in a harmonic basis. We then propose and analyze an iterative algorithm to solve the problem in a least-squares sense. Our principle result concerns the behavior of the solution in the limit as the number of measurements becomes large. The method is assessed on simulated data.

Dumitru Trucu (University of Leeds)
The Inverse Time-dependant Coefficient Identification Problem in Bio-Heat Transient Flow Equation

The governing equation for the heat transfer process within the human body tissue, namely

$$\Delta T - P_f T + S = \frac{\partial T}{\partial t},$$

has important applications in many biomedical investigations. Among other theoretical aspects that we are concerned with regard to this equation, the perfusion coefficient P_f receives a particularly important interest because of its physical meaning, that is $P_f = \frac{w_b c_b \mathcal{L}^2}{k_t}$, where w_b is the perfusion coefficient of blood, c_b is the heat capacity of blood, $\mathcal{L}^2$ is the characteristic dimension of the tissue and k_t is the thermal conductivity of the tissue.

In all of our analysis we consider the non-steady state time-dependent case with P_f dependant on time, as well as S dependent on both space and time.

Within this context, the following inverse problem focuses our interest:

Find the temparture $T(x,t)$, as a function in $C^{2,1}(\Omega(0,t_f]) \bigcap C^{1,0}(\overline{\Omega} \times [0,t_f])$, and the perfusion time-dependent coefficient $P_f(t) > 0$, $\forall t > 0$, satisfying both one and two dimensional bio-heat equation

$$\Delta T - P_f(t)T = \frac{\partial T}{\partial t}$$

where, besides the standard smooth enough initial conditions and Dirichlet boundary conditions, we consider the mass measurement

$$\int_{\Omega} T(x,t)dx = E(t), \quad \forall t \in (0,t_f].$$

At the conference the robustness of the solution of this inverse problem will be presented both from analytical and numerical stand point.

Gunther Uhlmann (University of Washington)

Travel Time Transmission and Reflection Tomography

We review several results that concern the determination of the anisotropic index of refraction of a medium by measuring the scattering relation, in the case of transmission tomography, joint work with L. Pestov and P. Srefanov, or the broken scattering relation in the case of reflection seismology, joint work with Y. Kurylev and M. Lassas.

Sergei Utyuzhnikov (University of Manchester)
Linear And Nonlinear Inverse Source Problems Of Active Shielding

The problem of active shielding of some domain from the effect of the field generated in another domain is considered. The active shielding is realized via the implementation of additional sources in such a way that the total contribution of all sources leads to the desirable effect. Mathematically the problem is reduced to seeking the source terms satisfying some a priori described requirements and belongs to the class of inverse source problems. From the application standpoint, this problem can be closely related to the active shielding of noise, active vibration control and active scattering. The solution of the problem of active shielding in the differential and finite-difference formulations is obtained under some general conditions. In contrast to many other approaches, it does not require either the knowledge of Green's function or any information on source distribution and surrounding medium. It is also important that along with undesirable field to be shielded a desirable filed is accepted in the analysis. The solution of the problem requires only the knowledge of the total field on the perimeter of the shielded domain. The active shielding sources are obtained for both linear and nonlinear statements of the problem. In the case of the system of first-order equations the active shielding source term is represented in the form of a single layer. Particular examples of the Helmholtz equation, acoustics equations, Maxwell equations and Euler equations are considered.

Nicolas P. Valdivia (Naval Research Laboratory)
Near-field Electromagnetic Holography: The inverse problem of electromagnetic continuation

We consider the problem of reconstructing the surface tangential components of the electromagnetic field from electric (or magnetic) measurements on a nearby surface. Mathematically the electric (or magnetic) measurements satisfy the Maxwell system. We show that any solution to this equation admits a unique representation by a magnetic dipole, so that the problem is reduced to the solution of a linear integral equation of the first kind. This integral equation is discretized using the method of equivalent sources and conjugate gradients is utilized as a regularization method for the numerical solution. We study uniqueness of the reconstruction and obtain stability estimates. In addition we report numerical reconstructions obtained from data measured over a cylindrical shell and a plate with a circular slot excited by an electromagnetic horn. This work was supported by the Office of Naval Research.

Barry Van Veen (University of Wisconsin)
Dimensionality Reduction in Inverse Scattering: Applications to Microwave Imaging for Breast Cancer Detection

Microwave tomography involves illuminating an object with low-power microwaves from an antenna array and measuring the scattered microwave signals for the purpose of estimating the spatial distribution of dielectric properties within the object. The estimated properties are obtained by applying inverse scattering techniques to the scattered signals.

Potential applications of microwave tomography are wide-ranging, spanning early-stage breast cancer detection to geophysical prospecting.

Microwave tomography is challenging because of the non-linear and very ill-posed nature of the inverse problem. The difficulties of the problem are compounded by the fact that the properties distribution is usually estimated on a dense regular mesh of voxels. This can result in tens of thousands of unknowns for 3-D imaging, which greatly complicates solution of the nonlinear inverse problem. Furthermore, the resolution implied by a dense voxel-based grid is generally not attainable, since the maximum resolution is limited by the sampling geometry and/or by the wavelength of the microwave signals.

We circumvent these obstacles by expanding the properties distribution in a small number of basis functions to greatly reduce the dimension of the inverse problem. The inverse problem then involves solving for a relatively small number of basis function expansion coefficients. This effectively regularizes and greatly reduces the complexity of the nonlinear inverse problem. Consequently, our approach enables the use of inverse problem solution techniques that fail with higher dimensional voxel-based formulations, such as the distorted Born iterative method. We illustrate the effectiveness of our approach in the context of early-stage breast cancer detection, although the methodology is general and applicable to other inverse scattering applications. Representative backscattered signals are acquired using computational electromagnetic simulations of antenna arrays surrounding MRI-derived 3-D numerical breast phantoms.

Barry Van Veen (University of Wisconsin)
Space-Time Sparse MEG Reconstruction

The ill-posed nature of the magnetoencephalographic (MEG) inverse problem has motivated use of constraints to regularize the so lution to the corresponding least squares problem. Examples of constraints include restricting the solution to lie on the cort ical surface and use of penalties to constrain the solution's norm or number of active terms. In particular, sparse solutio ns are encouraged using ℓ_1 penalties, but ℓ_1 penalties tend to produce spiky solutions that lack continuity i n space or time. In this talk we present the concept of space-time sparsity (STS) penalization, which encourages solutions to the inverse problem consisting of a small number of space-time events. A space-time event describes activity that occurs over a limited, yet contiguous time span and has local spatial support on the cortical surface. We describe such events using multi ple spatio-temporal basis functions. The STS penalty is then defined as the sum across events of the ℓ_∞ norm of the coefficients of each space-time event. This penalizes only the largest coefficient associated with each event and favo rs solutions consisting of a sparse set of space-time events. We present a novel expectation-maximization algorithm for find ing a minimum of the STS penalized least squares problem and illustrate its performance using both simulated and human subject data.

Lucas van Vliet (Delft University of Technology)
Robust Super-Resolution without Regularization

Super-resolution restoration is the problem of restoring a high-resolution scene from multiple degraded low-resolution images under motion. Due to imaging blur and noise, this problem is ill-posed. Additional constraints such as smoothness of the solution (i.e. regularization) is often required to obtain a stable solution. While regularization of the cost function is a standard practice in image restoration, we propose a restoration algorithm that does not require this extra regularization term. The robustness of the algorithm is achieved by a robust error norm that does not response to intensity outliers. With the outliers suppressed, our solution behaves similarly to a maximum-likelihood solution under the presence of Gaussian noise only. The effectiveness of our algorithm is demonstrated with super-resolution restoration of real infrared image sequences under severe aliasing and intensity outliers.

Pivi Johanna Vauhkonen (University of Kuopio)
Computational aspects of EIT in cylindrical geometry

EIT has been used in many medical and industrial applications where the targets are three-dimensional. Therefore also the potential and current distributions are three-dimensional, and numerical approximations of the models that connect the conductivity distribution, the electrical potentials and the current distributions include thousands of unknown parameters that have to be determined. However, if the shape of the target is regular, the computations can be simplified. For example if the target is symmetric along one axis the potentials can be considered as separable functions that are composed of two-dimensional and one-dimensional parts. This can be utilized for example when the potentials are applied for the recovery of the conductivity on the boundary from the Dirichlet-to-Neumann map. Further, it is also possible to take advantage of cylindrical symmetry and separability in a case that the domain extends almost to infinity in one direction so that the potentials and the currents far from the current carrying electrodes are diminished along that axis close to zero. When finite element-based approach is applied for reconstructing three-dimensional conductivity distributions, simple one dimensional infinite elements can be used in the direction where the domain in assumed to be unbounded.

Rossmary Villegas (Universidad Carlos III de Madrid)
A generalized level set technique for the simultaneous reconstruction of geological regions and region-specific model-based internal permeability profiles of petroleum reservoirs from production data

During the water flooding process of secondary oil recovery, water is injected into the petroleum reservoir at injection wells in order to enhance oil recovery at other production wells. The physical process is modeled here by a two-phase incompressible flow system of oil and water. The goal in the inverse problem is to reconstruct the different geological regions as well as the unknown model-based internal permeability profiles from the water-/oil-production data gathered at the wells. Here, the model used for the characterization of each of the regions (of unknown shapes) will be different for different regions. For example, in our numerical experiments one of the regions follows a linear parameterized model, whereas the other one follows a smoothly varying pixel-based model. We present a novel level set technique whose goal is to reconstruct simultaneously the correct interfaces of these different geological regions as well as the different internal model-based permeability profiles in each of these regions from few production data. This mixed inverse problem is solved by an iterative technique which employs an adjoint solver for back-propagating residual values from production wells into the reservoir. Using this technique, only one forward and one adjoint problem needs to be solved per iteration in order to extract gradient directions simultaneously for the level set function identifying the different regions, for the parameterized region values in one of these regions, and for the pixel-based profile in the corresponding other region. Numerical experiments in 2D are presented which demonstrate the performance of our new technique in realistic situations.

Eric Voth (St. Jude Medical, Inc.)
Reconstruction of Cardiac Electrical Activity

This talk will describe a clinically established system for diagnosing cardiac arrthythmias, based on a high-order boundary element solution of the inverse Cauchy problem for the Laplace equation. Open questions regarding accuracy, optimality, joint regularization in time and space, and developing a clinically relevant automated database for simulation and testing will also be discussed.

Michael Wakin (California Institute of Technology)
Sparse representations and low-dimensional geometry in image recovery

Concise models for signal and image structure are essential to developing efficient algorithms for acquiring and processing data. Sparse signal representations, for example, are at the core of the emerging theory of compressive sensing (CS), in which a signal having some sparse representation can be recovered from a small number of nonadaptive (even random) linear measurements. In this talk we will overview the basic theory of CS while emphasizing applications in imaging. We will also discuss generalizations of sparse representations to include other concise models for signal structure, in particular where the signal families live along low-dimensional manifold-like structures within the ambient high-dimensional signal space. As we will discuss, the structure of such manifolds remains well preserved (with high probability) under random projection to a lower-dimensional space of suitable dimension, for reasons very similar to the arguments that underly CS. We will also discuss the implications of this fact, again in the context of CS and imaging.

Jenn-Nan Wang (National Taiwan University)
Special solutions for some elliptic systems and applications

In this talk I would like to discuss how to construct special solutions with general complex phases for some elliptic systems in the plane. The important property of these solutions is that they decay exponentially on one side of some curve and grow exponentially on the other side of the same curve. These solutions are very useful in the object identification problem. I will show some numerical results if time permitted.

Ricardo Weder (UNAM)
A Rigorous Time-Domain Analysis of Full-Wave Electromagnetic Cloaking

There is currently a great deal of interest in the theoretical and practical possibility of cloaking objects from the observation by electromagnetic waves. The basic idea of these invisibility devices is to use anisotropic *transformation media* whose permittivity and permeability $^{\lambda\nu}$, $\mu^{\lambda\nu}$, are obtained from the ones, ${}_0^{\lambda\nu}$, $\mu_0^{\lambda\nu}$, of homogeneous isotropic media, by singular transformations of coordinates.

In this paper we study electromagnetic cloaking in the time-domain using the formalism of time-dependent scattering theory. This formalism provides us with a rigorous method to analyze the propagation of electromagnetic wave packets with finite energy in a *transformation media*. In particular, it allows us to settle in an unambiguous way the mathematical problems posed by the singularities of the inverse of the permittivity and the permeability of the *transformation media* on the boundary of the cloaked objects. Von Neumannś theory of self-adjoint extensions of symmetric operators plays an important role on this issue. We write Maxwellś equations in Schrödinger form with the electromagnetic propagator playing the role of the Hamiltonian. We prove that every self-adjoint extension of the electromagnetic propagator in a *transformation medium* is the direct sum of a fixed self-adjoint extension in the exterior of the cloaked objects, that is unitarily equivalent to the electromagnetic propagator in the homogeneous medium, with some self-adjoint extension of the electromagnetic propagator in the interior of the cloaked objects. This means that the electromagnetic waves inside the cloaked objects are not allowed leave them, and viceversa, electromagnetic waves outside can not go inside. Furthermore, we prove that the scattering operator is the identity. This implies that for any incoming finite-energy electromagnetic wave packet the outgoing wave packet is precisely the same. In other words, it is not possible to detect the cloaked objects in any scattering experiment where a finite energy wave packet is sent towards the cloaked objects, since the outgoing wave packet that is measured after interaction is the same as the incoming one.

Our results give a rigorous proof that the single coating construction of [**?**], [**?**], [**?**], [**?**] perfectly cloaks passive and active devices from observation with electromagnetic waves, without the need to introduce a double coating. Actually we consider a slightly more general construction than the one of [**?**], [**?**], [**?**], [**?**] in the sense that we allow for a finite number of star-shaped cloaked obstacles.

More importantly, we prove all of our results for general anisotropic homogeneous media, i.e., the permittivities and the permeabilities ${}_0^{\lambda\nu}$, $\mu_0^{\lambda\nu}$, are not required to be isotropic as it was the case in the previous papers on this problem . This means, for example, that it is also possible to cloak objects that are inside crystals.

Eung Je Woo (Kyung Hee University)
Conductivity Image Reconstruction in Magnetic Resonance Electrical Impedance Tomography (MREIT)

Injection current into an electrically conducting object such as the human body produces internal distributions of voltage, current density, and magnetic flux density. In magnetic resonance electrical impedance tomography (MREIT), we measure the distribution of the induced magnetic flux density inside the imaging object using an MRI scanner. Utilizing measured data of internal magnetic flux densities subject to multiple injection currents, we can reconstruct cross-sectional images of the conductivity distribution. We describe theoretical and experimental aspects of the MREIT technique to produce conductivity images with high spatial resolution. From our latest study of animal experiments, we present conductivity images of canine brains using a 3T MREIT system and 5-mA injection currents. Future research direction toward clinical applications of the technique will be discussed.

Yuan Xu (Ryerson University)
Magneto-Acousto-Electrical Tomography: a New Imaging Modality for Electrical Impedance

We report our theoretical and experimental investigations on a new imaging modality for the electrical impedance of biological tissues, Magneto-Acousto-Electrical Tomography (MAET). In MAET, an ultrasound beam is focused into the sample located in a static magnetic field. The vibration of ions in the sample caused by the ultrasound can induce electric current through the mechanism of Lorentz force. Consequently, a voltage can be measured at the boundary of the sample. This voltage is proportional to the current density that exists at the ultrasound focal point when a unit current is injected into the sample through the measurement electrodes. If the ultrasound beam is scanned throughout the samples, the current density distribution in the sample can be mapped. After that, the electrical impedance of the sample may be reconstructed from the current density distribution. MAET combines the good contrast of electrical impedance tomography with the good spatial resolution of sonography. In the theoretical part, we provide the formulas for both the forward and inverse problems of MAET. In the experimental part, the experiment setup and methods are introduced and the current density image of a gelatin object by means of MAET are presented.

Yuan Yao (Stanford University)
Topology Learning of High Dimensional Probability Density Functions

We present some technique on learning from random examples the topology of level sets of a probability distribution or density function, possibly in high dimensional spaces. Given a set of random samples of high dimension, due to the curse of dimensionality it is generally a difficult task to estimate the underlying probability distribution or density, however it may be relatively easier to estimate the topology of density level sets, such as the number of local maxima, the way of connectivity, etc. With this motivation, we utilize the Equi-Energy sampler to sample the density level sets uniformly and develop new tools based on computational topology to analyze density level sets, which leads to a cellular decomposition of the pre-image of probability density functions, in a spirit of Morse theory for manifolds. The new tools are certain generalizations of cluster trees in statistics to higher dimensional complexes.

This work is in collaborationwith Gunnar Carlsson (Math, Stanford), Wing Wong (Stat, Stanford), and Qing Zhou (Stat, UCLA). NULL

Lauri Ylinen (University of Helsinki)
Two-Dimensional Tomography with Unknown View Angles

In the standard mathematical formulation of the parallel beam tomography the projection directions are assumed to be known. In some practical applications, however, these directions might be known only approximately or they might be completely unknown. The former occurs for example in magnetic resonance imaging due to involuntary motion of the patient, whereas the latter occurs in cryo-electron microscopy of viral particles. In the talk the author presents some new results about two-dimensional parallel beam tomography with unknown view angles, i.e. tomography in which the projection directions are unknown. The first result is that infinitely many projections at unknown view angles of a sufficiently asymmetric object determine the object uniquely. An explicit expression for the required asymmetry is given in terms of the objects geometric moments. The second result is about the uniqueness of determination of the unknown view angles by finitely many projections. The analysis is based on some algebraic geometric properties of a system of polynomials determined by the Helgason-Ludwig consistency conditions.

Hongkai Zhao (UC Irvine)
Fast sweeping method for convex Hamilton-Jacobi equations

I will present an efficient iterative method, the fast sweeping method, for computing the numerical solution of general static convex HJ equations on both structured and unstructured meshs. Convergence, error estimate and optimal complexity will be shown. Applications to travel time computations will be discussed.

Mariya Zhariy (Zuse Institute Berlin (ZIB))
Frame-Based Adaptive Strategies for Iteratively Solving Linear Ill-posed Inverse Problems

In this talk we present a frame-based adaptive algorithm for approximating the generalized solution of a linear inverse and ill-posed problem. Inspired by an adaptive concept, which was suggested by R. Stevenson and designed to solve well-posed operator equations, we suggest modifications/extensions on the scheme that allow also the application to ill-posed inverse problems. The adaptivity concept applied in the scheme is based on the best N-term approximation in the coefficient space. The structure of the adaptive algorithm suggests two possible extensions: First, stabilize the ill-posed problem via Tikhonovs method (which is known to be a regualirization method) in order to obtain a well-posed operator equation which then allows the application of the Stevensons adaptive concept in its original form. Second, construct a stopping criterion for Stevensons adaptive iteration such that the iteration itself becomes a regularization procedure. For both extensions of the method, regularization properties and optimality results are shown. The applicability of the proposed regularization methods is verified by adaptively inverting the linear Radon transform.

Jun Zou (The Chinese University of Hong Kong)
Inverse Obstacle Scattering: Some Theory and Numerics

In this talk we shall address some recent advances that have been achieved in the theory and numerics on inverse acoustic and electromagnetic obstacle scattering problems. The theoretical part will focus on the uniqueness in the inverse obstacle scattering and discuss how many far field measurement data one can use to uniquely determine the underlying scatterer of general polyhedral type, while the numerical part will review some efficient numerical methods for inverse obstacle scattering problems.

This is a joint work with Hongyu Liu. The work was substantially supported by Hong Kong RGC grants (project 404105 and project 404606).

Habib Zribi (Kyung Hee University)
Multi-frequency Electrical Impedance Tomography for Anomaly Detection and Imaging

Multi-frequency electrical impedance tomography (EIT) systems can be used for both frequency-difference imaging and anomaly detection. We formulate the forward problem as a pair of partial differential equations coupled through conductivity σ and permittivity ϵ distributions: $\nabla \cdot (\sigma \nabla v) - \nabla \cdot (\omega\epsilon \nabla h) = 0$ and $\nabla \cdot (\omega\epsilon \nabla v) + \nabla \cdot (\sigma \nabla h) = 0$ with appropriate boundary conditions where v and h are real and imaginary parts of a complex voltage $U = v + ih$. Here, we note that both σ and ϵ affect v and h. We describe a mathematical analysis of the coupled equations for anomaly detection and frequency-difference imaging. Explaining algorithms for anomaly detection and imaging, we present experimental results using conductivity phantoms.

Johanna Zumer (University of California, San Francisco)
Probabilistic methods for MEG source reconstruction incorporating noise suppression

Magnetoencephalography (MEG) and electroencephalography (EEG) are popular methods of noninvasively measuring the spatiotemporal characteristics of human neural activity. Both techniques record the effects of neural activity at the scalp with millisecond precision. The neural source is most often assumed to arise from a point dipole. However, the inverse problem of reconstructing the location and time course of sources is ill-posed and standard inverse methods have various shortcomings. Over-determined methods that parametrically fit a small number of dipoles do not allow for sources distributed in space and are limited by user assumptions of number and location of dipoles. Under-determined methods reconstruct activity over a large grid covering the brain. Within this framework, non-adaptive minimum norm techniques tend to have large localization bias. Adaptive minimum variance techniques have much less bias, but can fail if two or more sources are highly correlated in time. All techniques suffer from many sources of noise. Background on-going brain activity, stimulus equipment, and sensor noise can drown out brain signals of interest.

We present several algorithms for source localization of MEG/EEG data based on a probabilistic modeling framework. We assume a generative model of the sensor data that involves a summation of various contributions, including evoked brain sources of interest, background activity, and sensor noise. Each of the contributions can be written as a linear mixture of factors. In the case of the evoked sources of interest, the mixing matrix is the known forward field. For all other interference sources, the mixing matrix is unknown and learned. Additionally, all background activity and sensor noise are assumed to be present in both a pre-stimulus period as well as post-stimulus, whereas evoked sources are only present in post-stimulus time. This helps to remove all noise contributions for improved source localization of the evoked sources of interest. The first general type of method presented here assumes that all the evoked and background factors are unknown and learned from the data, whereas the second general type assumes that the temporal dynamics of the denoised evoked factors are first learned from the data, and then fixed and subsequently localized. Performance of both algorithms in simulations and real data demonstrate significant improvement over existing source localization methods.

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Local Guide

Welcome

The Pacific Institute for the Mathematical Sciences welcomes you to the University of British Columbia and to the Greater Vancouver area. As a sponsor and host to all those participating in the PIMS conferences and workshops, we hope to help make your stay as comfortable as possible.

The guide to follow is designed to provide visitors with a list of services at UBC and a brief overview of services for the Greater Vancouver area.

Vancouver has 10-digit dialing therefore you must dial the 604 area code before the 7-digit phone number for all local calls. From a UBC campus phone, you must dial 9 before the 10-digit number to access an outside line.

UBC Information

Dining

Opening hours given are for the months of May to August. Many establishments will have longer hours in September.

99 Chairs	2015 Main Mall Next to David Lam Centre	(Monday–Friday) 8:00am–4:00pm	604.822.3256
The Barn	2323 Main Mall	(Monday–Friday) 7:45am-3:30pm	604.822.3651
Caffe Perugia	2350 Health Sciences Mall (Life Sciences Centre)	(Monday-Thursday) 7:30am-5:00pm (Friday) 7:30am-4:30pm	604.827.3291
Edibles	2125 Main Mall Neville Scarfe Building Lecture Block Lower Level Room 10A	(Monday-Friday) 7:45am-1:45pm	604.822.6258
IRC Snack Bar	2194 Health Sciences Mall Instructional Resources Centre	(Monday-Friday) 7:45am-3:00pm	604.822.4291
Pond Cafe	2071 West Mall (Ponderosa Centre)	(Monday-Friday) 7:30am-2:30pm	604.822.3663

Sage sage.ubc.ca	6331 Crescent Road (University Centre)	**BREAKFAST** (Monday-Friday) 7:15am-9:00am **LUNCH** (Monday-Friday) 11:30am-2:00pm	604.822.0968 *Special Event Booking call* 604.822.0429
Starbucks	2332 Main (Fred Kaiser Lobby)	(Monday-Friday) 7:00am-3:00pm	604.827.5779
Steamies	6200 University Boulevard (UBC Bookstore Lobby)	(Monday-Friday) 9:30am-4:45pm	604.822.3461
Tim Hortons	2424 Main Mall at Forest Sciences Centre SW corner	(Monday-Friday) 7:00am-6:00pm	604.822.1953
Pacific Spirit Place (PSP)	6138 Student Union Boulevard (Student Union Building, Main Floor)	(Monday-Friday) **BAKE SHOP** 7:30am-2:00pm **BREAKFAST/ LUNCH BAR** 7:30am-2:00pm **SALAD BAR** 11:00am-2:00pm	604.822.3461
A&W (at PSP)	6138 Student Union Boulevard (Student Union Building, Main Floor)	(Monday-Friday) 7:30am-4:00pm	604.822.3461
Starbucks (at PSP)	6138 Student Union Boulevard (Student Union Building, Main Floor)	(Monday-Friday) 7:00am-6:00pm (Saturday) 8:00am-3:00pm	604.822.3461
Subway (at PSP)	6138 Student Union Boulevard (Student Union Building, Main Floor)	(Monday-Friday) 9:00am-6:00pm	604.822.3461
Place Vanier	1935 Lower Mall, Place Vanier (Gordon Shrum Common Block, Dining Room)	(Monday-Thursday) 7:15am-7:30pm (Friday) 7:15am-7:00pm (Weekends) 8:00am-7:00pm	604.822.2622

Trek Express Deli Bar	2015 Main Mall (Next to David Lam Research Centre)	(Monday-Friday) 10:30am-2:30pm	604.822.3256
Tim Hortons	2015 Main Mall (Next to David Lam Research Centre)	(Monday-Friday) 7:30am-3:30pm	604.822.3256

Alma Mater Society

6138 SUB Boulevard
www.ams.ubc.ca/businesses.cfm

Bernoulli's Bagels	*Genuine New York style bagels.* www.ams.ubc.ca/bernoulli	(Monday-Friday) 7:00am-2:30pm (Saturday) 10:00am-4:00pm	604.822.8806
Blue Chip Cookies	*Coffee and baked goods.* www.ams.ubc.ca/bluechip	(Monday-Friday) 7:00am-7:00pm (Saturday-Sunday) 9:00am-4:00pm	Call to order In advance 604.822.6999
Burger Bar	Located inside the Pit Pub www.ams.ubc.ca/burger		604.822.6511
Gallery Lounge	*Open Mic Mondays, Karaoke on Tuesdays, Gallery Night on Wednesdays, live bands on Thursdays and on Fridays are just a few events you will find in the Gallery.* www.ams.ubc.ca/gallery	(Monday-Friday) *Food service is from* 11:00am-9:00pm	
Honour Roll	*Sushi* SUB lower level www.ams.ubc.ca/honourroll	(Monday-Friday) 10:00am-5:00pm (Saturday) 11:00am-3:00pm	604.827.5589
The Moon	*Noodle Bar. Chinese fast food.* SUB basement. www.ams.ubc.ca/moon	(Monday-Friday) 11:00am-6:00pm	604.822.3164
Outdoor BBQ	At the south entrance to the SUB, you'll find the AMS Patio BBQ www.ams.ubc.ca/bbq	Bbq usually runs from 3rd week of March for as long as the weather holds on.	

The Pendulum	*Breakfast menu, sandwiches, Bagels, desserts, vegetarian Choices and licensed.* www.ams.ubc.ca/pendulum	(Monday-Thursday) 8:00am-8:00pm (Friday) 8:00am-4:00pm (Saturday) 11:00am-3:00pm	604.822.3411
Pie R Squared	*Pizza by the slice.* www.ams.ubc.ca/piersquared	(Daily) 10:00am-11:00pm	604.822.4396
Pit Pub	*Pub style food. SUB basement.* www.ams.ubc.ca/pit	(Monday-Tuesday) 12:00pm-12:00am (Wednesday-Saturday) 12:00pm–2:00am	Event info 604.822.5336
Snack Attack	*Gourmet hot dogs, donairs, soft tacos, malts and frozen yoghurt.* www.ams.ubc.ca/snackattack		604.822.3481

Other Outlets on Campus

Café Crepe	103 – 2151 Westbrook Mall *Serves French crepes with a variety of fillings. Includes both sit down and takeout. Bar within the restaurant*	(Daily) 8:30am-11:30pm	604.221.1142
The Boulevard Coffee Roasting Company	*Coffee, muffins, pastries*	Open 8am	
Mahony & Sons Public House	www.mahonyandsons.com *Menu includes salads, appetizers, pasta And rice bowls, sandwiches, pizza and Grilled chicken/meats.*	(Monday-Saturday) 11:00am-1:00am (Sunday)	604.827.4444

Shoppers (Drugmart) on Campus	5940 University Boulevard	(Monday-Sunday) 8:00am-10:00pm	604.253.1533
Copiesmart	103–5728 University Boulevard *Photocopying, scanning and Passport photos; located in the University Village next to McDonald's.* www.copiesmart.com	(Monday-Thursday) 8:30am-7:00pm (Friday) 8:30am-6:00pm (Saturday) 10:00am-6:00pm (Sunday) 12:00pm-6:00pm	604.222.3189
Discount Textbooks	#206 – 5728 University Boulevard	(Monday-Friday) 9:30am-5:00pm	604.221.1822
Copy Right	6138 SUB Boulevard SUB basement www.ams.ubc.ca/copyright	(Monday-Friday) 9:00am-5:00pm	604.822.4388
Postal Outlet	6138 SUB Boulevard SUB main floor *Courier service available.* www.ams.ubc.ca/canadapost	(Monday-Friday) 8:00am-6:00pm (Saturday) 10:00am-4:00pm	604.822.8196
Bank of Montreal	2142 Western Parkway Unit 105 UBC Village	(Monday-Friday) 9:30am – 5:00pm	604.665.7076
CIBC (Canadian Imperial Bank of Commerce)	5796 University Boulevard	(Monday-Wednesday) 9:30am-4:00pm (Thursday-Friday) 9:30am-5:00pm (Saturday) 9:30am-4:00pm	604.221.3550
Outpost	6138 SUB Boulevard *Canada Post & Ticketmaster.* www.ams.ubc.ca/outpost	(Monday-Friday) 9:00am-5:00pm (Saturday) 9:00am-4:00pm	604.822.6239
Granville Island Produce @ University	5767 Dalhousie Road	(Monday-Saturday) 9:00am-9:00pm (Sunday) 10:00am-9:00pm	604.677.3388

Starbucks	#112 – 5761 Dalhousie Road	(Monday-Saturday) 6:00am-11:00pm Sunday 7:00am-11:00pm	604.221.0200
Omio Japan	#115 – 5743 Dalhousie Road	(Daily) 11:00am-9:00pm	604.221.4514
Only U Cafe	#116 – 5737 Dalhousie Road	(Monday-Friday) 8:00am-8:00pm (Saturday & Sunday) 9:00am-3:00pm	604.221.6511
House of Vision Optical *One hour service*	5731 Dalhousie Road	(Monday-Friday) 10:30am-6:30pm (Saturday) 10:30am-5:00pm	604.225.0708
University Insurance	5727 Dalhousie Road	(Monday-Friday) 8:30am-6:00pm (Saturday) 10:00am-6:00pm	604.221.7080
Dollar "N" Plus *Dollar store*	5721 Dalhousie Road	(Monday-Thrusday) 8:30am – 8:30pm (Friday) 8:30am-9:00pm (Saturday) 9:00am-7:30pm (Sunday) 10:00am-7:00pm	604.228.9818
Pita Pit	5717 Dalhousie Road	(Monday-Saturday) 10:00am-11:00pm Weekends open until 1am	604.221.7488
Staples	#101- 2135 Allison Road www.staples.ca	(Monday-Saturday) 10:00am-6:00pm (Sunday) 12:00pm-5:00pm	604.221.4780

Gold's Gym	#23- - 2155 Allison Road www.goldsgymbc.ca	(Monday-Friday) 6:00am-10:00pm (Saturday & Sunday) 8:00am-8:00pm (Holidays) 9:00am-5:00pm	604.224.4653
Little Mountain Campus Academy	#224 – 2155 Allison Road http://www.lmacademics.com/		604.221.2363
One More Sushi	#222 – 2155 Allison Road	(Monday-Friday) 11:00am-3:00pm (Sat, Sun & Holidays) 12:00pm-10:00pm	604.228.9773
Rogers Wireless	2160 Western Parkway	(Monday-Friday) 11:00am-5:00pm Sat. & Sun Call for an appointment	604.221.5505 Or *811 free from mobile phone
Liquor Store	#102A – 2158 Western Parkway www.bcliquorstores.com	(Monday-Thursday) 10:30am-7:00pm (Friday) 10:30am-9:00pm (Saturday) 10:30-7:00pm	604.225.5220
Filomena's Day Spa	2166 Western Parkway www.filomenasdayspa.com	(Monday-Tuesday & Sat.) 10:00am-5:00pm (Wednesday & Friday) 10:00am-7:00pm (Thursday) 10:00am-6:00pm	604.222.3456
Prime News *(Tobacconist, Magazines & Gifts)*	2168 Western Parkway	(Monday-Thursday) 9:00am-7:30pm (Friday) 9:00am-9:30pm (Saturday & Holidays) 9:00am-7:00pm	604.221.1197

Damask Designs Inc. *Unique gifts*	2178 Western Parkway	(Monday-Saturday) 10:00am-6:00pm	604.739.6887
Pearl Fever *(Tea House)*	2182 Western Parkway	(Monday-Sunday) 11:00am-11:00pm	
DVD Zone	2138 Western Parkway	(Monday, Thursday & Sunday) 12:30pm-10:00pm (Friday & Saturday) 12:30pm-11:00pm	604.221.9355 *reservations*
Bakery	2136 Western Parkway	(Monday-Friday) 7:30am-7:00pm (Saturday) 8:30am-6:00pm	604.222.8886
Hannah & Samuel Flower Shop	2130 Western Parkway	(Monday-Thursday) 9:30am-7:00pm (Saturday) 10:00am-7:00pm	604.228.0113
Blenz	5784 University Boulevard	Winter Hours Weekdays 6:00am-12:00am Weekends 7:00am-11:00pm Summer Hours Weekdays 7:00am-11:00pm Weekends 8:00am-10:00pm	
IDA University Pharmacy	5754 University Boulevard	(Monday-Friday) 9:00am-8:00pm (Saturday, Sunday & Holidays) 10:00am-6:00pm	604.224.3203

UBC Marketplace

University Boulevard between
Western Parkway and Allison Road,
one block east of Westbrook Mall

Student Lucky Market	106 – 5728 University Boulevard	(Monday-Sunday) 9:00am-11:00pm	604.224.5131
University Dry Cleaners	105 – 5728 University Boulevard *GARMENT CARE & SHOE REPAIR SERVICE* www.universitydrycleaners.com	(Monday-Friday) 8:30am-6:00pm (Saturday) 10:00am-2:00pm	***FREE PICK-UP & DELIVERY*** 604.228.9414 604.307.7406
University Pizza	#205 – 5728 University Boulevard http://www.upass.ubc.ca/valupass/companies/universitypizza.html		604.222.2922
Limelight	203a – 5728 University Boulevard *Hair, Nail, Body*	Call for information and times	604.224.9188
Suga Sushi	201 – 5728 University Boulevard	(Monday-Saturday) 11:30am-3:00pm 5:00pm-9:30pm	604-228-9912
McDonald's	Burgers		604.221.5738

UBC Marketplace Foodfair

Located in the basement at:
5728 University Boulevard

A-1 Vietnamese Food	Soup, noodles		604.222.2128
Donair Town	Donairs, kebabs		604.221.4446
Timpo Mongolian	Mongolian		

Combo Express	Taiwanese		604.228.1038
Curry Point	East Indian		604.221.0112
Hong Kong Chinese Food	Chinese		604.222.1311
My Home Cuisine	Chinese		
Yi Kou Xiang Foods	Chinese		
Osaka Sushi	Japanese		
University Village Restaurant	5778 University Boulevard Chinese, budget, casual, take out	(Monday-Saturday) 11:00am-10:00pm Sunday 4:00pm-10:00pm	604.224.0640
Vera's Burgers	2188 Western Parkway http://www.verasburgershack.com *Reputedly Vancouver's best!*	Daily 11:00am-10:00pm	604.221.8372

Other Facilities on Campus

Libraries	Asian Library, David Lam Library, Main Library, Koerner Library, etc. www.library.ubc.ca		Main Library Information 604.822.6375
Triumf	4004 Wesbrook Mall Located at the South end of Westbrook mall. *Free tours of the world's largest Cyclotron.* www.triumf.info	September 1-May 31: Tours Wednesdays and Fridays at 1:00pm June 1-August 31: Tours Monday to Friday at 11:00am & 2:00pm	604.222.7355
UBC Bookstore	6200 University Boulevard www.bookstore.ubc.ca	(Monday-Friday) 9:30am-5:00pm (Saturday) 11:00am-5:00pm	604.ubc.book 604.822.2665

Recreational Activities on Campus

Aquatic Centre	6121 University Boulevard www.aquatics.ubc.ca	Call or check website for schedule	604.822.4522
Botanical Gardens	6804 SW Marine Drive *Oldest University Garden in Canada* *$7.00 Adults* www.ubcbotanicalgarden.org	March 17-October 10 (Open Daily) 10:00am-6:00pm	604.822.9666
Nitobe Gardens	6804 SW Marine Drive (Gate 4) *Japanese Gardens* *$5.00 Adults* www.nitobe.org	(Open Daily) 10:00am-6:00pm	604.822.6038
Chan Centre for the Performing Arts	6265 Crescent Road www.chancentre.com	Call or check website for information	604.822.9197
Student Recreation Centre	6000 Student Union Boulevard www.rec.ubc.ca	Call or check website for details	604.822.6000
UBC Tennis Centre	6160 Thunderbird Boulevard www.tennis.ubc.ca	(Daily) 8:00am-10:00pm	604.822.2505
UBC Golf Club	5185 University Boulevard *Licensed restaurant and driving range.* www.universitygolf.com www.ubcgolfclub.com	Call or check websites for details	604.224.7799
Pacific Spirit Regional Park	Parking: 4915 West 16th Avenue *Hiking and biking trails*	(Daily) 8:00am-9:00pm	604.224.5739
Pacific Museum of the Earth	6339 Stores Road www.eos.ubc.ca then click on museum	(Monday-Friday) 9:00am-5:00pm	604.822.2267

UBC Astronomical Observatory	2219 Main Mall www.astro.ubc.ca		604.822.2267
Norm Theatre	Located on the Main Concourse of the Student Union Building (next to Bernoulli's Bagels) Admission is $3.50 www.ams.ubc.ca/normtheatre	Call for info.	24 hr film hotline 604.822.3697

Medical Facilities

UBC Dental Clinic	2151 Westbrook Mall www.dentistry.ubc.ca/dental_clinic	End of August until end of June 8:00am-11:00am 2:00pm-5:00pm	604.822.2112
University Hospital	2211 Westbrook Mall www.vanhosp.bc.ca	24 hr emergency	604.822.7121
University Village Medical & Dental Clinic	228 – 2155 Allison Road University Village www.universityvillageclinic.com	(Monday-Friday) 8:00am-6:00pm	604.222.2273

Vancouver Information

DINING	**ON TENTH AVENUE** *Located within 10 mins. of campus*		
Candia Taverna	4510 West 10th Avenue	Traditional Greco-Roman	604.731.4135
Provence Mediterranean Grill	4473 West 10th Avenue	Provence Style	604.222.1980
Some Kinda Pasta	4409 West 10th Avenue	Italian	604.222.0220
The Diner	4556 West 10th Avenue	English Pub	604.224.1912

ON WEST BROADWAY
Located within 15 mins. of campus

Athene's	3618 West Broadway	Greek	604.731.4135
Fortune Gardens	1475 West Broadway	Chinese Seafood	604.736.6868
Ohako Sushi	1414 West Broadway	Japanese	604.732.0112
Raga Restaurant	1177 West Broadway	Indian	604.733.1127
Greens & Gourmet	2582 West Broadway	Vegetarian	604.737.7373

ON GRANVILLE ISLAND
Located within 25 mins. of campus
www.granvilleisland.bc.ca

Bridges	1696 Duranleau www.bridgesrestaurant.com	Continental	604.687.4400
The Keg	1499 Anderson	Steak / Seafood	604.685.4735

DOWNTOWN
Located within 25 mins. of campus

The Old Spaghetti Factory	53 Water Street	Italian	604.684.1288
La Bodega	1277 Howe Street	Spanish	604.684.8815
Sitar Restaurant	8 Powell Street	East Indian	604.687.0049
Won More	201 – 1184 Denman	Szechuan	604.688.8856
The Boathouse	1795 Beach	West Coast	604.669.2225
Yoshi on Denman	689 Denman	Japanese	604.738.8226

CHINATOWN
http://www.vancouverchinatown.ca
Located within 30 mins. of campus

Hon's Wun-tun House	108 – 268 Keefer Street	Cantonese Diner	604.685.0871
Pho Hoang	238 East Georgia Street	Vietnamese	604.682.5666
Phnom-Penh	244 East Georgia Street	Cambodian	604.682.5777

SCENIC VIEWS & FINE DINING

Bridges	1696 Duranleau www.bridgesrestaurant.com	Continental	604.687.4400
Monk McQueen's	601 Stamps Landing http://www.monkmcqueens.com/	Seafood	604.877.1351
Salmon House	2229 Folkestone Way West Vancouver http://www.salmonhouse.com/	Seafood	604.926.3212
Sequoia Grill at the Teahouse	Ferguson Point, Stanley Park http://www.vancouverdine.com/	Continental	604.669.3281
Chartwell	791 West Greorgia Street Four Seasons Hotel www.fourseasons.com/vancouver/dining.html	Continental	604.689.9333

LODGING — Bed & Breakfast

Kitsilano Heritage House	2455 West 6th Avenue www.kitsbb.com	604.732.8004
English Bay Inn	1968 Comox Street www.englishbayinn.com	604.683.8002
Maple House	1533 Maple Street www.maplehouse.com	604.739.5833
West End Guest House	1362 Haro Street www.westendguesthouse.com	604.681.2889

Hotels

Best Western Chateau Granville	1100 Granville www.chateaugranville.com	604.669.7070
Century Plaza Hotel	1015 Burrard Street www.century-plaza.com	604.687.0575
Coast Plaza at Stanley Park	1763 Comox Street www.coasthotels.com	604.688.7711
The Fairmont Hotel Vancouver	900 West Georgia Street http://www.fairmont.com/hotelvancouver/	604.684.3131
The Holiday Inn	711 West Broadway www.holidayinn.com	604.879.0511
The Listel Hotel	1300 Robson Street www.thelistelhotel.com	604.684.8461
The Barclay	1348 Robson Street www.barclayhotel.com	604.688.8850
Park Plaza Hotel Vancouver	898 West Broadway www.parkplaza.com/vancouverca	604.872.8661
Plaza 500	500 West 12th Avenue www.plaza500.com	604.873.1811
The Fairmont Waterfront Hotel	900 Canada Place Way www.fairmont.com/waterfront	604.691.1991
Sylvia Hotel	1154 Gilford www.sylviahotel.com	604.681.9321

Shopping

Vancouver

Chinatown http://www.vancouverchinatown.ca

Vancouver's Chinatown is the second-largest Chinatown in North America (after San Francisco's) and well worth a visit. Here you'll find everything from ginseng to green tea, fine embroidered linens, silk robes, splendid and exotic fresh produce plus traditional Chinese tableware and cooking utensils-plus one of the world's narrowest buildings (at the corner of Carrall and Pender). Located east of Downtown on Pender at Main.

Gastown http://www.gastown.org

If you're looking for Northwest Coast and Inuit art and crafts, head for historic Gastown. Two must-visit shops are the government licensed Inuit Gallery of Vancouver (345 Water St., 604-688-7323) and Images ForA Canadian Heritage (164 Water St., 604-685-7046).

Granville Island http://www.granvilleisland.bc.ca

If Granville Island had to be described in one word, it would be fresh. Fresh seafood, vegetables, plants, flowers, candy, fudge and baked goods. Artisans and craftsmen—potters, weavers, textile artists, designers, jewelers—all occupy a complex of once empty warehouses, foundries and machine shops. Check out local artists' work at the Circle Craft Co-op (1666 Johnstone St., 604-669-8021). The colourful Kids Only Market (1496 Cartwright, 604-689-8447) is geared to kids, from clothes to toys, but "accompanied" adults are welcome. Open 7 days a week10am-6pm.

Oakridge Centre http://oakridge.shopping.ca

Situated at Cambie and W 41st, it provides free parking. By transit, take bus #41. For trendy shopping in glass-covered comfort, the Oakridge Centre offers over 150 stores and services featuring fashions for the whole family, gift items, gourmet foods, books and numerous label retailers. Oakridge Centre also has its own movie theatre, located near the White Spot. The telephone number for Oakridge Centre is 604-261-2511.

Point Grey's West Tenth Avenue

This beautiful neighbourhood street runs from Alma to the University Gates with a casual mix of stores. A pleasant walk from UBC along the perimeter of the University Golf Club will lead you to this; one of the oldest communities in Vancouver.

Downtown

Pacific Centre Shopping Mall http://www.pacificcentre.com

You will find that Pacific Centre is a little closer to UBC. At 550-700 W Georgia in downtown Vancouver, it only takes one short bus ride to get to this large complex of stores, theatres and restaurants.

Robson Street http://www.robsonstreet.ca

On the map it's Robson Street, a "see and be seen" street for wining, dining and shopping. Robson is to Vancouver what Rodeo Drive is to Los Angeles. Browse the high-end fashion boutiques mixed among the coffee shops and small local run groceries in downtown Vancouver.

Richmond

Richmond Centre http://www.richmondcentre.com

With 240 stores and services, Richmond Centre has everything you need.
6551 No. 3 Road, Richmond
Open Mon-Tues 9:30am-6:00pm, Wed-Fri 9:30am-0:00pm, Sat 9:30am-6:00pm, Sun & Holiday 11:00am-6:00pm, 604-273-4828
http://www.richmondcentre.ca

Parker Place http://www.parkerplace.com

With more than 130 shops and services, Parker Place is the largest Asian shopping centre in British Columbia. Browse through European fashion boutiques, antique dealers, hi-tech Japanese electronic stores, authentic Chinese teashops, and exotic oriental grocery stores. Open daily 11am to 7pm and to 9pm on Friday and Saturday. Parker Place is located in Richmond on Number 3 Road and Cambie—nearby but a world away from the ordinary.

Aberdeen Centre

4400 Hazelbridge Way, Richmond
Open daily 11am-7pm, Thu-Sat 11am-9pm
http://www.aberdeencentre.com/
604-273-1234

Burnaby

Metrotown Shopping / Entertainment Complex http://metropolis.shopping.ca

Metrotown is BC's largest shopping complex with over 450 stores, services, theatres, and restaurants—including The Bay, Sears, Zellers, and Chapters. It is easy to get to by Sky Train, car or bus and there is free parking at all adjoining centers (Metrotown, Eaton's Centre and Station Square). Metrotown is located at 4700 Kingsway in Burnaby (604-438-3610).

Recreational Activities

Arts Club Theatre http://www.artsclub.com

This theatre, which is located on Granville Island, stages a variety of live theatre. The theatre telephone number is 604-687-1644. Tickets may be obtained from Ticketmaster (604-280-4444) or at the box office in the SUB building on the UBC campus.

Bard on the Beach http://www.bardonthebeach.org

Shakespeare's plays staged outdoors down by Kitsilano Beach in Vanier Park. The theatre telephone number is 604-739-0559. Tickets may be obtained from Ticketmaster (604-280-4444) or at the box office in the SUB building on the UBC campus.

Queen Elizabeth Theatre http://www.city.vancouver.bc.ca/theatres/qet/qet.html

Stages large live performances. Located downtown at Hamilton and Georgia St. The theatre telephone number is 604-665-3050. Tickets may be obtained from Ticketmaster (604-280-4444) or at the box office in the SUB building on the UBC campus.

The Centre in Vancouver for Performing Arts http://www.centreinvancouver.com

Stages mostly musicals. Located downtown at 777 Homer St. The telephone number is 604-602-0616. Tickets may be obtained from Ticketmaster (604-280-4444) or at the box office in the SUB building on the UBC campus.

5th Avenue Cinemas http://www.festivalcinemas.ca

Movie theatre located at 2110 Burrard. 24 Hour Info Line: 604-734-7469.

Hollywood Theatre

3123 West Broadway, Vancouver. See http://www.hollywoodtheatre.ca for information. Or call 604.738.3211 / 604.515.5864 24 hour hot line

Ridge Theatre

3131 Arbutus Street. See http://www.festivalcinemas.ca for information. Or call 604.732.3352

Silvercity Metropolis http://www.cineplex.com

Movie theatre is located inside Metrotown Shopping Centre, Burnaby.
Telephone: 604-435-7474

CN Imax Theatre http://www.imax.com/vancouver

Located at Canada Place in Downtown area. It features giant five-storey high screen and wraparound IMAX Digital Sound, IMAX and IMAX 3D films. Open daily for afternoon and evening features. Tickets can be purchased at the CN IMAX Theatre or by calling 604-682-4629.

Science World http://www.scienceworld.bc.ca
A hard to miss, giant silver ball, located at 1455 Quebec Street or 1/4 mile south of Main street sky train station. A Vancouver favourite, it features many exciting and eye-opening scientific activities, inventions and shows. Call 604-443-7443 for more information.

Vancouver Aquarium in Stanley Park www.vanaqua.org

Open 9:30am to 7:00pm daily. Admission: adults $19.95, youths, students, and seniors $14.95, children over 3 year old $11.95. Children 3 years and under FREE. Telephone: 604-659-3474.

Museums

UBC Museum of Anthropology http://www.moa.ubc.ca

Located at 6393 NW Marine Drive; Featuring some of the world's finest displays of Northwest Coast First Nations history and arts; Admission: adults $9, seniors $7, students $7 (free on Tue 5pm-9pm). Open daily 10am-5pm, Tue 10am-9pm. Call 604-822-5087 for further information.

Vancouver Museum http://www.vanmuseum.bc.ca

Located at 1100 Chestnut St. in Vanier Park in Kitsilano. It is Canada's largest civic museum and carries extensive collections in natural history, archaeology, ethnology and Asian arts. Open daily 10am-5pm, Thursday 10am-9pm. Admission: adults $10, seniors $8 youth $6. Before visiting, be sure to call 604-736-4431 for up-to-date programs.

The Chinese Cultural Centre Museum & Archives http://www.cccvan.com

Located at 555 Columbia Street. It is the first museum and archives dedicated to Chinese Canadian history and culture. Open Tue-Sun 11am-5:00pm (closed Monday).
Call 604-658-8880 for further information.

The Vancouver Police Centennial Museu http://www.vancouverpolicemuseum.ca

Located at 240 E. Cordova St. In addition to historical displays of some of Vancouver's best-known crimes (and the morgue where Errol Flynn lay after his death), you'll find a strong educational component and a modern hands-on atmosphere such as weaponry displays, and a 6'x 26' mural (110 year history of the Vancouver Police Department). Open Mon-Sat 9am-5pm year round. Closed over Easter holidays. Call 604-665-3346 for further information.

Galleries

Vancouver Art Gallery http://www.vanartgallery.bc.ca

Located at 750, Hornby St. (across from Hotel Georgia). International and local talents present a variety of exhibitions and collections that highlight BC's contemporary artists including an extensive Emily Carr exhibit. Talks, interpretive sites, Gallery shop and cafe are all well worth visiting. Open daily 10am-5:30pm, Thurs 10am-9pm. Admission: adults $12.50, seniors $9, students $8; Tuesday evenings by donation. Call 604-662-4719 -24 hour info line.

Crafthouse Gallery http://www.cabc.net/mem_sect/ChGall.html

Located at 1386 Cartwright St. in Granville Island. Call 604-687-7270 for admissions and other information.

Teck Gallery http://www.sfu.ca/artgallery/information.html

Located at 515 W. Hastings St. (SFU at Harbour Centre). Open Mon-Fri 10am-4pm. Call 604-291-4266 for admissions and other information.

Equinox Gallery http://www.equinoxgallery.com

Located at 2321 Granville, Downtown. Open Tue-Sat 10am-5pm. Call 604-736-2405 for appointment.

Vancouver Public Library http://www.vpl.ca

Central library is located at 350 W. Georgia St. (southwest of Queen Elizabeth theatre and between Georgia and Robson). This massive architectural gem is definitely worth seeing. For central branch's and other local branches' opening hours or any other information, call 604-331-3603.

Transportation

Automobile Rental

Budget Car Rental	www.budget.ca	604.668.7000
National Car Rental	www.nationalcar.ca	604.738.6006
Lo-Co$t Rent-A-Car	www.locost.com	604.689.9664
Discount Car and Truck Rentals	www.discountcar.com	604.310.2277
Thrifty	www.thrifty.com	604.681.4869
Rent-A-Wreck	www.rentawreck.ca	1.800.327.0116

Bicycle Rental

Bike Co-Op (on campus!)	www.bikecoop.ca	604.827.7333
Alley Cat Rental	1779 Robson Street	604.684.5117
Bayshore Bicycles & Rollerblades	745 Denman Street www.bayshorebikerentals.ca	604.688.2453
Bikes 'N Blades		604.602.9899
Spokes	1798 West Georgia Street www.spokesbicyclerentals.com	604.688.5141
Steveston Bicycle & Kayak	4924 Chisholm, Ladner	604.271.5544

Taxi Cabs

MacLures Taxi	www.maclurescabs.com	604-683-6666
Black Top \ Checker Cabs		604-731-1111
Bonny's Taxi		604-435-6655
Yellow Cab		604-681-1111
Vancouver Taxi	www.vancouvertaxi.ca	604-871-1111

Public Transit

Bus, Sea Bus and Sky Train Service. Call Customer Info for specific directions or follow the bus route map to where you want to go.

Translink Customer Information	www.translink.bc.ca	604-953-3333
Lost Property		604-682-7887

Medical Facilities

Broadway and Burrard Walk-In Clinic	Drop-in clinic 1816 W. Broadway	Open Daily 9am-9pm	604-736-1888
Granville Medical Clinic	Drop-in clinic 2578 Granville Street	Mon-Fri 8:30am-9pm Sat/Sun 9am-5pm	604-733-4700
Kitsilano Medical Clinic	Drop-in clinic 206-2678 W Broadway	Mon-Fri 9am-5pm	604-737-2699

Canadian Goods and Services Tax

There is a 7% Goods and Services Tax currently in effect in Canada. Visitors may be able to obtain an instant GST rebate by submitting all GST receipts (up to $500 CAN) to a participating duty-free shop when they exit Canada. Alternatively, they may file for a GST refund with Revenue Canada and be reimbursed by cheque. For information on how to receive your tax refund on GST please visit the website www.cra-arc.gc.ca or call the following numbers:

From inside Canada	902-432-5608
From outside Canada	1-800-668-4748

There is also a non-refundable provincial sales tax of 7% in effect in BC.

Tourism Vancouver

Visit the Vancouver Tourist info centre at 200 Burrard Street or at www.tourismvancouver.com or call 1-800-663-6000.

The *Georgia Straight* is Vancouver's top-rated weekly magazine, featuring the best in movies, music, the arts, restaurants, sports, outdoors, and travel. Pick up a free copy at the UBC Bookstore or outside the Pendulum restaurant in the SUB basement.

2007 HSBC Celebration of Light

www.hsbccelebrationoflight.com/fireworks/

Event Information

The largest fireworks competition in the world.

2007 Schedule

Wednesday, July 25 – Spain
Saturday, July 28 – Canada
Wednesday, August 1 – China
Saturday, August 4 – Celebration Finale

Each show is approximately 25 minutes

Location: English Bay, Vancouver

Start time: 10:00 p.m. rain or shine

Best viewing points: English Bay, Kitsilano, Vanier Park, Jericho Beach, West Vancouver. The event is **free** to watch from public parks and beaches.

Music simulcast begins at 10:00 p.m. on radio station ROCK 101 (101.1 FM).

Estimated annual attendance: 1.4 million people.

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AIP Reception

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(Free, served with red wines and white wines)

Date and time: Monday, June 25, 2007 at 7:30pm
Location: Rich Ocean Seafood Restaurant (See map on page 184)
Address: Room 108 - 777 West Broadway Vancouver, BC (at Willow Street.)
Vancouver B.C. V5Z 1T5
Tel: 604 876-8388

To Rich Ocean Restaurant:

Method 1:

- Take bus #99 at the UBC bus loop. Departure time: 6:52pm, 7:00pm, 7:08pm, 7:16 (every 8-10 min)
- Get off at Willow St. (You will see Holiday Inn on the opposite side, about 20 min)
- Bus #99 return times to UBC: 9:00pm, 9:12pm, 9:24pm, 9:36pm, 9:48pm, 10:00pm (every 10-12 min)

Method 2:

- Take a taxi (about $20-$25 CAD from UBC for a one-way trip)

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AIP Dinner Banquet

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($35/person, free soft drinks but alcoholic beverages at your own cost)

Date and time: Thursday, June 28, 2007 at 7:45pm
Location: Sun Sui Wah Seafood Restaurant (See map on page 185)
Address: 3888 Main Street (at 23rd Avenue) Vancouver B.C. V5V 3N9
Tel: 604-872-8822
Toll Free: 1-866-872-8822

To Sun Sui Wah Restaurant:

Method 1:

- Take bus #25 at the UBC bus loop. Departure time: 6:10pm, 6:25pm, 6:40pm, 6:55pm, 7:10pm, 7:25pm, 7:40pm
- Get off at Main and King Edward (a.k.a. 25th Ave, about 30 min)
- Walk up to 23rd Avenue (5 min)
- Bus #25 return times (to UBC): 9:10pm, 9:25pm, 9:40pm, 10:10pm, 10:40pm, 11:09pm, 11:39pm

Method 2:

- Take 99 to Main and get off at Main street
- Take #3 south on Main to 22nd (about 10 minutes)

Method 3:

- Take a taxi (about $20-$25 CAD from UBC for a one-way trip)

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Note

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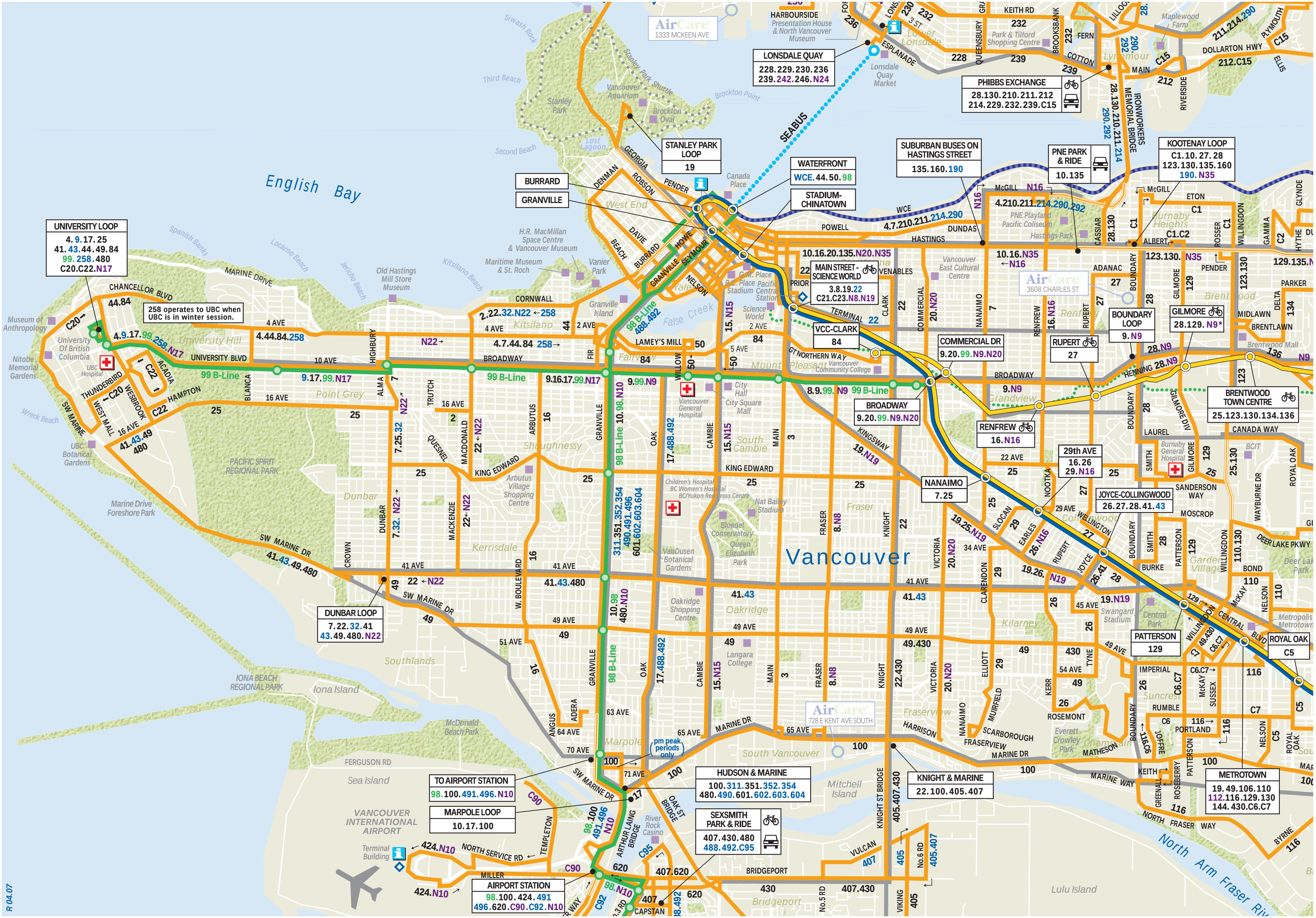
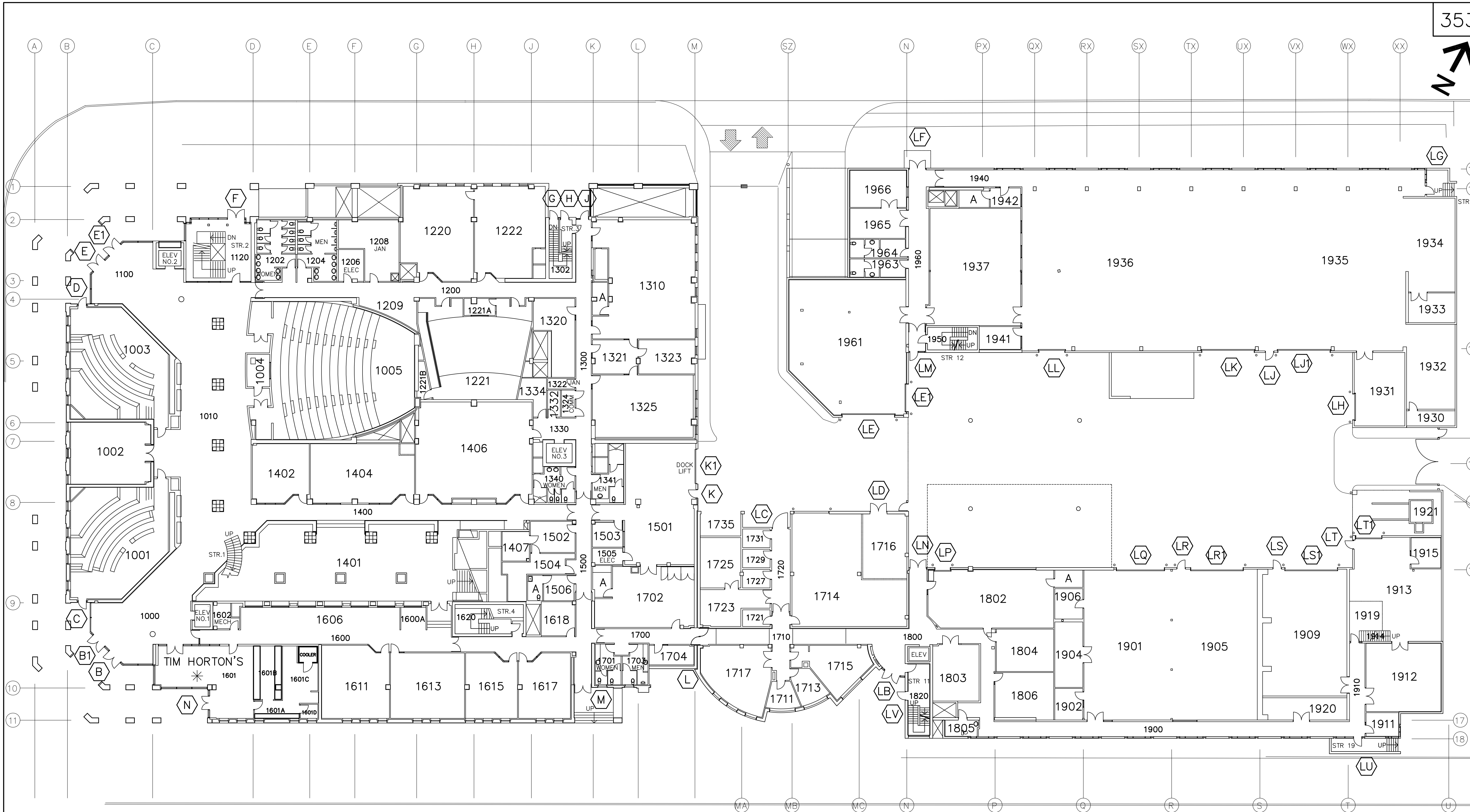
- Bus fare within Vancouver is $2.25 for 1 zone ($1.50 seniors)
- Exact change required.
- Bus transfer lasts 90 minutes no matter how many switches.
- Books of 10 tickets available for $18 (sold at UBC Outpost in Student Union Building)


English Bay
Vancouver
UNIVERSITY LOOP
4.9.17.25
41.43.44.49.84
99.258.480
C20.C22.N17
258 operates to UBC when UBC is in winter session.
BURRARD
GRANVILLE
STANLEY PARK LOOP
19
WATERFRONT
WCE.44.50.98
STADIUM-CHINATOWN
LONSDALE QUAY
228.229.230.236
239.242.246.N24
PHIBBS EXCHANGE
28.130.210.211.212
214.229.232.239.C15
SUBURBAN BUSES ON HASTINGS STREET
135.160.190
PNE PARK & RIDE
10.135
KOOTENAY LOOP
C1.10.27.28
123.130.135.160
190.N35
MAIN STREET-SCIENCE WORLD
3.8.19.22
C21.C23.N8.N19
VCC-CLARK
84
COMMERCIAL DR
9.20.99.N9.N20
RUPERT
27
BOUNDARY LOOP
9.N9
GILMORE
28.129.N9*
BRENTWOOD TOWN CENTRE
25.123.130.134.136
BROADWAY
9.20.99.N9.N20
RENFREW
16.N16
29th AVE
16.26
29.N16
NANAIMO
7.25
JOYCE-COLLINGWOOD
26.27.28.41.43
PATTERSON
129
ROYAL OAK
C5
METROTOWN
19.49.106.110
112.116.129.130
144.430.C6.C7
DUNBAR LOOP
7.22.32.41
43.49.480.N22
TO AIRPORT STATION
98.100.491.496.N10
MARPOLE LOOP
10.17.100
HUDSON & MARINE
100.311.351.352.354
480.490.601.602.603.604
KNIGHT & MARINE
22.100.405.407
SEXSMITH PARK & RIDE
407.430.480
488.492.C95
AIRPORT STATION
98.100.424.491
496.620.C90.C92.N10
AirCare 1333 MCKEEN AVE
AirCare 3608 CHARLES ST
AirCare 728 E KENT AVE SOUTH
VANCOUVER INTERNATIONAL AIRPORT
Terminal Building
SEABUS
99 B-Line
98 B-Line
pm peak periods only
Stanley Park
University of British Columbia
Pacific Spirit Regional Park
Iona Beach Regional Park
Sea Island
Mitchell Island
Lulu Island
North Arm Fraser River
R 04.07



✳ DENOTES LAST REVISION

No.	DATE	PROJ. No.	DWG. No.	BY
02	16-APR-07		353-06-128	JEL
01	08 MAR 99		SITE CHECK	AI

BUILDING: FOREST SCIENCES CENTRE

ADDRESS: 2424 Main Mall, V6T 1Z4

CONSTRUCTION DATE: 1998

FLOOR: GROUND

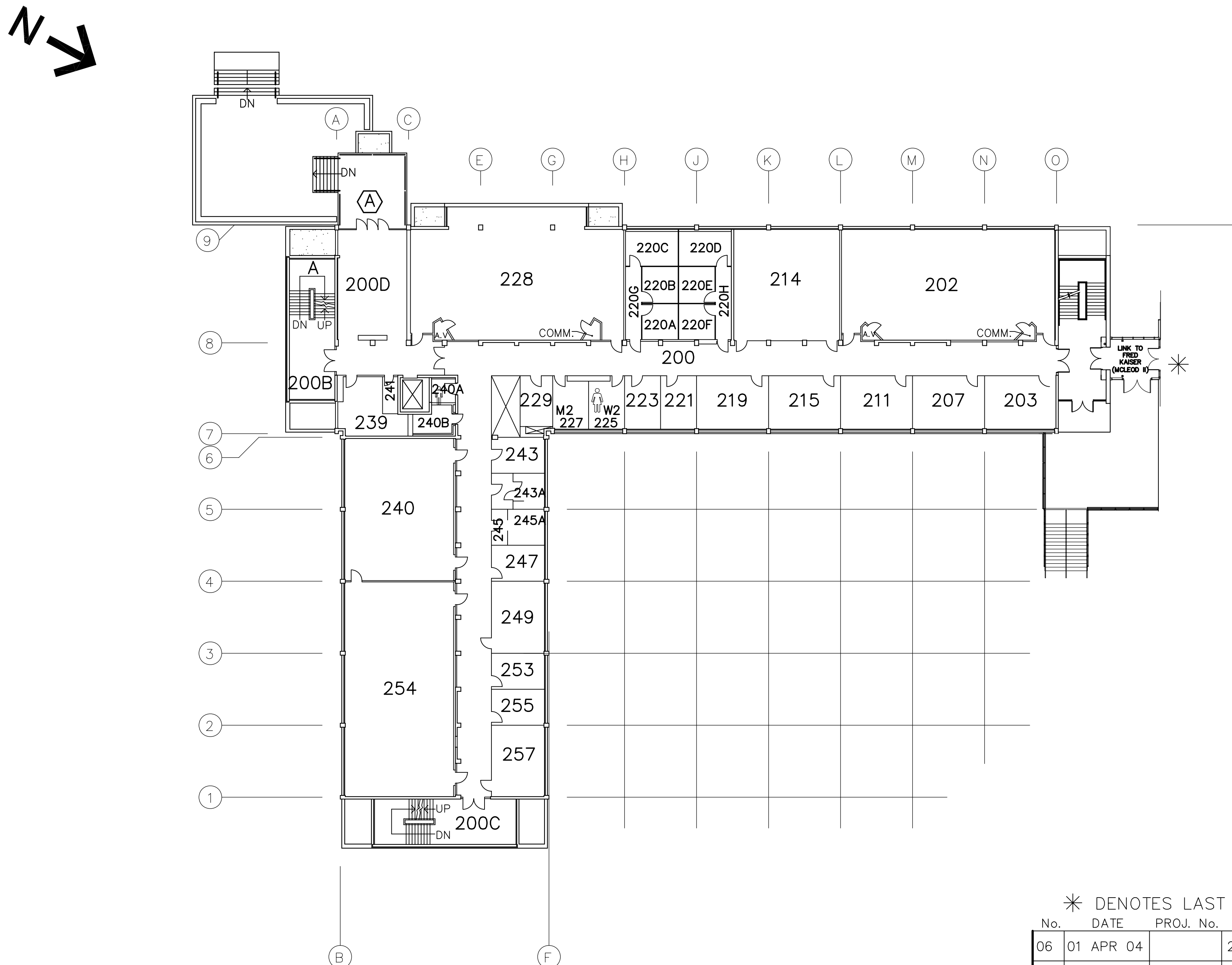
SCALE: 1=400

KEYPLAN DATE: 27 MAY 97

DRAWN: AI

VEC

312



\KEYPLANS\312\312--A2.DWG

✳ DENOTES LAST REVISION

No.	DATE	PROJ. No.	DWG. No.	BY
06	01 APR 04		200–B/ BRIDGE	JEL
08	25 JAN 06		313–06–006	KAC
07	22 NOV 04	312–8826	LEN SORBO	DCB

UBC BUILDING: MacLEOD BUILDING	ADDRESS: 2356 Main Mall, V6T 1Z4		CONSTRUCTION DATE: 1963
	FLOOR: SECOND	SCALE: 1"= 40'	KEYPLAN DATE: 28 JAN 93 / DRAWN: AI / DIG