FIELDS INSTITUTE
Research in Mathematical Sciences
222 COLLEGE STREET, 2ND FLOOR
TORONTO, ONTARIO M5T 3J1 CANADA
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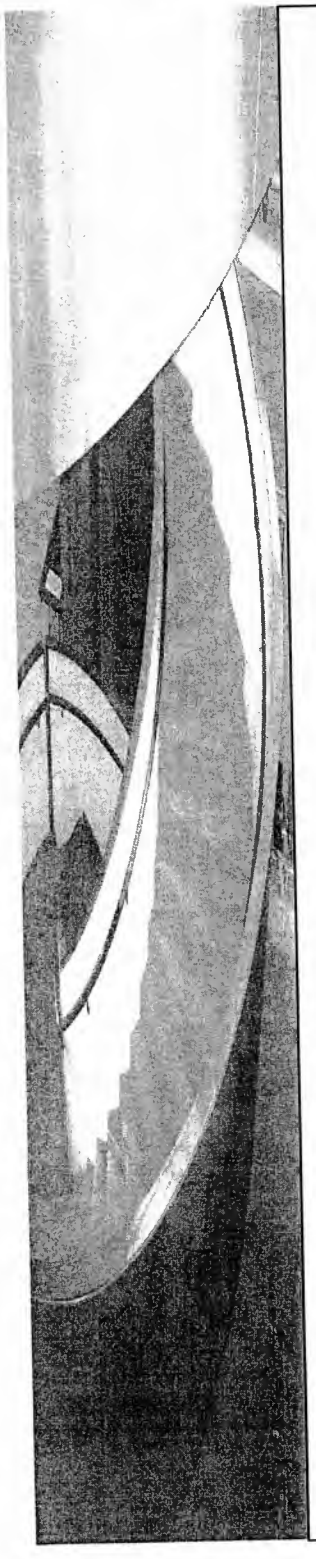
www.fields.utoronto.ca

FIELDS

A focal point for excellence in mathematics, bridging research, education and industry.



CONFERENCE ON MATHEMATICS OF MEDICAL IMAGING

Hosted by the Fields Institute
Held at the University of Toronto, Medical Sciences Building

June 20-24, 2011

Organizing Committee:
Adrian Nachman, Dhavide Aruliah, Hongmei Zhu

Sponsors:

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MITACS

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Major funding is provided by the Ontario Ministry of Training, Colleges and Universities and the federal Natural Sciences and Engineering Research Council (NSERC).

Our seven principal sponsoring universities are: Carleton University, McMaster University, the University of Ottawa, the University of Toronto, the University of Waterloo, the University of Western Ontario, and York University.

In addition there are sixteen affiliate universities: Brock University, Lakehead University, Nipissing University, Queen's University, the Royal Military College of Canada, Ryerson University, the University of Guelph, the University of Houston, Iowa State University, the University of Manitoba, the University of Maryland, the University of Ontario Institute of Technology, the University of Saskatchewan, the University of Windsor, Trent University, and Wilfrid Laurier University.

The Corporate Affiliate Members of the Fields Institute are: Algorithmics, General Motors, QWeMA Group Inc., R2 Financial Technologies Inc., and Sigma Analysis and Management.

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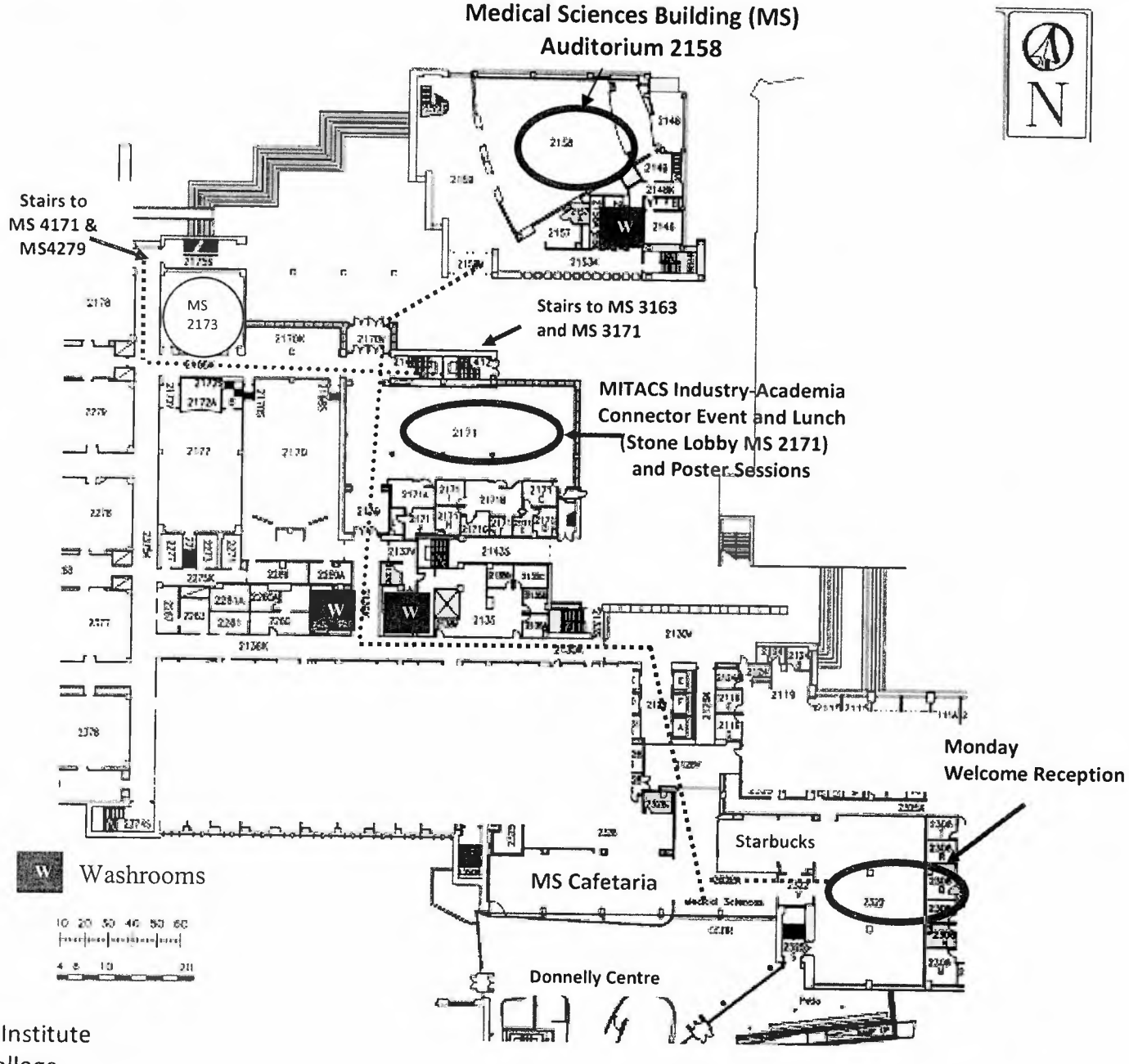
MEDICAL SCIENCES BUILDING MAP



Fields Institute
222 College

College Street

Health Sciences
155 College Street

The Medical Sciences Building is also accessible
through the Donnelly Centre to the south.

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SCHEDULE 1.1

S1 **New Hybrid Modalities in Medical Imaging** Organizers: Guillaume Bal (Columbia University), John Schotland, (University of Michigan)	S.6 **Numerical Methods in Imaging** Organizer: Eldad Haber (University of British Columbia)	S.11 **Mathematical Methods in Biophotonics: Charting a Course for New Opportunities** Organizers: Alex Vitkin (University of Toronto), Brian Wilson (Ontario Cancer Institute and University of Toronto)
S2 **Computational Hemodynamic Imaging** Organizers: David Steinman (University of Toronto), Alessandro Veneziani (Emory University)	S.7 **Recent Progress on Tomography** Organizer: David Finch, (Oregon State University)	S.12 **Statistical Methods in Medical Imaging** Organizer: Hanna Jankowski (York University)
S3. **Advances on Numerical Methods for Electrical Impedance Tomography** Organizer: Samuli Siltanen (University of Helsinki)	S.8 **Cardiac image segmentation and registration** Organizers: Perry Radau (Sunnybrook Health Sciences), Graham Wright (Sunnybrook Health Sciences and U. of Toronto)	S.13 **Graph-Based Methods in Medical Imaging** Organizer: Paul Dufort (University Health Network)
S4 **Dynamic Image Analysis** Organizers: Anne Martel (Sunnybrook Health Sciences), Stephen Strother (Rotman Research Institute and University of Toronto)	S.9 **Imaging Electric Properties of Tissues** Organizers: Alexandru Tamasan (University of Central Florida), Michael Joy (University of Toronto)	S.14 **Brain Imaging** Organizers: Adrian Crawley (Toronto Western Hospital)
S5 **Medical Imaging: Mathematical Methods and Industrial Applications** Organizers: Siv Sivaloganathan (Centre for Mathematical Medicine and University of Waterloo), Edward Vrscay (University of Waterloo), Arsen Hajian(Tornado Medical Systems and Arjae Enterprises)	S.10 **Compressed Sensing in Medical Imaging** Organizers: Hongmei Zhu (York University), Adrian Nachman (University of Toronto)	S.15 **Magnetoencephalography** Organizer: Douglas Cheyne (SickKids and University of Toronto)
S.C. Contributed Talks Organizer: Dhavide Aruliah (University of Ontario Institute of Technology)		

Schedule Overview

Monday, June 20							
8:00-8:30	Morning Coffee and Registration (Med Sci Auditorium, MS 2158 Lobby)						
8:30-8:45	**MS 2158**	Welcome & Introduction					
8:30-9:30	**MS 2158** Plenary Talk	**Lihong V. Wang**, Washington University, St. Louis *Photoacoustic Tomography: Ultrasonically Breaking through the Optical Diffusion Limit*					
9:35-10:20	**MS 2158** Plenary Talk	**Guillaume Bal**, Columbia University *Hybrid Inverse Problems and Internal Functionals*					
10:25-10:50	Coffee Break						
10:50-11:35	**MS 2158** Plenary Talk	**Michael I. Miller**, Johns Hopkins University *Diffeomorpic Shape Momentum in Computational Anatomy and Neuroinformatics*					
11:40-12:25	**MS 2158** Plenary Talk	**Anne Martel**, Sunnybrook Health Sciences *Assessing response of cancer to therapy using MRI*					
12:25-2:10	Lunch Break						
	Special Sessions						
Room	**MS 2158**	**MS 2173**	**MS 3163**	**MS 4279**	**HS 100**	**HS 106**	**HS 108**
2:10-3:10	-	S3	S1	S2	SC	-	S4
3:10-3:40	Coffee Break						
3:40-5:40	-	S3	S1	S2	SC	S14	S4
5:45-7:00	**Welcome Reception** (Cash Bar); **MS 2322** (Cafeteria)						

FIELDS

SCHEDULE 1.1

Tuesday, June 21		
8:30-8:45	Morning Coffee	
8:45-9:30	**MS 2158** Plenary Talk	**Gunther Uhlmann**, UC Irvine and University of Washington *Thermoacoustic tomography with a variable sound speed*
9:35-10:20	**MS 2158** Plenary Talk	**Yoram Rudy**, Washington University, St. Louis *Noninvasive Electrocardiographic Imaging (ECGI) of Cardiac Electrophysiology and Arrhythmia*
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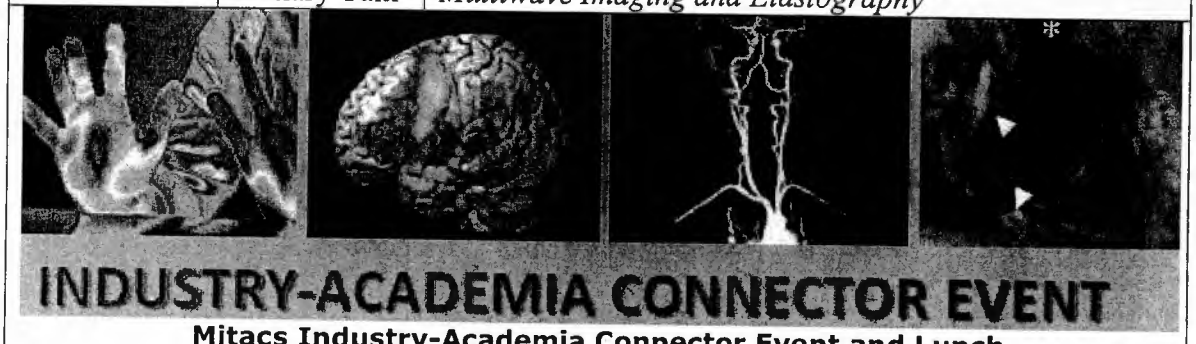
11:40-12:25	**MS 2158** Plenary Talk	**Justin Romberg**, Georgia Institute of Technology *A Survey of Compressed Sensing and Applications to Medical Imaging*
12:25-2:10	Lunch Break	

	Special Sessions						
Room	**MS 2158**	**MS 2173**	**MS 3163**	**MS 3171**	**MS 4171**	**HS 106**	**Fields Institute**
2:10-3:10	-	S8	S1	S7	S2	S15	S5
3:10-3:40	Coffee Break						
3:40-5:40	-	S8	S10	S7	-	S15	S5

FIELDS

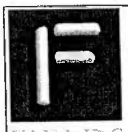
SCHEDULE 1.1

Wednesday, June 22		
8:30-8:45	Morning Coffee	
8:45-9:30	**MS 2158** Plenary Talk	**Charles Epstein**, University of Pennsylvania *New approaches to the numerical solution of Maxwell's Equations*
9:35-10:20	**MS 2158** Plenary Talk	**Samuli Siltanen**, University of Helsinki *Low-dose three-dimensional X-ray imaging*
10:25-10:50	Coffee Break	
10:50-11:35	**MS 2158** Plenary Talk	**Xavier Pennec**, INRIA Sophia Antipolis *Statistical Analysis on Manifolds in Medical Image Analysis*
11:40-12:25	**MS 2158** Plenary Talk	**Mathias Fink**, Universite Paris 7 *Multiwave Imaging and Elastography*



Mitacs Industry-Academia Connector Event and Lunch (Stone Lobby, MS 2171)

12:30-1:40	**Stone Lobby**	Lunch: Introductions to MITACS programs, the Focus Period and the Participating Companies.
1:40-2:00	**Stone Lobby**	Discussion: success stories, from the PDF and Industrial Perspectives
2:10-3:00	**MS 2158** Special Plenary Talk	**David Jaffray** Fidani Chair and Head, Radiation Therapy Physics Princess Margaret Hospital Vice Chair and Professor, Department of Radiation Oncology Professor, Department of Medical Biophysics and IBBME University of Toronto
3:00-5:40	**Stone Lobby**	Coffee, Networking, Discussion & Poster Session



SCHEDULE 1.1

Thursday, June 23					
8:30-8:45	Morning Coffee				
8:45-9:30	**MS 2158** Plenary Talk	**Polina Golland**, Massachusetts Institute of Technology *Non-parametric Atlas-Based Segmentation of Highly Variable Anatomy*			
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Room	**MS 2158**	**MS 2173**	**MS 3163**	**MS 3171**	**MS 4279**
2:10-3:10	S6	S12	S9	S11	-
3:10-3:40	Coffee Break				
3:40-5:40	S6	S12	S9	S11	-

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SCHEDULE 1.1

Friday, June 24						
8:30-8:45	Morning Coffee					
8:45-9:30	**MS 2158** Plenary Talk	**Emil Sidky**, University of Chicago *What does compressive sensing mean for X-ray CT and comparisons with its MRI application*				
9:35-10:20	**MS 2158** Plenary Talk	**Ender Konukoglu**, Microsoft Research, Cambridge *Personalizing Mathematical Models with Sparse Medical Data: Applications to Tumor Growth and Electrocardiophysiology*				
10:25-10:50	Coffee Break					
10:50-11:35	**MS 2158** Plenary Talk	**Elsa Angelini**, Telecom-Paris Tech *Compressed Biological Imaging*				
11:40-12:25	**MS 2158** Plenary Talk	**Aaron Fenster**, Robarts Research Institute *Use of 3D Ultrasound Imaging in Diagnosis, Treatment and Research*				
12:25-2:10	Lunch Break					
	Special Sessions					
Room	**MS 2158**	**MS 2173**	**MS 3163**	**MS 3171**	**MS 4171**	**MS 4279**
2:10-3:10	-	S3	S9	S5	-	S13
3:10-3:40	Coffee Break					
3:40-5:40	-	S3	S10	S5	-	S13

Schedule by Day

Monday, June 20

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(MedSci Auditorium, MS 2158 Lobby)

8:30-8:45 Welcome & Introduction *(MS 2158)*

8:45-9:30 Plenary Talk, **Lihong V. Wang**, Washington University
Photoacoustic Tomography: Ultrasonically Breaking through the Optical Diffusion Limit (MS 2158)

9:35-10:20 Plenary Talk, **Guillaume Bal**, Columbia University
Hybrid Inverse Problems and Internal Functionals (MS 2158)

10:25-10:50 Coffee Break (MS 2158 Lobby)

10:50-11:35 Plenary Talk, **Michael I. Miller**, Johns Hopkins University
Diffeomorpic Shape Momentum in Computational Anatomy and Neuroinformatics (MS 2158)

11:40-12:25 Plenary Talk, **Anne Martel**, Sunnybrook Health Sciences
Assessing response of cancer to therapy using MRI (MS 2158)

12:30-2:10 Lunch Break

2:10-2:35 S1 **Simon Arridge,** University College London
Quantitative PhotoAcoustic Tomography using Diffusion and Transport Models (MS3163)

S2 **Jean-Frederic Gerbeau,** INRIA Paris-Rocquencourt
MagnetoHemoDynamics in MRI devices (MS 4279)

S3 **Jennifer Mueller**, Colorado State University
Direct Electrical Impedance Tomography Reconstructions of Nonsmooth Conductivities (MS2173)

S4 **Bojana Stefanovic,** Sunnbrook Research Institute
In Vivo Imaging of Cerebral Hemodynamics with Two Photon Fluorescence Microscopy (HS 108)

SC **Michael Smith,** University of Calgary
Moving the Best Ideas from 1985's Constrained Reconstruction Techniques into 2011's Compressed Sensing Reconstruction (HS 100)

2:40-3:05 S1 **Claude Boccara,** Institut Langevin ESPCI-ParisTech
Wavefront Control and Optical Tomography of Scattering Media (MS3163)

S2 **Umberto Morbiducci,** Politecnico di Torino
Visualization and Quantification of Blood Flow in the Human Aorta. From in vivo 4D Phase Contrast MRI to Subject-Specific Computational Hemodynamics (MS 4279)

S3 **Fabrice Delbarry**, Technical University of Denmark
Electrical Impedance Tomography: 3D Reconstructions Using Scattering transforms (MS2173)

S4 **Nathan Churchill**, University of Toronto and Rotman Research Institute
Data-Driven Measurement and Removal of Physiological Noise in BOLD fMRI (HS 108)

SC **Lakshminarayan V. Chinta**, Sunnybrook Research Institute
Quantitative Perfusion Estimation from Two Photon Fluorescence Microscopy Microvasculature Maps (HS 100)

3:10-3:35 Coffee Break (MS 2158 Lobby)

3:40-4:05 S1 **Kui Ren,** University of Texas at Austin
Numerical Solution of Inverse Helmholtz Problems with Interior Data (MS3163)

S2 **Jordi Alastruey-Arimon,** Imperial College London
Reducing the Data: Analysis of the Role of Vascular Geometry on the Features of Blood Flow in Curve Vessels (MS 4279)

S3 **Ville Kolehmainen**, University of Eastern Finland
Compensation of Modelling Errors Due to Unknown Domain Boundary in Electrical Impedance Tomography (MS2173)

S4 **John Sled,** Hospital for Sick Children
Growth Dynamics in the Mouse (HS 108)

S14 **Jason Lerch**, Hospital for Sick Children
Detecting small changes in the brain with structural MRI (HS 106)

SC **Qiong Wu**, McMaster University
A Semi-Definite, Nonlinear Model for Optimizing k-Space Sample Separation in Parallel Magnetic Resonance Imaging (HS 100)

4:10-4:35

S1 **Andreas Mandelis,** University of Toronto
The Biomedical Photoacoustic Radar Imager: Principles, Signal-to-Noise Ratio, Contrast and Resolution (MS 3163)

S2 **Shawn Shadden,** Illinois Institute of Technology
Transport Studies of Patient Specific Hemodynamics: Methods of Modeling and Characterization (MS 4279)

S3 **Alexander Mamonov**, University of Texas at Austin (talk presented by **Fernando Guevara Vasquez**)
Resistor Networks and Optimal Grids for Electrical Impedance Tomography with Partial Boundary Measurements (MS 2173)

S4 **Hai-Ling Margaret Cheng,** Hospital for Sick Children
Quantitative Dynamic Contrast-Enhanced MRI (DCE-MRI) of Tumor Angiogenesis (HS 108)

S14 **Ragini Verma**, University of Pennsylvania
Analyzing Diffusion MRI Based "Connectivity" for Diagnosis (HS 106)

SC **Yogesh Chinta Venkateswarao,** McMaster University
Sparse Sampling of Velocity MRI (HS 100)

4:40-5:05

S1 **Amir Moradifam,** University of Toronto
Conductivity Imaging from One Interior Measurement in the Presence of Perfectly Conducting and Insulating Inclusions (MS 3163)

S2 **Elena S Di Martino,** University of Calgary
Wall Stress and Flow Dynamics in Abdominal Aortic Aneurysms (MS 4279)

S3 **Fernando Guevara Vasquez**, University of Utah
Uncertainty Quantification in Resistor Network Inversion (MS 2173)

S4 **Hatef Mehrabian**, University of Toronto
Application of Independent Component Analysis (ICA) to Identify and Separate Tumor Arterial Input Function (AIF) in Dynamic Contrast Enhanced MRI (HS 108)

S14 **Cheryl Grady**, Rotman Research Institute
The Use of Multivariate Methods for the Analysis of fMRI Studies of Cognition (HS 106)

SC **Jessica L. M. Pavlin,** McMaster University
Determining a Flow Profile from Multi-Scale Phase Contrast Angiographic MRI Data (HS 100)

5:10-5:35 S1 **Sarah Patch,** University of Wisconsin Milwaukee
Thermoacoustic Imaging over Large Fields of View (MS 3163)

S2 **Irene Vignol-Clementel,** INRIA Paris-Rocquencourt, France
From Imaging and Hemodynamic Data to Patient-Specific Simulations of Glenn to Fontan Conversion (MS 4279)

S3 **Fernando Guevara Vasquez**, University of Utah
Uncertainty Quantification in Resistor Network Inversion (MS 2173)

S4 **John M.Hudson,** University of Toronto
Functional Imaging of Cancer Using Contrast-Enhanced Ultrasound (HS 108)

S14 **Rhodri Cusack**, The Centre for Brain & Mind, U of Western Ontario
Characterizing Neural Representation with Multivariate Pattern Analysis of fMRI Data (HS 106)

5:45-7:00 Welcome Reception (Cash Bar) (MS 2322, Medical Sciences Cafeteria)

Tuesday, June 21

8:30-8:45 Morning Coffee (MS 2158 Lobby)

8:45-9:30 Plenary Talk, **Gunther Uhlmann**, UC Irvine and University of Washington
Thermoacoustic tomography with a variable sound speed (MS 2158)

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11:40-12:25 Plenary Talk, **Justin Romberg**, Georgia Institute of Technology
A Survey of Compressed Sensing and Applications to Medical Imaging (MS 2158)

12:30-2:10 Lunch Break

2:10-2:35 S1 **Joyce McLaughlin,** Rensselaer Polytechnic Institute
Viscoelastic models for tissue: Theoretical results for the forward problem (MS 3163)

S2 **Leopold Grinberg,** Brown University
Multi-Scale Patient-Specific Modeling of Brain Blood Flow (MS 4171)

S5 **Michael Sharpe,** Princess Margaret Hospital & U. of Toronto
Advancements in Radiation Therapy Treatment Planning and Optimization (Fields Institute Library)

S7 **Eric Ritman**, Mayo Clinic
Spectral X-ray Imaging - Implications for Attenuation and Scatter-based Tomography (MS 3171)

S8 **Marshall Sussman,** Toronto General Hospital and U. of Toronto
A Novel Method for Motion Correction in Cardiac MRI (MS 2173)

S15 **John Mosher**, Cleveland Clinic Epilepsy Center
Imaging and Localizing Neural Sources from MEG Data (HS 106)

TUESDAY, JUNE 21 - SCHEDULE 1.1

2:40-3:05

S1 **Sergey Telenkov,** University of Toronto
Frequency-Domain Photoacoustics: Specifics of Signal Processing and Image Reconstruction (MS 3163)

S2 **Alessandro Veneziani,** Emory University
An Integrated Morphology+CFD Statistical Investigation of Parent Vessel in Cerebral Aneurysms (MS 4171)

S5 **Mehran Ebrahimi,** Sunnybrook Health Sciences Centre
Mathematical Methods for Breast Image Registration
(Fields Institute Library)

S7 **Nicholas Hoell**, University of Toronto
Some Results on the Attenuated Ray Transform (MS 3171)

S8 **Xiahai Zhuang,** University College London
A Registration-Based Atlas Propagation Framework for Automatic Whole Heart Segmentation (MS 2173)

S15 **Douglas Cheyne**, Hospital for Sick Children and University of Toronto
Use of Adaptive Beamformers in MEG Source Modeling (HS 106)

3:10-3:35 Coffee Break (MS 2158 Lobby)

3:40-4:05

S5 **Oleg Michailovich,** University of Waterloo
Fast and Accurate HARDI and its Application to Neurological Diagnosis (Fields Institute Library)

S7 **Adel Faridani**, Oregon State University
Numerical Aspects of Pi-line Reconstruction Algorithms in Tomography (MS 3171)

S8 **Shuo Li,** GE Healthcare
Mathematics of Cardiac Image Segmentation and Registration
(MS 2173)

S10 **Richard Frayne,** University of Calgary
Potential for Compressed Sensing in Clinical MR Imaging (MS 3163)

S15 **Bernhard Ross**, Rotman Research Institute and University of Toronto
Identifying Brain Networks of Coherent Oscillations with MEG
(HS 106)

TUESDAY, JUNE 21 - SCHEDULE 1.1

4:10-4:35

S5 **Kristy Brock,** University of Toronto
The Role of Deformable Registration Algorithms in Adaptive Radiotherapy (Fields Institute Library)

S7 **Mark Anastasio**, Washington University
Advances in photoacoustic tomography image reconstruction (MS 3171)

S8 **Yingli Lu,** Sunnybrook Health Sciences
Automated Analysis of Infarct Heterogeneity on Delayed Enhancement Magnetic Resonance Images (MS 2173)

S10 **Jong Chul Ye,** Korea Advanced Institute of Science & Technology
Compressive MUSIC for diffuse optical tomography using joint sparsity (MS 3163)

S15 **J.L. Perez Velazquez,** Hospital for Sick Children and University of Toronto
The Clinical and Basic Significance of Studying Fluctuations of Brain Coordinated Activity (HS 106)

4:40-5:05

S5 **Nataliya Portman,** McConnell Brain Imaging Centre, Montreal
The Modelling of Biological Growth: a Pattern Theoretic Approach (Fields Institute Library)

S10 **Gabriel Rilling,** University of Edinburgh
Optimized Model-based Undersampling and Reconstruction for Dynamic MRI Based on Support Splitting. Application to Phase Contrast MRI Carotid Blood Flow Imaging (MS 3163)

5:10-5:35

S5 **David Koff,** McMaster University
Rewards and Challenges in Adoption of Diagnostically Acceptable Irreversible Compression (Fields Institute Library)

S10 **Mehmet Akcakaya,** Harvard University
Compressed Sensing in Cardiac MRI (MS 3163)

Wednesday, June 22

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3:00-5:40	Coffee, Networking, Discussion & Poster Session (Stone Lobby MS 2171)

FIELDS

THURSDAY, JUNE 23 - SCHEDULE 1.1

Thursday, June 23

8:30-8:45	Morning Coffee (MS 2158 Lobby)
8:45-9:30	Plenary Talk, **Polina Golland**, Massachusetts Institute of Technology *Non-parametric Atlas-Based Segmentation of Highly Variable Anatomy* (MS 2158)
9:35-10:20	Plenary Talk, **John Schotland**, University of Michigan *Inverse Transport with Large Data Sets* (MS 2158)
10:25-10:50	Coffee Break (MS 2158 Lobby)
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11:40-12:25	Plenary Talk, **Jeremy Magland**, University of Pennsylvania *Processing strategies for real-time neurofeedback using fMRI* (MS 2158)
12:30-2:10	Lunch Break
2:10-3:10	S6 **Lior Horesh**, IBM Watson Research Center *Optimal Design in Medical Inversion* (MS 2158)
	S9 **Greig Scott,** Stanford University *The Physical Basis of RF Electrical Properties Contrast Imaging by MRI* (MS 3163)
	S11 Invited Participants (MS 3171)
	S12 **Hanna Jankowski,**York University *Confidence Regions and Means of Random Sets using Oriented Distance Functions* (MS 2173)
2:40-3:05	S6 **Prashant Athavale,** University of California *Novel Techniques for Multiscale Representations* (MS 2158)
	S9 **Jin Keun Seo,** Yonsei University, Korea *Inverse Problems in Medical Imaging: Electrical Property Imaging using MRI* (MS 3163)

S11 Invited Participants (MS 3171)

S12 **Timothy Johnson,** University of Michigan
Predicting Treatment Efficacy by Quantitative MRI via a Bayesian Joint Model (MS 2173)

3:10-3:35 Coffee Break (MS 2158 Lobby)

3:40-4:05 S6 **Christoph Schwarzbach**, University of British Columbia
Computational Tools for Microwave Imaging – some Finite Element Aspects (MS 2158)

S9 **Eric Bonnetier,** Université Joseph Fourier, Grenoble
Some Stability Results for Electric Impedance Tomography under Elastic Deformation (MS 3163)

S11 Invited Participants (MS 3171)

S12 **Alejandro Murua,** Université de Montréal
Functional Connectivity Exploration with the Potts and Random Cluster Models (MS 2173)

4:10-4:35 S6 **Eldad Haber**, University of British Columbia
Inverse Problems for Multi-source Experiments (MS 2158)

S9 **Rosalind Sadleir,** University of Florida
Imaging conductivity changes deep in the brain (MS 3163)

S11 Invited Participants (MS 3171)

S12 **Z. Jane Wang,** University of British Columbia
fMRI Signal Processing Methods for Brain Connectivity Modeling (MS 2173)

4:40-5:05 S6 **Alessandro Veneziani**, Emory University
4D Image-Based CFD Simulation of a Compliant Blood Vessel (MS 2158)

S9 **Dinghui Wang**, Keller Center for Imaging Innovation, Phoenix, AZ (talk presented by **Michael Joy)**
Radio Frequency Current Density Imaging with a 180-Degree Sample Rotation (MS 3163)
S11 Invited Participants (MS 3171)

5:10-5:35

S6 **Michal Holtzman Gazit,** University of British Columbia
A Scale Consistent Approach to Image Completion (MS 2158)

S9 **Weijing Ma,** University of Toronto
Active B1 Imaging Using Polar Decomposition Method (MS 3163)

S11 Invited Participants (MS 3171)

FIELDS

FRIDAY, JUNE 24 - SCHEDULE 1.1

Friday, June 24

8:30-8:45	Morning Coffee (MS 2158 Lobby)
8:45-9:30	Plenary Talk, **Emil Sidky**, University of Chicago *What does compressive sensing mean for X-ray CT and comparisons with its MRI application* (MS 2158)
9:35-10:20	Plenary Talk, **Ender Konukoglu**, Microsoft Research, Cambridge *Personalizing Mathematical Models with Sparse Medical Data: Applications to Tumor Growth and Electrocardiophysiology* (MS 2158)
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11:40-12:25	Plenary Talk, **Aaron Fenster**, Robarts Research Institute *Use of 3D Ultrasound Imaging in Diagnosis, Treatment and Research* (MS 2158)
12:30-2:10	Lunch Break
2:10-2:35	S3 **Nuutti Hyvonen**, Aalto University, Finland *Electrical Impedance Tomography with Two Electrodes* (MS 2173)
	S5 **Stergios Stergiopoulos,** Defence R&D Canada Toronto *Advanced Signal Processing for Non-Invasive Medical Diagnostic System Applications* (MS 3171)
	S9 **Frédéric de Gournay,** Université de Versailles *TBA* (MS 3163)
	S13 **Dana Cobzas**, University of Alberta *Random Walks for Deformable Image Registration* (MS 4279)
2:40-3:05	S3 **Armin Lechleiter**, Ecole Polytechnique, France *Newton Methods for the Complete Electrode Model of Electrical Impedance Tomography* (MS 2173)

S5 **Arsen Hajian,** Tornado Medical Systems & University of Waterloo
An Algorithm's Journey Through Government, Academia, and Industry (MS 3171)

S9 **Yuan Xu, Ryerson University,** yxu@ryerson.ca
Ultrasound methods to image the electrical/electrokinetic properties of biomaterials (MS 3163)

S13 **Paul Dufort,** University of Toronto
Joint Segmentation and Deformable Registration of Fractured Vertebra Using a Synthesis of the Expectation Maximization and Belief Propagation Algorithms (MS 4279)

3:10-3:35 Coffee Break (MS 2158 Lobby)

3:40-4:05 S3 **Mikyoung Lim**, KAIST, South Korea
Optimization Algorithm for the Reconstruction of a Conductivity Inclusion (MS 2173)

S10 **Christopher Kumar Anand**, McMaster University
INADEQUATE Sparse Data and Carbon Skeletons (MS 3163)

S13 **Leo Grady**, Siemens Corporate Research, Princeton
Universal Models for Targeted Image Segmentation (MS 4279)

4:10-4:35 S3 **Janne Tamminen**, University of Helsinki, Finland
Boundary Correction for d-bar EIT Reconstructions (MS 2173)

S10 **Julia Velikina,** University of Wisconsin
Application of Temporally Constrained Compressed Sensing for High Spatial and Temporal Resolution Magnetic Resonance Imaging (MS 3163)

S13 **Réne Donner**, Medical University Vienna
3D Anatomical Structure Localization (MS 4279)

4:40-5:05 S10 **Alexey Samsonov,** University of Wisconsin
A Novel Iterative Thresholding Algorithm for Compressed Sensing Reconstruction of Quantitative MRI Parameters from Insufficient Data (MS 3163)

S13 **Mona K. Garvin**, University of Iowa
Use of 3D Graph-Theoretic Approaches in the Segmentation of Ophthalmic Structures (MS 4279)

5:10-5:35 S10 **Xiteng Liu,** Hospital for Sick Children, Toronto
System compression: theory and application (MS 3163)

FIELDS

SCHEDULE 1.1
S1 NEW HYBRID MODALITIES IN MEDICAL IMAGING

Session Schedules

S1 New Hybrid Modalities in Medical Imaging

Organizers: Guillaume Bal, Columbia University,
John Schotland, University of Michigan

Monday, June 20 (MS 3163)

2:10-2:35 **Simon Arridge,** University College London
Quantitative PhotoAcoustic Tomography using Diffusion and Transport Models

2:40-3:05 **Claude Boccara,** Institut Langevin ESPCI-ParisTech
Wavefront Control and Optical Tomography of Scattering Media

3:40-4:05 **Kui Ren,** University of Texas at Austin
Numerical Solution of Inverse Helmholtz Problems with Interior Data

4:10-4:35 **Andreas Mandelis,** University of Toronto
The Biomedical Photoacoustic Radar Imager: Principles, Signal-to-Noise Ratio, Contrast and Resolution

4:40-5:05 **Amir Moradifam,** University of Toronto
Conductivity Imaging from One Interior Measurement in the Presence of Perfectly Conducting and Insulating Inclusions

5:10-5:35 **Sarah Patch,** University of Wisconsin Milwaukee
Thermoacoustic Imaging over Large Fields of View

Tuesday, June 21 (MS 3163)

2:10-2:35 **Joyce McLaughlin,** Rensselaer Polytechnic Institute
Viscoelastic models for tissue: Theoretical results for the forward problem

2:40-3:05 **Sergey Telenkov,** University of Toronto
Frequency-Domain Photoacoustics: Specifics of Signal Processing and Image Reconstruction

FIELDS

SCHEDULE 1.1
S2 COMPUTATIONAL HEMODYNAMIC IMAGING

S2 Computational Hemodynamic Imaging

Organizers: David Steinman, University of Toronto,
Alessandro Veneziani, Emory University

Monday, June 20 (MS 4279)

2:10-2:35 **Jean-Frederic Gerbeau**, INRIA Paris-Rocquencourt
MagnetoHemoDynamics in MRI devices

2:40-3:05 **Umberto Morbiducci,** Politecnico di Torino
Visualization and Quantification of Blood Flow in the Human Aorta. From in vivo 4D Phase Contrast MRI to Subject-Specific Computational Hemodynamics

3:40-4:05 **Jordi Alastruey-Arimon,** Imperial College London
Reducing the Data: Analysis of the Role of Vascular Geometry on the Features of Blood Flow in Curve Vessels

4:10-4:35 **Shawn Shadden,** Illinois Institute of Technology
Transport Studies of Patient Specific Hemodynamics: Methods of Modeling and Characterization

4:40-5:05 **Elena S Di Martino,** University of Calgary
Wall Stress and Flow Dynamics in Abdominal Aortic Aneurysms

5:10-5:35 **Irene Vignon-Clementel,** INRIA Paris-Rocquencourt, France
From Imaging and Hemodynamic Data to Patient-Specific Simulations of Glenn to Fontan Conversion

Tuesday, June 21 (MS 4171)

2:10-2:35 **Leopold Grinberg,** Brown University
Multi-Scale Patient-Specific Modeling of Brain Blood Flow

2:40-3:05 **Alessandro Veneziani,** Emory University
An Integrated Morphology+CFD Statistical Investigation of Parent Vessel in Cerebral Aneurysms

FIELDS

SCHEDULE 1.1
S3 ADVANCES ON NUMERICAL METHODS FOR ELECTRICAL IMPEDANCE TOMOGRAPHY

S3 Advances on Numerical Methods for Electrical Impedance Tomography

Organizer: Samuli Siltanen, University of Helsinki

Monday, June 20 (MS 2173)

2:10-2:35 **Jennifer Mueller**, Colorado State University
Direct Electrical Impedance Tomography Reconstructions of Nonsmooth Conductivities

2:40-3:05 **Fabrice Delbarry**, Technical University of Denmark
Electrical Impedance Tomography: 3D Reconstructions Using Scattering transforms

3:40-4:05 **Ville Kolehmainen**, University of Eastern Finland
Compensation of Modelling Errors Due to Unknown Domain Boundary in Electrical Impedance Tomography

4:10-4:35 **Alexander Mamonov**, University of Texas at Austin (talk presented by **Fernando Guevara Vasquez**)
Resistor Networks and Optimal Grids for Electrical Impedance Tomography with Partial Boundary Measurements

4:40-5:05 **Fernando Guevara Vasquez**, University of Utah
Uncertainty Quantification in Resistor Network Inversion

Friday, June 24 (MS 2173)

2:10-2:35 **Nuutti Hyvonen**, Aalto University, Finland
Electrical Impedance Tomography with Two Electrodes

2:40-3:05 **Armin Lechleiter**, Ecole Polytechnique, France
Newton Methods for the Complete Electrode Model of Electrical Impedance Tomography

3:40-4:05 **Mikyoung Lim**, KAIST, South Korea
Optimization Algorithm for the Reconstruction of a Conductivity Inclusion

4:10-4:35 **Janne Tamminen**, University of Helsinki, Finland
Boundary Correction for d-bar EIT Reconstructions

S4 Dynamic Image Analysis

Organizers: Anne Martel, Sunnybrook Health Sciences, Stephen Strother, Rotman Research Institute and University of Toronto

Monday, June 20 (HS 108)

2:10-2:35 **Bojana Stefanovic,** Sunnbrook Research Institute
In Vivo Imaging of Cerebral Hemodynamics with Two Photon Fluorescence Microscopy

2:40-3:05 **Nathan Churchill**, University of Toronto and Rotman Research Institute
Data-Driven Measurement and Removal of Physiological Noise in BOLD fMRI

3:40-4:05 **John Sled,** Hospital for Sick Children
Growth Dynamics in the Mouse

4:10-4:35 **Hai-Ling Margaret Cheng,** Hospital for Sick Children
Quantitative Dynamic Contrast-Enhanced MRI (DCE-MRI) of Tumor Angiogenesis

4:40-5:05 **Hatef Mehrabian**, University of Toronto
Application of Independent Component Analysis (ICA) to Identify and Separate Tumor Arterial Input Function (AIF) in Dynamic Contrast Enhanced MRI

5:10-5:35 **John M.Hudson,** University of Toronto
Functional Imaging of Cancer Using Contrast-Enhanced Ultrasound

FIELDS

SCHEDULE 1.1
S5 MEDICAL IMAGING: MATHEMATICAL METHODS AND INDUSTRIAL APPLICATIONS

S5 Medical Imaging: Mathematical Methods and Industrial Applications

Organizers: Siv Sivaloganathan, Centre for Mathematical Medicine and University of Waterloo, Edward Vrscay, University of Waterloo, Arsen Hajian, Tornado Medical Systems and Arjae Enterprises

Tuesday, June 21 (Fields Institute Library)

2:10-2:35 **Michael Sharpe,** Princess Margaret Hospital & U of Toronto
Advancements in Radiation Therapy Treatment Planning and Optimization

2:40-3:05 **Mehran Ebrahimi,** Sunnybrook Health Sciences Centre
Mathematical Methods for Breast Image Registration

3:40-4:05 **Oleg Michailovich,** University of Waterloo
Fast and Accurate HARDI and its Application to Neurological Diagnosis

4:10-4:35 **Kristy Brock,** Princess Margaret Hospital, University of Toronto
The Role of Deformable Registration Algorithms in Adaptive Radiotherapy

4:40-5:05 **Nataliya Portman,** McConnell Brain Imaging Centre, Montreal
The Modelling of Biological Growth: a Pattern Theoretic Approach

5:10-5:35 **David Koff,** McMaster University
Rewards and Challenges in Adoption of Diagnostically Acceptable Irreversible Compression

Friday, June 24 (MS 3171)

2:10-2:35 **Stergios Stergiopoulos,** Defence R&D Canada Toronto
Advanced Signal Processing for Non-Invasive Medical Diagnostic System Applications

2:40-3:05 **Arsen Hajian,** Tornado Medical Systems & University of Waterloo
An Algorithm's Journey Through Government, Academia, and Industry

FIELDS

SCHEDULE 1.1
S6 NUMERICAL METHODS IN IMAGING
S7 RECENT PROGRESS ON TOMOGRAPHY

S6 Numerical Methods in Imaging

Organizer: Eldad Haber, University of British Columbia

Thursday, June 23 (MS 2158)

2:10-2:35 **Lior Horesh**, IBM Watson Research Center
Optimal Design in Medical Inversion

2:40-3:05 **Prashant Athavale,** University of California
Novel Techniques for Multiscale Representations

3:40-4:05 **Christoph Schwarzbach**, University of British Columbia
Computational Tools for Microwave Imaging – some Finite Element Aspects

4:10-4:35 **Eldad Haber**, University of British Columbia
Inverse Problems for Multi-source Experiments

4:40-5:05 **Alessandro Veneziani**, Emory University
4D Image-Based CFD Simulation of a Compliant Blood Vessel

5:10-5:35 **Michal Holtzman Gazit,** University of British Columbia
A Scale Consistent Approach to Image Completion

S7 Recent Progress on Tomography

Organizer: David Finch, Oregon State University

Tuesday, June 21 (MS 3171)

2:10-2:35 **Eric Ritman**, Mayo Clinic
Spectral X-ray Imaging - Implications for Attenuation and Scatter-based Tomography

2:40-3:05 **Nicholas Hoell**, University of Toronto
Some Results on the Attenuated Ray Transform

3:40-4:05 **Adel Faridani**, Oregon State University
Numerical Aspects of Pi-line Reconstruction Algorithms in Tomography

4:10-4:35 **Mark Anastasio**, Washington University
Advances in photoacoustic tomography image reconstruction

S8 Cardiac image segmentation and registration

Organizers: Perry Radau, Sunnybrook Health Sciences, Graham Wright, Sunnybrook Health Sciences and University of Toronto

Tuesday, June 21 (MS 2173)

2:10-2:35 **Marshall Sussman,** Toronto General Hospital and U. of Toronto
A Novel Method for Motion Correction in Cardiac MRI

2:40-3:05 **Xiahai Zhuang,** University College London
A Registration-Based Atlas Propagation Framework for Automatic Whole Heart Segmentation

3:40-4:05 **Shuo Li,** GE Healthcare
Mathematics of Cardiac Image Segmentation and Registration

4:10-4:35 **Yingli Lu,** Sunnybrook Health Sciences
Automated Analysis of Infarct Heterogeneity on Delayed Enhancement Magnetic Resonance Images

S9 Imaging Electric Properties of Tissues

Organizers: Alexandru Tamasan, University of Central Florida, Michael Joy, University of Toronto

Thursday, June 23 (MS 3163)

2:10-2:35 **Greig Scott,** Stanford University
The Physical Basis of RF Electrical Properties Contrast Imaging by MRI

2:40-3:05 **Jin Keun Seo,** Yonsei University, Korea
Inverse Problems in Medical Imaging: Electrical Property Imaging using MRI

3:40-4:05 **Eric Bonnetier,** Université Joseph Fourier, Grenoble
Some Stability Results for Electric Impedance Tomography under Elastic Deformation

4:10-4:35 **Rosalind Sadleir,** University of Florida
Imaging conductivity changes deep in the brain

4:40-5:05 **Dinghui Wang**, Keller Center for Imaging Innovation, Phoenix, AZ (talk presented by **Michael Joy)**
Radio Frequency Current Density Imaging with a 180-Degree Sample Rotation

5:10-5:35 **Weijing Ma,** University of Toronto
Active B1 Imaging Using Polar Decomposition Method

Friday, June 24 (MS 3163)

2:10-2:35 **Frédéric de Gournay,** Université de Versailles
TBA

2:40-3:05 **Yuan Xu, Ryerson University,** yxu@ryerson.ca
Ultrasound methods to image the electrical/electrokinetic properties of biomaterials

S10 Compressed Sensing in Medical Imaging

Organizers: Hongmei Zhu, York University, Adrian Nachman, University of Toronto

Tuesday, June 21 (MS 3163)

3:40-4:05 **Richard Frayne,** University of Calgary
Potential for Compressed Sensing in Clinical MR Imaging

4:10-4:35 **Jong Chul Ye,** Korea Advanced Institute of Science & Technology
Compressive MUSIC for diffuse optical tomography using joint sparsity

4:40-5:05 **Gabriel Rilling,** University of Edinburgh
Optimized Model-based Undersampling and Reconstruction for Dynamic MRI Based on Support Splitting. Application to Phase Contrast MRI Carotid Blood Flow Imaging

5:10-5:35 **Mehmet Akcakaya,** Harvard University
Compressed Sensing in Cardiac MRI

Friday, June 24 (MS 3163)

3:40-4:05 **Christopher Kumar Anand**, McMaster University
INADEQUATE Sparse Data and Carbon Skeletons

4:10-4:35 **Julia Velikina,** University of Wisconsin
Application of Temporally Constrained Compressed Sensing for High Spatial and Temporal Resolution Magnetic Resonance Imaging

4:40-5:05 **Alexey Samsonov,** University of Wisconsin
A Novel Iterative Thresholding Algorithm for Compressed Sensing Reconstruction of Quantitative MRI Parameters from Insufficient Data

5:10-5:35 **Xiteng Liu,** Hospital for Sick Children, Toronto
System compression: theory and application

S11 Mathematical Methods in Biophotonics: Charting a Course for New Opportunities

Organizers: Alex Vitkin, University of Toronto, Brian Wilson, Ontario Cancer Institute and University of Toronto

Thursday, June 23 (MS 3171)

This Special Session will not consist of formal talks. It will bring together researchers in biophotonics, biomedical optics, mathematics and engineering to identify challenges, possible mathematical approaches, and opportunities for future collaborations.

Invited Participants:

Simon Arridge, University College London
A. Claude Boccara, Institut Langevin, Laboratoire d'Optique ESPCI-ParisTech
James Colliander, Dept. of Math., University of Toronto
Ted Dixon, Huron Technologies
Peter R. Herman, ECE, University of Toronto
Ofer Levi, IBBME and ECE, University of Toronto
Mohamed A. Naser, Med. Phys. and Applied Radiation Sciences, McMaster
Mary Pugh, Dept. of Math., University of Toronto
John Schotland, University of Michigan
Sherif Sherif, ECE, University of Manitoba
Catherine Sulem, Dept. of Math., University of Toronto
Fred Sweeney, Tornado Medical
Sergey Telenkov, MIE, University of Toronto
Robert Weersink, Princess Margaret Hospital
Michael Wood, University Health Network

FIELDS

SCHEDULE 1.1
S12 STATISTICAL METHODS IN MEDICAL IMAGING
S13 GRAPH-BASED METHODS IN MEDICAL IMAGING

S12 Statistical Methods in Medical Imaging

Organizer: Hanna Jankowski, York University

Thursday, June 23 (MS 2173)

2:10-2:35 **Hanna Jankowski,** York University
Confidence Regions and Means of Random Sets using Oriented Distance Functions

2:40-3:05 **Timothy Johnson,** University of Michigan
Predicting Treatment Efficacy by Quantitative MRI via a Bayesian Joint Model

3:40-4:05 **Alejandro Murua,** Université de Montréal
Functional Connectivity Exploration with the Potts and Random Cluster Models

4:10-4:35 **Z. Jane Wang,** University of British Columbia
fMRI Signal Processing Methods for Brain Connectivity Modeling

S13 Graph-Based Methods in Medical Imaging

Organizer: Paul Dufort, University Health Network

Friday, June 24 (MS 4279)

2:10-2:35 **Dana Cobzas,** University of Alberta
Random Walks for Deformable Image Registration

2:40-3:05 **Paul Dufort,** University of Toronto
Joint Segmentation and Deformable Registration of Fractured Vertebra Using a Synthesis of the Expectation Maximization and Belief Propagation Algorithms

3:40-4:05 **Leo Grady,** Siemens Corporate Research, Princeton
Universal Models for Targeted Image Segmentation

4:10-4:35 **Réne Donner,** Medical University Vienna
3D Anatomical Structure Localization

4:40-5:05 **Mona K. Garvin,** University of Iowa
Use of 3D Graph-Theoretic Approaches in the Segmentation of Ophthalmic Structures

SCHEDULE 1.1
S14 BRAIN IMAGING
S15 MAGNETOCEPHALOGRAPHY

S14 Brain Imaging

Organizer: Adrian Crawley, Toronto Western Hospital

Monday, June 20 (HS 106)

3:40-4:05 **Jason Lerch**, Hospital for Sick Children
Detecting small changes in the brain with structural MRI

4:10-4:35 **Ragini Verma**, University of Pennsylvania
Analyzing Diffusion MRI Based "Connectivity" for Diagnosis

4:40-5:05 **Cheryl Grady**, Rotman Research Institute
The Use of Multivariate Methods for the Analysis of fMRI Studies of Cognition

5:10-5:35 **Rhodri Cusack**, Centre for Brain & Mind, U of Western Ontario
Characterizing Neural Representation with Multivariate Pattern Analysis of fMRI Data

S15 Magnetoencephalography

Organizer: Douglas Cheyne, Hospital for Sick Children and University of Toronto

Tuesday, June 21 (HS 106)

2:10-2:35 **John Mosher**, Cleveland Clinic Epilepsy Center
Imaging and Localizing Neural Sources from MEG Data

2:40-3:05 **Douglas Cheyne**, Hospital for Sick Children and University of Toronto
Use of Adaptive Beamformers in MEG Source Modeling

3:40-4:05 **Bernhard Ross**, Rotman Research Institute and University of Toronto
Identifying Brain Networks of Coherent Oscillations with MEG

4:10-4:35 **J.L. Perez Velazquez,** Hospital for Sick Children and University of Toronto
The Clinical and Basic Significance of Studying Fluctuations of Brain Coordinated Activity

SC Contributed Talks

Organizer: Dhavide Aruliah, University of Ontario Institute of Technology

Monday, June 20 (HS 100)

2:10-2:35 **Michael Smith,** University of Calgary
Moving the Best Ideas from 1985's Constrained Reconstruction Techniques into 2011's Compressed Sensing Reconstruction

2:40-3:05 **Lakshminarayan V. Chinta**, Sunnybrook Research Institute
Quantitative Perfusion Estimation from Two Photon Fluorescence Microscopy Microvasculature Maps

3:40-4:05 **Qiong Wu**, McMaster University
A Semi-Definite, Nonlinear Model for Optimizing k-Space Sample Separation in Parallel Magnetic Resonance Imaging

4:10-4:35 **Yogesh Chinta Venkateswarao,** McMaster University
Sparse Sampling of Velocity MRI

4:40-5:05 **Jessica L. M. Pavlin,** McMaster University
Determining a Flow Profile from Multi-Scale Phase Contrast Angiographic MRI Data

ELSA ANGELINI
Institut Telecom, Telecom ParisTech

Compressed Biological Imaging

Coauthors: Jean-Christophe Olivo-Marin, Marcio Marim de Moraes, Michael Atlan, Yoann Le Montagner

Compressed sensing (CS) is a new sampling theory that was recently introduced for efficient acquisition of compressible signals. In the presented work, we have studied practical applications of the Fourier-based CS sampling theory for biological microscopy imaging, with two main contributions:

(i) Image denoising: microscopic images suffer from complex artifacts associated with noise and non-perfect illumination conditions. In fluorescence microscopy, noise and photobleaching degrade the quality of the image. In this work, we have exploited the CS theory as an image denoising tool, using multiple random undersampling in the Fourier domain and the Total Variation as a spatial sparsity prior. Compounding of images reconstructed from multiple sets of random measurements enforce spatial coherence of meaningful signal components and decorrelate noisy components. We have studied the relation between signal sparsity and noise reduction performance under different noise conditions. We have demonstrated on simulated and practical experiments on fluorescence microscopy that the proposed denoising framework provide images with similar or increased signal-to-noise ratio (SNR) compared to state of the art denoising methods while relying on a limited number of samples.

If Fourier-domain image point acquisitions were feasible, the proposed denoising could be used as a fast acquisition scheme which would enable to reduce exposition times, and reduce the photobleaching effects.

(ii) Compressed digital holographic microscopy: high data throughput is becoming increasingly important in microscopy, with high-resolution cameras (i.e. large numbers of samples per acquisition) and long observation times. The compressed sensing theory provides a framework to reconstruct images from fewer samples than traditional acquisition approaches. However, the very few measurements must be spread over a large field of view, which is difficult to achieve in conventional microscopy.

In a first experiment, we have proposed a computational scheme to perform fast temporal acquisitions of sequences of Fourier amplitude measures in optical Fourier imaging and estimate the missing phase information from spectra interpolation between few in-between complete keyframes. This approach was evaluated for high-frame rate imaging of moving cells.

In a second experiment, we have implemented a real CS acquisition scheme for digital holographic microscopy, acquiring a diffraction map of the optical field and recovering high quality images from as little as 7

GUILLAUME BAL
Columbia University

Hybrid Inverse Problems and Internal Functionals

Hybrid inverse problems aim at combining the high contrast of one imaging modality (such as e.g. Electrical Impedance Tomography or Optical Tomography in medical imaging) with the high resolution of another modality (such as e.g. based on ultrasound or magnetic resonance). Mathematically, these problems often take the form of inverse problems with internal information. This talk will review several results of uniqueness and stability obtained recently in the field of hybrid inverse problems.

CHARLES L. EPSTEIN
University of Pennsylvania

New approaches to the numerical solution of Maxwell's Equations

Coauthors: Leslie Greengard (NYU) Michael O'Neil (NYU)

We develop a new integral representation for the solution of the time harmonic Maxwell equations in media with piecewise constant dielectric permittivity and magnetic permeability in R^3. This representation leads to a coupled system of Fredholm integral equations of the second kind for four scalar densities supported on the material interface. Like the classical Muller equation, it has no spurious resonances. Unlike the classical approach, however, the representation does not suffer from low frequency breakdown. We earlier presented a similar method for the perfect conductor problem.

AARON FENSTER
Robarts Research Institute

Use of 3D Ultrasound Imaging in Diagnosis, Treatment and Research

The last two decades have witnessed unprecedented developments of new imaging systems making use of 3D visualization. These new technologies have revolutionized diagnostic radiology, as they provide the clinician with information about the interior of the human body never before available. Ultrasound imaging is an important cost-effective technique used routinely in the management of a number of diseases. However, 2D viewing of 3D anatomy, using conventional ultrasound, limits our ability to quantify and visualize the anatomy and guide therapy, because multiple 2D images must be integrated mentally. This practice is inefficient, and leads to variability and incorrect diagnoses. Also, since the 2D ultrasound image represents a thin plane at an arbitrary angle in the body, reproduction of this plane at a later time is difficult. Over the past 2 decades, investigators have addressed these limitations by developing 3D ultrasound techniques. In this paper

we describe developments of 3D ultrasound imaging instrumentation and techniques for use in diagnosis and image-guided interventions. As ultrasound imaging is an interactive imaging modality, providing the physician with real-time visualization of anatomy and function, the development of image analysis and guidance tools is challenging. Typically, these tools require segmentation, classification, tracking and visualization of pathology and instruments to be executed in real-time, accurately, reproducibly and robustly. As an illustration of these needs, we will present some diagnostic and image-guided intervention applications that would benefit from these developments. Examples will be given for imaging various organs, such as the prostate, carotid arteries, and breast, and for the use in 3D ultrasound-guided prostate therapy. In addition, we describe analysis methods to be used for quantitative analysis of disease progression and regression.

MATHIAS FINK
Institut Langevin, ESPCI ParisTech, 10 rue Vauquelin, 75005, Paris, France

Multiwave Imaging and Elastography

Interactions between different kinds of waves can yield images that beat the single-wave diffraction limit. Multiwave Imaging consists of combining two different waves– one to provide contrast, another to provide spatial resolution - in order to build a new kind of image. Contrary to single-wave imaging that is always limited by the contrast and resolution properties of the wave that generated it, multiwave imaging provides a unique image of the most interesting contrast with the most interesting resolution. Multiwave imaging opens new avenues in medical imaging and a large interest for this approach is now emerging in geophysics and non-destructive testing. We will describe the different potential interactions between waves that can give rise to multiwave imaging and we will emphasize the various multiwave approaches developed in the domain of medical imaging. Common to all these approaches, ultrasonic waves are almost always used as one of the wave to provide spatial resolution, while optical, electromagnetic or sonic shear waves provide the contrast. Among various multiwave techniques, we will mainly focus on photo-acoustic and shear wave imaging. Through various medical applications going from cancer diagnosis to cardiovascular imaging, we will emphasize the recent clinical successes of multiwave imaging.

POLINA GOLLAND
MIT

Non-parametric Atlas-Based Segmentation of Highly Variable Anatomy

Coauthors: Michal Depa, Mert Sabuncu

We propose a non-parametric probabilistic model for automatic segmentation of medical images. The resulting inference algorithms register individual training images to the new image, transfer the segmentation labels and fuse them to obtain the final segmentation of the test subject. Our generative model yields previously proposed label fusion algorithms as special cases, but also leads to a new variant that aggregates evidence locally in determining the segmentation labels. We demonstrate the advantages of our approach in two clinical application: segmentation of neuroanatomical structures and segmentation of the left heart atrium whose shape varies significantly across the population.

DAVID ISAACSON
Mathematical Sciences Department, Rensselaer Polytechnic Institute

Problems in Electrical Impedance Imaging

Coauthors: J.C. Newell, and G. Saulnier

Electrical impedance imaging systems apply currents to the surface of a body and measure the resulting voltages. From this electromagnetic data an approximate reconstruction and display of the internal electrical properties of the body are made. We explain how this process leads to inverse boundary value problems for Maxwell's equations. Since the conductivity of hearts, and lungs change as blood enters and leaves these organs , impedance images can be used to monitor heart and lung function. Since the electrical properties of some cancers are different from surrounding normal tissues, electrical impedance spectroscopy may be used to help diagnose some cancers. Images and movies of heart and lung function, as well as breast cancers, made with the RPI Adaptive current tomography systems will be shown. It will be explained how the analysis of spectral properties of the Dirichlet to Neumann map lead to the design of these adaptive current tomography systems.

ENDER KONUKOGLU
Microsoft Research Cambridge

Personalizing Mathematical Models with Sparse Medical Data: Applications to Tumor Growth and Electrocardiophysiology

Coauthors: Nicholas Ayache, Maxime Sermesant, Olivier Clatz, Bjoern H. Menze

Mathematical models for biophysical systems are crucial in understanding the underlying physiological dynamics as well as tailoring patient-specific treatment. One of the biggest challenges for biophysical models is the identification of patient-specific parameters and the personalized model. This talk will focus on the problem of parameter identification using sparse medical data. Challenges associated with the medical data will be demonstrated with two model problems, tumor growth and electrocardiophysiology, incorporating different types of data, i.e. MR images and cardiac mappings. Different techniques for dealing with sparse data will be presented including deterministic and probabilistic methods.

JEREMY MAGLAND
University of Pennsylvania

Processing strategies for real-time neurofeedback using fMRI

Coauthors: Anna Rose Childress

Functional magnetic resonance imaging (fMRI) is traditionally used as a probe for patterns of brain activity in response to instructed cognitive tasks and stimuli by averaging of the blood oxygenation level-dependent (BOLD) response over an entire scan session (usual 10-60 minutes). Recently, real-time feedback approaches have expanded fMRI from a brain probe to include potential brain interventions. However, real-time measurements and analyses require entirely different data processing techniques, because measurements must be made prospectively (on the fly) throughout the scan using only a subset of the acquired data. In this talk, we outline the challenges associated with performing real-time fMRI experiments, and describe the specific techniques we have found to be successful for providing meaningful and robust neurofeedback in real time.

ANNE MARTEL
Sunnybrook Health Sciences Centre, University of Toronto

Assessing response of cancer to therapy using MRI

Personalized medicine, the practice of tailoring medical therapies to the specific genetic and disease profiles of patients, represents a major shift from the epidemiologically based model of traditional medicine. This has lead to the development of novel new therapies for cancer, for example Herceptin for breast cancer and Gleevec for chronic myelogenous leukemia. Although this is an exciting development it poses several challenges to the clinician. These therapies are extremely expensive and are only designed to work on a subset of patients hence there is a pressing need for tools that can determine whether a therapy is effective early in the treatment regime. Dynamic contrast-enhanced MRI (DCE-MRI) can provide valuable information about the efficacy of drug therapy. In addition to traditional measures of lesion size, it has been shown that DCE-MRI can provide important information about tumour function, for example by providing information about blood flow and permeability. In this talk I will give an overview of the role DCE-MRI has to play in monitoring response to therapy and outline some of the challenges involved in bringing this technology into routine clinical use. I will also describe some of the work done in my lab in the areas of quantitative analysis and image registration to address some of these challenges.

DR MICHAEL MILLER
Johns Hopkins University Center for Imaging Science

Diffeomorpic Shape Momentum in Computational Anatomy and Neuroinformatics

Over the past decade Computational Anatomy has been the study of structure and function in registered atlas coordinates. Unlike Google Maps which has been based on the rigid motions with scale for aligning coordinate systems, the underlying "alignment" groups in CA are the infinite dimensional diffeomorphisms. For rigid motion angular momentum plays a parsimonious roll; in diffeomorphic motion the analogous roll is played by diffeomorphic shape momentum.

We present results from computational codes for generating diffeomorphic correspondences between anatomical coordinate systems and their encoding via diffeomorphic shape momentum. Statistics will be examined for quantifying probabilistic shape momentum representations of neuroanatomy at 1mm scale. As well we will present results on functional and structural neuroinformatics in populations of normals and diseased populations in registered atlas coordinates.

PLENARY SPEAKER ABSTRACTS 1.2

XAVIER PENNEC
INRIA, Asclepios team, Sophia-Antipolis, France

Statistical Analysis on Manifolds in Medical Image Analysis

To analyze and model the biological variability of the human anatomy, the general method is to identify anatomically representative geometric features (points, tensors, curves, surfaces, volume transformations), and to describe and compare their statistical distribution in different populations. As these geometric features most often belong to manifolds that have no canonical Euclidean structure, we have to rely on more elaborated algorithmical bases.

I will first describe the Riemannian structure, which proves to be powerfull to develop a consistent framework for simple statistics on manifolds. It can be further extend to a complete computing framework on manifold-valued images. For instance, the choice of a convenient Riemannian metric on symmetric positive define matrices (SPD) allows to generalize consistently to fields of SPD matrices (e.g. DTI images) many important geometric data processing algorithms. This allows for instance to introduce anisotropic spatial priors in DTI estimation or to realize statistical models of the cardiac muscle fibers.

Then I will focus on statistics on deformations. The natural extension of the Riemannian framework is the use of right-invariant metrics on diffeomorphisms (often called LDDMM). When used on curves and surfaces modeled with geometric currents, the registration problem becomes finite-dimensional thanks to the representer theorem. An example application is the construction of a statistical model of the remodeling of the heart in rToF. For continuous images, however, the complexity remains very high. Dropping the metric, we propose to use the geodesics of the canonical Cartan connection (translates of one-parameter subgroups) for which very efficient algorithms exist. This log-demons framework will be illustrated with the individual and groupwise modeling of the morphological changes of the full brain in Alzheimer's disease.

JUSTIN ROMBERG
Georgia Tech

A Survey of Compressed Sensing and Applications to Medical Imaging

We will overview the fundamental results and recent theoretical trends in compressive sensing, and discuss current state-of-the-art models and algorithms for image reconstruction. We will present applications in medical imaging (including accelerated MRI and ultrasound), and discuss sparsity-based models being used for other imaging modalities and how they might apply to medical imaging.

YORAM RUDY
Washington University in St Louis

Noninvasive Electrocardiographic Imaging (ECGI) of Cardiac Electrophysiology and Arrhythmia

A noninvasive imaging modality for cardiac electrophysiology and arrhythmias is not yet available for clinical application. Such modality could be used to identify patients at risk, provide accurate diagnosis and guide therapy. Standard noninvasive diagnostic techniques, such as the electrocardiogram (ECG) provide only low-resolution reflection of cardiac electrical activity on the body surface. In my presentation, I will describe the application in humans of a new imaging modality called Electrocardiographic Imaging (ECGI) that noninvasively images cardiac electrical activity on the hearts epicardial surface. In ECGI, a multi-electrode vest (or strips) records 250 body-surface electrocardiograms; then, using geometrical information from a CT scan and an inverse solution to Laplace equation, electrical potentials, electrograms, activation sequences (isochrones) and repolarization patterns are reconstructed on the hearts surface. I will show examples of imaged atrial and ventricular activation and ventricular repolarization in the normal heart and during cardiac arrhythmias.

References C. Ramanathan, R.N. Ghanem, P. Jia, K. Ryu, Y. Rudy, Noninvasive Electrocardiographic Imaging for cardiac electrophysiology and arrhythmia Nature Medicine 2004; 10: 422-428.

C. Ramanathan, P. Jia, R.N. Ghanem, K. Ryu, Y. Rudy, Activation and repolarization of the normal human heart under complete physiological conditions Proc Nat Acad Sci USA (PNAS) 2006; 103: 6309-6314.

P.S. Cuculich, Y. Wang, B.D. Lindsay, M.N. Faddis, R.B. Schuessler, R.D. Damiano, L. Li, Y. Rudy, Noninvasive Characterization of Epicardial Activation in Humans with Diverse Atrial Fibrillation Patterns Circulation 2010;122:1364-1372.

JOHN SCHOTLAND
University of Michigan

Inverse Transport with Large Data Sets

There is considerable interest in the development of optical methods for biomedical imaging. The mathematical problem consists of recovering the optical properties of a highly-scattering medium. This talk will review recent work on related inverse scattering problems for the radiative transport equation and efficient fast image reconstruction algorithms for large data sets. Numerical simulations and experimental data from model systems are used to illustrate the results.

EMIL SIDKY
University of Chicago

What does compressive sensing mean for X-ray CT and comparisons with its MRI application

This talk will trace our attempts at understanding compressive sensing (CS) concepts in the context of X-ray computed tomography (CT) and translating CS ideas to realize sparse-data image reconstruction in CT.

The arrival of CS could not come at a more interesting time for CT. Research on iterative image reconstruction applied to actual CT systems has only recently begun due to the developments in computational technology that allow for data processing at the gigabyte level. From the application side, more and more CT exams are being prescribed and there is pressure to reduce dose to the patients as evidenced by the rapid deployment of "low-dose CT" products by the major CT manufacturers. The promise of sparse-data image reconstruction from CS may thus play an important role in these recent technological developments.

I will show results with actual CT data that seem to indicate that CS style optimization problems do indeed yield "high quality" images from sparse projection data. I will then point out various issues that arise in integrating iterative image reconstruction, in general, and CS methods, specifically, into CT systems. I will address questions such as: Which data model to use and how accurate does it have to be? Given that object functions are continuous, ...what is meant by object sparsity? ...what is sparse data and what is fully sampled data? How should we validate the new CS algorithms? These questions will be addressed for CT and comparisons made with MRI where the application of CS is more familiar.

SAMULI SILTANEN
University of Helsinki, Finland

Low-dose three-dimensional X-ray imaging

A new kind of tomographic X-ray imaging modality is discussed, where the patient is radiated as little as possible while recovering enough three-dimensional information for the clinical task at hand. The input can be only a dozen projection images collected from different directions. Such sparse data typically represent limited-angle and local tomography configurations and lead to severely ill-posed reconstruction problems. This differs from traditional CT imaging, where a comprehensive data set is collected and the (only mildly ill-posed) reconstruction problem is solved using the classical filtered back-projection (FBP) algorithm. The incompleteness of sparse data violates the assumptions of FBP, leading to unacceptable reconstruction quality. However, statistical inversion methods can be used with sparse tomographic data. They yield clinically useful

reconstructions, as demonstrated by real-data examples related to mammography, surgical imaging and dental imaging. Some of these methods have already entered commercial products: see http://www.vtcube.com.

GUNTHER UHLMANN
University of California irvine and University of Washington

Thermoacoustic tomography with a variable sound speed

Coauthors: Plamen Stefanov

We will discuss some recent results on termoacoustic tomography with a variable sound speed including the smooth case and the non-smooth one, the latter motivated by brain imaging. We will also present some numerical results based on the analytic reconstruction which is joint work with Jianliang Qian and Hongkai Zhao.

LIHONG V. WANG
Washington University in St. Louis

Photoacoustic Tomography: Ultrasonically Breaking through the Optical Diffusion Limit

We develop photoacoustic imaging technologies for in vivo early-cancer detection and functional or molecular imaging by physically combining non-ionizing electromagnetic and ultrasonic waves. Unlike ionizing x-ray radiation, non-ionizing electromagnetic wavessuch as optical and radio wavespose no health hazard and reveal new contrast mechanisms. Unfortunately, electromagnetic waves in the non-ionizing spectral region do not penetrate biological tissue in straight paths as x-rays do. Consequently, high-resolution tomography based on non-ionizing electromagnetic waves alonesuch as confocal microscopy, two-photon microscopy, and optical coherence tomographyis limited to superficial imaging within approximately one optical transport mean free path (1 mm in the skin) of the surface of scattering biological tissue. Ultrasonic imaging, on the contrary, provides good image resolution but has strong speckle artifacts as well as poor contrast in early-stage tumors. Ultrasound-mediated imaging modalities that combine electromagnetic and ultrasonic waves can synergistically overcome the above limitations. The hybrid modalities provide relatively deep penetration at high ultrasonic resolution and yield speckle-free images with high electromagnetic contrast.

In photoacoustic computed tomography, a pulsed broad laser beam illuminates the biological tissue to generate a small but rapid temperature rise, which leads to emission of ultrasonic waves due to thermoelastic expansion. The short-wavelength pulsed ultrasonic waves are then detected by unfocused ultrasonic transducers. High-resolution tomographic images of optical contrast are then formed through image reconstruction. Endogenous

optical contrast can be used to quantify the concentration of total hemoglobin, the oxygen saturation of hemoglobin, and the concentration of melanin. Melanoma and other tumors have been imaged in vivo. Exogenous optical contrast can be used to provide molecular imaging and reporter gene imaging.

In photoacoustic microscopy, a pulsed laser beam is focused into the biological tissue to generate ultrasonic waves, which are then detected with a focused ultrasonic transducer to form a depth resolved 1D image. Raster scanning yields 3D high-resolution tomographic images. Super-depths beyond the optical diffusion limit have been reached with high spatial resolution.

Thermoacoustic tomography is similar to photoacoustic tomography except that low-energy microwave pulses, instead of laser pulses, are used. Although long-wavelength microwaves diffract rapidly, the short-wavelength microwave-induced ultrasonic waves provide high spatial resolution, which breaks through the microwave diffraction limit. Microwave contrast measures the concentrations of water and ions.

The annual conference on this topic has been doubling in size approximately every three years since 2003 and has become the largest in SPIEs Photonics West as of 2009.

GRAHAM WRIGHT
Sunnybrook Health Sciences Centre, University of Toronto

MRI for Management of Ventricular Arrhythmias

Ventricular Arrhythmias are a major cause of sudden cardiac death. Magnetic resonance imaging (MRI) has the potential to identify those at greatest risk. In this presentation, current approaches to detection and treatment of ventricular arrhythmias as well as evidence of MRIs potential clinical role are briefly reviewed. Emerging methods to better characterize the structural substrate of ventricular arrhythmia, notably scar and heterogeneous infarct, with MRI are presented . This characterization has been used to customize mathematical models of electrical propagation in the heart. The modeling results correspond well to experimental measurements of electrical activity in porcine hearts. Combining these tools with the development of MRI-compatible electrophysiology systems holds the promise of guiding ablation therapy to disrupt the arrhythmogenic substrate, yielding more effective solutions for patients at risk of life-threatening events.

MEHMET AKCAKAYA
Department of Medicine (Cardiovascular Division), Beth Israel Deaconess Medical Center, Harvard Medical School

Compressed Sensing in Cardiac MRI

In this talk, we will discuss utility of compressed sensing (CS) to accelerate image acquisition in cardiac MRI. A brief review of the clinical needs, and the associated cardiac MRI scans will be presented. Then, recent techniques for improving CS reconstruction and their clinical applications in cardiac MRI will be discussed.

JORDI ALASTRUEY-ARIMON
Imperial College London, UK

Reducing the data: Analysis of the role of vascular geometry on the features of blood flow in curve vessels

Coauthors: Jennifer Siggers (Imperial College London, UK), Luca Antiga (Mario Negri Institute, Italy), Denis Doorly (Imperial College London, UK), Spencer Sherwin (Imperial College London, UK)

In recent years, numerical models using anatomical reconstruction techniques have generated a plethora of simulations of blood flow in three-dimensional (3-D) patient-specific geometries. These are usually performed in localised areas of the arterial system, although more recently within larger arterial networks. The motivation behind these studies is typically to determine distributions of flow-related quantities (e.g. wall shear stress, WSS) due to their association with vascular disease. Such simulations provide insight into clinically relevant fluid dynamics, but unfortunately they often produce such large quantities of data that they are unlikely to be of practical use in a clinical setting.

In particular regimes, researchers in the applied mathematics community have reduced the data to a handful of parameters by constructing asymptotic solutions (e.g. Dean flow and Sexl-Womersley flow). However, without full knowledge of the details of the flow, the validity of the assumptions of these flows is unknown. The aim of this work is to reduce the amount of data whilst retaining the important flow features. We are investigating the effect of vascular geometry on the forces and accelerations that govern the evolution of primary and secondary flows in curved vessels and their association with axial velocity profiles, vortical structures and WSS distributions. For a given vascular geometry, we express the Navier-Stokes and continuity equations in a centreline (local) coordinate system. This allows us to decompose the effects of the geometry on the blood flow into components: local accelerations and inertia (centrifugal and Coriolis), pressure and viscous forces. Taking cross-sectional averages of these local quantities reduces the dynamics of the system onto the vessel centreline.

In this presentation we will describe the technique we have developed to post-process the pressure and velocity fields produced using 3-D blood flow simulations, and investigate the effects of vascular curvature and torsion of the artery. We have first used this technique to study flow patterns in idealised planar and non-planar bends, which retain the dominant features of flow structures while significantly reducing the number of parameters that define the problem. The knowledge gained from these studies can then be applied to analyse the flow patterns in anatomically-correct geometries.

CHRISTOPHER KUMAR ANAND
McMaster University

INADEQUATE Sparse Data and Carbon Skeletons

Coauthors: Alex D. Bain and Sean Watson

The first step in determining the structure of a new organic molecule is usually to determine the structure of the carbon skeleton. That is, which carbons are bonded to which other carbons. This can be determined by examining the 2d spectra produced by an INADEQUATE experiment, although doing so by eye is extremely difficult because the spectra are inherently very noisy, depending as they do on the rare occurrences of bonded carbon-13s (which occur once per 10000 bonds). Various filtering and fitting methods have been applied to the signals, with some success. We propose a novel approach using variable-splitting, regularization in a sparse image subdomain, and penalty functions which embody a priori knowledge about the specturm determined by the likelihood of different bond patterns. Initial experimental results showed a 4-fold reduction in experiment time is possible by using this method which can process much noisier data.

MARK A. ANASTASIO
Washington University in St. Louis, Department of Biomedical Engineering, St. Louis, MO USA

Advances in photoacoustic tomography image reconstruction

Coauthors: Chao Huang, Robert Schoonover, Kun Wang

Photoacoustic tomography, also known as thermoacoustic tomography, is a rapidly emerging bioimaging modality that employs optical contrast and ultrasonic detection principles. In this talk, we describe recent advances in image reconstruction methods. Specifically, we will present iterative reconstruction methods that are based on accurate models of the measurement system and analytic methods for acoustically heterogeneous layered media.

SIMON ARRIDGE
University College London

Quantitative PhotoAcoustic Tomography using Diffusion and Transport Models

Coauthors: Ben Cox, Tanya Tarvainen, Paul Beard

The task in quantitative photoacoustic imaging (QPAT) is to recover the optical properties of an imaged region from a reconstructed photoacoustic image. Thus the data, considered as the product of the absorption coefficient and the light fluence, depends on both the absorption and the scattering properties in a nonlinear way. In this talk we apply model-based inversions developed in diffuse optical tomography (DOT) to the QPAT problem. As the domain of photoacoustic images is relatively small scale, the differences between fluence models based on diffusion and radiative transport can become significant. In this talk we present simulations of QPAT absed on both models and discuss the differences.

PRASHANT ATHAVALE
University of California

Novel Techniques for Multiscale Representations

Coauthors: Eitan Tadmor

Multiscale analysis can give useful insight into various natural and manmade phenomena. In this talk, we will discuss some new techniques of multiscale analysis in the context of digital images. Nevertheless, the techniques presented are universal and can be applied to wide range of applications.

Digital images can be thought of as sampled analogue signals. Images obtained from a camera could be noisy and blurry. Denoising and deblurring an image sometimes give rise to multiscale image representations, where we obtain different scales of the same image.

We will talk about some historical background of the mathematical image processing methods and how they are interlinked with each other. I will then introduce two interesting types of integro-differential equations (IDEs) which produce multiscale representations. These IDEs are motivated by the hierarchical decompositions of images. We will see their results and also some innovative variants of the IDEs.

SESSION SPEAKER ABSTRACTS 1.3

A. CLAUDE BOCCARA
Institut Langevin ESPCI-ParisTech

Wavefront Control and Optical Tomography of Scattering Media

Coauthors: Sylain Gigan

A number of experimental approaches such as Optical Coherence Tomography, Diffuse Tomography, acousto-optics etc. are used to image through scattering media. We will underline a number of their limits in term of resolution, depth and signal to noise ratio. In parallel a number of new approaches have emerged these last years that allow revisiting these techniques in order to improve their performances in term of contrast, resolution, speed etc. Then we will point few results that have been obtained using wavefront control in the space domain or in the time domain and discuss how these wavefront controls could help to enlarge the field of optical tomography.

ERIC BONNETIER
Laboratoire Jean Kuntzmann, Universit Joseph Fourier, Grenoble

Some stability results for electric impedance tomography under elastic deformation

Coauthors: Guillaume Bal (Columbia) François Monard (Columbia) Faouzi Triki (Universit Joseph Fourier, Grenoble)

We consider electric impedance tomography under elastic perturbations, where one tries to determine the conductivity in a bounded domain from the knowledge of pairs of Dirichlet and Neumann data and from their associated internal energy densities. In 2D, using a result of Alessandrini and Nesi, one can show the injectivity and stability of the map that associates the conductivity to the internal data corresponding to 2 diffeomorphic imposed currents. In 3D, the situation is more complex, and we only obtain a local result of uniqueness and stability.

References : [1] H. Ammari, E. Bonnetier, Y. Capdeboscq, M. Tanter, and M. Fink, Electrical impedance tomography by elastic deformation, SIAM J. APPL. MATH. Vol. 68, No. 6, pp. 1557-1573 (2008). [2] G. Bal, E. Bonnetier, F. Monard and F. Triki, Inverse diffusion from knowledge of power densities, submitted. [3] G. Bal and G. Uhlmann, Inverse diffusion theory for photoacoustics, Inverse Problems, 26(8) (2010), p. 085010. [4] Y. Capdeboscq, J. Fehrenbach, F. de Gournay, and O. Kavian, An optimal control approach to imaging by modification, SIAM Journal on Imaging Sciences, 2, pp. 1003-1030 (2009).

KRISTY BROCK
Princess Margaret Hospital, University of Toronto

The Role of Deformable Registration Algorithms in Adaptive Radiotherapy

Advances in imaging and treatment planning have improved the precision and sophistication with which external beam radiation therapy can be planned. In addition, image guidance at the time of treatment delivery can improve the ability to accurately deliver this treatment. However, the information obtained from volumetric images at the time of treatment delivery has also provided information on the changes that can occur in the patient anatomy over the course of treatment, including weight loss, normal tissue response, and tumor response. These changes compromise the ability to accurately deliver the intended dose. In many cases, these changes can be substantial, warranting the need to generate a new treatment plan to ensure that the therapeutic intent is administered in the presence of these changes, termed adaptive radiotherapy. The infrastructure to enable adaptive radiotherapy in the clinical environment is not trivial. One key component is deformable registration, which enables mapping of the anatomy in the initial planning images with the image or images obtained over the course of treatment or at the time that the treatment adaptation is performed. Once the anatomical mapping is complete, dose accumulation can be performed. The results of the deformable registration become an important component linking the geometric states of the patient, and therefore ensuring that the mapping is accurate is critical.

This presentation will review the key components of adaptive radiotherapy, specifically focusing on the role of deformable registration. A brief survey of the algorithms often used in the field will be provided. Results of a multi-institution deformable registration accuracy study will be presented, highlighting the importance of algorithm implementation. Mathematical, phantom, and image-based metrics to assess accuracy of the algorithms will be discussed.

HAI-LING MARGARET CHENG
Hospital for Sick Children

Quantitative Dynamic Contrast-Enhanced MRI (DCE-MRI) of Tumor Angiogenesis

Angiogenesis, the growth of new blood vessels, plays a critical role in tumor growth and metastasis. The morphology and function of tumor vessels, however, are distinct from healthy blood vessels. In general, tumor blood vessels are poorly formed, resulting in a chaotic vessel hierarchy with leaky endothelial linings, enlarged lumens, and poor perfusion, all of which contribute to an environment (e.g. hypoxic, high interstitial fluid pressure) that further drives malignant progression. Functional information on tumor

vessels can, therefore, inform us on tumor biology, its progression and response to conventional chemo/radiotherapy or novel antiangiogenic therapies. As a non-invasive imaging modality, DCE-MRI has been increasingly used over the last decade in the staging of patients with cancer and monitoring their therapeutic response. Quantitative DCE-MRI, which extracts physiologically meaningful parameters (e.g. perfusion, vessel permeability, and cell packing), can further extend the role of MRI and potentially allow response prediction for patient selection and therapy planning, as well as elucidate the biological effects of new therapeutic developments. We will describe the current state-of-the-art in DCE-MRI technology, the requirements for robust and reliable quantitation, and recent advances that will enable clinical implementation of quantitative DCE-MRI for cancer management.

DOUGLAS CHEYNE, PHD
Program in Neurosciences and Mental Health, Hospital for Sick Children / Dept. of Medical Imaging, University of Toronto

Use of adaptive beamformers in MEG source modeling

Neuromagnetic inverse solutions involve determining the distribution of electrical activity within the brain that contributes to the magnetic field recorded by sensors outside of the head. Solutions to such inverse problems are non-unique and highly underdetermined. Traditional approaches to this problem model the underlying neural generators as combinations of discrete point sources (dipole fitting) or as distributed current solutions (e.g., minimum-norm). These approaches can be limited by crosstalk between multiple brain sources, or the presence of interference sources that are not included in the forward models. An alternative approach is to construct 3-dimensional source images from a lattice of spatial filters based on adaptive (minimum-variance) beamforming. This method minimizes crosstalk between sources based on the observed correlation between signals measured across the array of detectors, and is thus ideally suited to modern whole-head MEG systems that consist of a hundred or more recording channels distributed over the head. I will review current beamforming approaches used in MEG source analysis, and describe some of the advantages and disadvantages of this source modeling approach. I will also show examples of the application of a spatiotemporal beamforming algorithm developed in our lab at SickKids in both clinical and basic studies of human brain function.

LAKSHMINARAYAN V. CHINTA
Sunnybrook Research Institute and Department of Medical Biophysics, University of Toronto

Quantitative Perfusion Estimation from Two Photon Fluorescence Microscopy Microvasculature Maps

Coauthors: Liis Lindvere, Bhupinder Sahota, John G. Sled, Bojana Stefanovic

OBJECTIVE: Many models have been proposed to explain the relationship between neural activity and hemodynamic parameters but in their present forms these models fail to provide a detailed understanding of the neurovascular coupling on the micron scale. Our laboratory has been recently using two photon fluorescence microscopy (2PFM) to image the 3D vascular network close to the epicenter of neural activity elicited by somatosensory stimulation and quantitatively analyzing the 3D vascular morphology to deduce dynamic changes in the cerebral blood volume across the vascular tree. The current work estimates cerebral blood flow and perfusion from the 3D geometry and a 2D time series tracking the bolus passage of an injected fluorescent dextran. METHODS: Experiments were conducted on male adult Sprague Dawley rats (140+/-45g). The animals were anesthetized with isoflurane during surgical preparation and alpha-choralose during imaging. The right femoral artery, femoral vein, and tail vein were cannulated for blood gas analysis, intravenous administration of anesthesia, and fluorescent agents respectively. Stereotaxic surgery was performed to prepare a small cranial window (4mm x 3mm) over the forelimb representation in the primary somatosensory cortex. Two-photon microscopy imaging was performed following three 5 mg/kg bolus of Texas Red dextran (70 kDa). To measure the vascular transit time, the bolus passage was tracked by acquiring a time series of a single $\approx$ 300μm2 imaging plane, $\approx$ 50μm below the cortical surface, at 0.31 +/- 0.07 fps and with a spatial resolution of 1.59 μm/pixel. To estimate vessel-wise volume, we obtained a stack of high-resolution images, 300 slices at 1μm lateral and 3μm axial resolution. ANALYSIS: The signal intensity curves from bolus passage experiments were integrated over time for all labeled vessels in the bolus plane. A second order plus dead time model [1] was used to estimate dead time (θ), damping ratio (ξ), and natural frequency (ω). Laplace domain transfer functions were next calculated and the corresponding impulse response was used to compute onset and peak time. Imaris (Bitplane Scientific Software) was used for semi-automatic segmentation of the 3D vascular network. Next, the 2D bolus passage time series was registered to the segmented 3D network and a standard method applied for estimating the transit time between transected vessels [2]. We identified closed paths between any two vessels of the bolus tracking plane by tracing through the 3D network. For the multiple connecting paths, we devised a methodology to estimate the transit times of the individual segments. We solved for the unknown transit times based on equations of transit times and CBF, where CBF at each segment was calculated from the central volume principle as CBF=CBV/TT. Perfusion was then computed by normalizing CBF by

the volume of the irrigated tissue. Based on the 2PFM literature [3], the diffusion distance for oxygen was assumed to be ≈55-70 μm in the rats somatosensory cortex and the tissue volume irrigated was thus estimated as a convolution of ≈65 μm sphere and our vascular subtree centrelines. RESULTS AND CONCLUSION: The application of our methodology to a sample subject shows a skewed distribution of perfusion in the vascular paths: most (≈65%) of the paths exhibit perfusion in the 0.56 +/- 0.25 mL/g/min range, ≈25% exhibit a mean perfusion of 1.53 +/- 0.36 mL/g/min while ≈10% show high perfusion of 2.56 +/- 0.5 mL/g/min under alpha-chloralose anesthesia in the somatosensory cortex of rats. Recent work using iodo[14C]antipyrine autoradiographic estimated perfusion at ≈0.6 mL/g/min [4] and optical coherence tomography measurements suggested 0.51-0.68 mL/g/min [5] in the somatosensory cortex of rats under the same anesthesia protocol. Our results show evidence of heterogeneity in perfusion, we expect this heterogeneity to relate to local vascular density. This work describes a novel methodology to estimate perfusion at the micron level from the 2PFM imaging of cerebral microvasculature, its application to a cohort of subjects should allow detailed investigation of the relationship between cortical microvascular topology and blood flow. [1] Rangaiah, Chem. Eng. Sci (1996); [2] Kety, Am J Physiol (1945); [3] Masamoto, J Applied Physiology (2007); [4] Nakao, Proc Natl Acad Sci USA. (2001); [5] Srinivasan, Opt Express. (2010)

NATHAN CHURCHILL
Department of Medical Biophysics, University of Toronto; Rotman Research Institute, Baycrest

Data-Driven Measurement and Removal of Physiological Noise in BOLD fMRI

Coauthors: Grigori Yourganov, Robyn Spring, Peter M. Rasmussen, Jon E. Ween, Stephen C. Strother

BOLD fMRI is an invaluable tool for measuring correlates of brain function; however, this technique is limited by a relatively poor Contrast-to-Noise-Ratio, making it difficult to obtain robust, accurate measurements. One of the principal confounds of fMRI is physiological noise, including the effects of respiration and pulsatile bloodflow, which exhibit complex, undersampled temporal structure in standard fMRI. In addition, physiological noise is often non-orthogonal to the neuronally-linked BOLD response, presenting a significant challenge in separating subject-derived signal and noise. In this talk, we present a multivariate, data-driven procedure for estimating physiological noise in fMRI data, based on physiologically-derived constraints. This method identifies high frequency, autocorrelated noise sources with reproducible spatial structure, using an adaptation of Canonical Correlation Analysis, in a split-half resampling framework. The technique is able to identify a physiological noise subspace with vascular-linked spatial structure, and

an intrinsic dimensionality that is task- and subject-dependent. In addition, we demonstrate that subjects with higher variance in respiratory and cardiac rates generally require a higher-dimensional subspace to optimize the detection of physiological noise in fMRI. This technique may be used to remove the physiological noise component from fMRI data, which increases spatial reproducibility and prediction accuracy of analyses. These results provide novel information about the structure of physiological noise in BOLD fMRI, as well as a principled method of removing physiological artifact.

DANA COBZAS
Computing Science, University of Alberta

Random walks for deformable image registration

Coauthors: Abhishek Sen, Martin Jagersand

I will present a novel discrete optimization formulation of deformable image registration, that can be solved by the random walker (RW) framework. The space of deformations is discretized and the image registration problem is formulated as a Gaussian MRF where continuous labels correspond to the probability of a point having a certain discrete deformation. The interaction (regularization) term of the corresponding MRF energy is convex and image dependent, thus being able to accommodate different types of tissue elasticity. This formulation results in a fast algorithm that can easily accommodate a large number of displacement labels, has provable robustness to noise, and a global solution. We experimentally demonstrate the validity of our formulation on synthetic and real medical data.

RHODRI CUSACK
Centre for Brain and Mind, University of Western Ontario

Characterizing neural representation with multivariate pattern analysis of fMRI data

A traditional functional MRI experiment aims to identify the brain regions recruited by some cognitive function. To best identify regions activated in the majority of volunteers, data are typically spatially smoothed with a kernel of diameter 1-2cm and statistics subsequently performed on single voxels in a mass univariate regime. In a new approach of rapidly increasing popularity, multivariate (or multi-voxel) pattern analysis (MVPA), a measure is taken of the consistency of the relationship between cognitive state and the pattern of activity across a local brain region within an individual. Data are typically not smoothed and it is not assumed that all voxels will be positively activated (some may carry information by deactivating). Group analyses are then performed on statistics that summarize the extent of representation of a given aspect of the cognitive state within a

local region, and power is not reduced if the patterns of activity that signal these states are quite distinct in different volunteers. This method is often more sensitive than conventional fMRI, and is capable of distinguishing much more finely differentiated mental states. The method will be illustrated with examples from studies of auditory and visual memory and object recognition.

FABRICE DELBARY
Technical University of Denmark

Electrical Impedance Tomography: 3D reconstructions using scattering transforms

Coauthors: Per Christian Hansen (Technical University of Denmark), Kim Knudsen (Technical University of Denmark)

In late 1980s, the theoretical foundation of a direct quantitative method for Electrical Impedance Tomography was formulated (J. Sylvester, G. Uhlmann, R. G. Novikov, A. Nachman) and successfully implemented in the 2D case (S. Siltanen, J. Mueller, D. Isaacson) and in the 3D case for radial symmetric conductivities (J. Bikowski, K. Knudsen, J. Mueller). The method is based on the reformulation of the electrical potential equation as a Schrödinger equation and the reconstruction algorithm makes use of ideas from inverse scattering theory. The measurements are modelled by the Dirichlet-to-Neumann map, which, roughly speaking, contains the measurement of currents at electrodes when voltages are imposed. The main difficulty in the inverse problem of recovering a conductivity from the knowledge of the Dirichlet-to-Neumann map (Calderón problem) is the ill-posedness of the problem, a difficulty the reconstruction algorithm inherits. When not treated carefully, even small measurement errors can lead to aberrant reconstructions.

In this talk, we propose to show the feasibility and relative efficiency of a 3D implementation of the algorithm for general conductivities in the unit ball, with a reasonable computation time. First, the reconstruction algorithm and its possible simplifications obtained by approximation, will be introduced. After briefly presenting the implementation, the reconstructions for numerical phantoms will be showed and the obtained resolution for the different simplifications will be discussed.

REN DONNER
Medical University Vienna

3D Anatomical Structure Localization

Coauthors: Georg Langs, Bjrn Menze, Horst Bischof

We propose a method for the automatic localization of complex anatomical structures using interest points derived from Random Forests and matching based on discrete optimization. During training landmarks are annotated in a set of example volumes. A sparse elastic model encodes the geometric constraints of the landmarks. A Random Forest classifier learns the local appearance around the landmarks based on Haar-like 3D descriptors.

Classifying all voxels in the query volume yields probabilities indicating its correspondence with the landmarks. Mean-shift clustering obtains a subset of 3D interest points at the locations with the highest similarity in a local neighboorhood. We encode these points together with the conformity of the connecting edges to the learnt geometric model in a Markov Random Field. By solving the discrete optimization problem the most probable locations for each model landmark are found in the query volume, i.e. the anatomical structure is localized.

PAUL DUFORT
Department of Medical Imaging, University of Toronto, Canada

Joint Segmentation and Deformable Registration of Fractured Vertebrae Using a Synthesis of the Expectation Maximization and Belief Propagation Algorithms

A new surgical procedure aims to restore the height of damaged vertebral bodies that have suffered a compression fracture as a result of severe trauma. A computational method is needed to assess the efficacy of the procedure by automatically measuring the change in shape of the vertebral bodies in CT scans taken before and afterward.

While nominally a problem of registering the CT scans, the details of the required measurements pose unique difficulties. Rigid registration alone is inadequate due to the differing curvatures of the spine across scans, and the fact that the target vertebra may itself have changed shape substantially due to the surgical procedure. While the shape changes of interest could be derived from a deformable registration field, intensity-based registration techniques in general are problematic due to the large quantity of extremely electron-dense (3000 HU) materials injected into the vertebra during the surgical procedure, greatly reducing the image quality.

Instead, we describe a joint segmentation/registration technique based on deformably registering a model vertebra to the target vertebra in the CT scans before and after the procedure. While the vertebral body is damaged in these cases, the posterior regions are

typically left intact. The segmentation allows the posterior regions of the vertebra to be isolated and rigidly registered, so that the remaining misalignment of the vertebral body can be attributed to physical changes in its shape.

The joint segmentation/registration method is feature-based, attempting to match a dense set of simple features extracted from the model vertebra surface to features extracted from the CT data. The expectation-maximization (EM) algorithm is used to simultaneously compute the deformation field and the match correspondence probabilities. However, since EM is an ascent-based mechanism, it is prone to converging to inappropriate minima in the presence of the clutter introduced by nearby adjacent vertebrae, ribs, aortic calcifications, and the cement and implants used in the procedure.

We therefore augment the expectation step with one or more loopy belief propagation (BP) iterations on an associated Markov random field that assign low probabilities to matches less consistent with the global shape of a vertebra. A probability metric is described for quantifying the agreement between two shapes that is invariant to translation and rotation, and whose sensitivity to scaling can be adjusted independently of shape. We demonstrate the technique and discuss its application, pros, and cons in the general context of finding correspondences in medical image data.

MEHRAN EBRAHIMI
Sunnybrook Health Sciences Centre

Mathematical Methods for Breast Image Registration

Dynamic contrast enhanced magnetic resonance imaging (DCE-MRI) provides a very high sensitivity for the detection of breast cancer and a sharp delineation of breast lesions. In the first part of this talk, we present an efficient numerical methodology for automated simultaneous registration and intensity correction of DCE-MRI series. The model separates the intensity correction term from the images being registered in a regularized expression. A joint objective functional is formed for which the corresponding Hessian and Jacobian is computed and employed in a multi-level Gauss-Newton minimization approach.

The second part of the talk is devoted to evaluating thin-plate spline registration of the breast in two supine positions. Breast MRI is performed prior to breast conserving surgery in order to assess the location and extent of the lesion. It is, however, difficult for the surgeon to use the MR images to guide the surgery as the MRI is typically performed in the prone position whilst surgery is performed in the supine position and the breast undergoes significant distortion as a result. To overcome this restriction, breast MRI with supine patient position has been recently proposed. However, in most clinical MR scanners the arm of the patient has to be placed parallel to the body, whereas the arm is placed in an outstretched position during surgery. Here, a thin-plate spline registration scheme will be discussed which matches these two configurations using the positional information of surface markers.

ADEL FARIDANI
Oregon State University

Numerical aspects of pi-line reconstruction algorithms in tomography

Coauthors: Ryan Hass

We investigate algorithms of filtered backprojection type that are based on pi-line inversion formulas such as Katsevich's inversion formula in two and three dimensions. The location of a characteristic artifact is identified and related to the region of backprojection as well as the support of the backprojected derivative. An application to data alignment is presented and some advantages of pi-line reconstruction algorithms are pointed out.

RICHARD FRAYNE
Radiology and Clinical Neurosciences, Hotchkiss Brain Institute, University of Calgary, and Seaman Family Centre, Foothills Medical Centre, Alberta Health Services

Potential for Compressed Sensing in Clinical MR Imaging

Magnetic resonance (MR) is a commonly used method for acquiring cross-sectional (tomographic) images through the human body. Most large medical centre across Canada have one or more, heavily utilized, MR scanners. Unlike computed tomography (CT a modality that forms tomographic images from collected projection x-ray images), MR uses radiowaves and magnetic fields to image hydrogen in the body and thus does not expose patients to ionizing radiation. Drawbacks to MR imaging include the need to operationally tradeoff resolution, signal-to-noise (SNR) and total acquisition times. Clinically useful MR examinations require a sufficiently lengthy total acquisition time in order to achieve resolution or SNR targets. Most clinical MR imaging uses a linear image reconstruction methodology (typically based on the Fourier transform). Compressed sensing is a recently proposed reconstruction methodology that can partially decouple the relationship between resolution, SNR and total acquisition time, provided specific conditions are met. The principle condition is that the reconstructed image, or a representation of it in another domain, must have sparsity. An increasing number of theoretical, phantom and patient-based studies are beginning to investigate the application of compressed sensing in MR imaging. This presentation reviews when it may be possible to decouple the relationship between resolution, SNR and total acquisition time, and overviews some of the applications currently under investigation. It will also discuss current limitations relating to the iterative nature and slowness of the compressed sensing

MONA K. GARVIN
VA Center of Excellence for the Prevention and Treatment of Visual Loss at the Department of Veterans Affairs in Iowa City, IA and The Department of Electrical and Comptuer Engineering at The Unversity of Iowa

Use of 3D Graph-Theoretic Approaches in the Segmentation of Ophthalmic Structures

Coauthors: Michael Abramoff, Xiaodong Wu, and Milan Sonka

Three-dimensional graph-theoretic techniques, such as graph cuts and the Layered-Optimal-Graph-Image-Segmentation-of-Multiple-Objects-and-Surfaces (LOGISMOS) approach, are becoming increasingly popular for segmenting three-dimensional structures within medical images. Such approaches enable globally optimal (with respect to a cost function) segmentations of 3D objects to be achieved in polynomial time. Furthermore, approaches such as LOGISMOS enable the simultaneous optimal detection of multiple surfaces in volumetric images, which is important in many medical image segmentation applications for which interrelationships between surfaces and objects are important. The first part of this talk reviews the theory behind the LOGISMOS approach and presents an overview of a number of applications. The second part of this talk discusses some of the ophthalmic applications in greater depth, such as the simultaneous segmentation of multiple layers of the retina within spectral-domain optical coherence tomography volumes.

MICHAL HOLTZMAN GAZIT
University of British Columbia

A Scale Consistent Approach to Image Completion

Coauthors: Irad Yavneh

Most patch based algorithms for completing missing parts of images fill in the absent regions by copying patches from the known part of the image into the unknown part, somewhat like plastic surgery. The criterion for deciding which patch to copy is compatibility of the copied patch with the vicinity of the region being completed. In this research we propose introducing a new dimension to this compatibility criterion, namely, scale. The patch is thus chosen by evaluating its consistency with respect to a hierarchy of smoothed (less detailed) versions of the image, as well as its surroundings in the current version. Applied recursively, this approach results in a multi-scale framework that is shown to yield a dramatic improvement in the robustness of patch based image completion.

JEAN-FREDERIC GERBEAU
INRIA Paris-Rocquencourt

MagnetoHemoDynamics in MRI devices

Coauthors: A. Drochon, O. Fokapu, V. Martin

In presence of a high magnetic field (typically in a MRI device), the blood flow in the aorta induces an electrical potential which is responsible for an increase of the T-wave in the electrocardiogram (ECG). This phenomenon may perturb ECG-gated medical imaging. The aim of this study is to reproduce this experimental observation through computer simulations. The model consists of three components: magnetohydrodynamics (MHD) in the aorta, bidomain equations in the heart and electrical diffusion in the rest of the body. These models are strongly coupled together and solved with finite elements. Some numerical results without and with a magnetic field are presented and discussed.

CHERYL GRADY
Rotman Research Institute

The use of multivariate methods for the analysis of fMRI studies of cognition

In this talk I will discuss the motivation for why a scientist interested in the brain mechanisms underlying cognition would want to use multivariate methods for analyzing functional neuroimaging datasets. This will be followed by presentation of one particular multivariate method, Partial Least Squares (PLS), and some examples of how PLS can be used to answer questions about cognition. These will include descriptions of how we assess brain activity differences across cognitive tasks and groups (e.g., young vs. older adults), functional connectivity of specific brain regions, and relations between brain measures and behaviour.

LEO GRADY
Imaging Analytics and Informatics, Siemens Corporate Research

Universal Models for Targeted Image Segmentation

Traditional image segmentation methods have the goal of localizing all objects which are present in an image. In contrast, many medical imaging applications of image segmentation seek to localize a particular object within an image. Unfortunately, the design of these targeted image segmentation algorithms is often very specific to the particular object and acquisition device, which requires a new algorithm design for each targeted segmentation application. I will discuss progress toward creating a universal segmentation algorithm that can successfully find any target object in any image when sufficient targeting information has been supplied.

FIELDS

SESSION SPEAKER ABSTRACTS 1.3

LEOPOLD GRINBERG
Brown University

Multi-scale patient-specific modeling of brain blood flow

Coauthors: George Em Karniadakis

Realistic simulations of thrombus formation in intracranial aneurysms require resolution of the macro (centimeter) scale as well as the micro and sub-micron scale flow features. In this talk we will review some mathematical models and computational approaches we have developed over the last few years for multi-scale blood flow simulations. We will also present new simulation results of platelets aggregation in a patient-specific model of intracranial aneurysm. The simulation has been carried out using patient-specific geometry and with high spatio-temporal resolution on 131,074 processors of BlueGene/P supercomputer. To resolve the macro and micro scale flow features we have coupled two parallel codes: NEKTAR - a high-order spectral element parallel Navier-Stokes solver, and DPD-LAMMPS a coarse-grained molecular dynamics solver based on the dissipative particle dynamics method.

ELDAD HABER
UBC

Inverse Problems for multi-source experiments

Many parameter estimation problems involve with a parameter-dependant PDEs with multiple right hand sides. The computational cost and memory requirements of such problems increases linearly with the number of right hand sides. For many applications this is the main bottleneck of the computation. In this work we show that problems with multiple right hand sides can be reformulated as stochastic optimization problems that are much cheaper to solve. We discuss the solution methodology and use the direct current resistivity as a model problem to show the effectiveness of our approach.

ARSEN HAJIAN
Tornado Medical Systems and University of Waterloo

An Algorithm's Journey Through Government, Academia, and Industry

I will discuss the progression of a simple algorithm that has value in government, academia and industrial positions I have held or currently hold. I will focus on the metrics that define value in all three of these knowledge-building arenas.

NICHOLAS HOELL
University of Toronto

Inversion of the Attenuated Ray Transform

We discuss some recent progress in obtaining closed form inversion formulae for the attenuated ray transform on nontrivial families of curves in 2-dimensional space. Some novel formulae are discussed whose derivation rely on complex-analytic methods. This work arose initially from the nuclear medical diagnostic modality SPECT and arises in electrical impedance tomography.

NICHOLAS HOELL
University of Toronto

Some results on the attenuated ray transform

We present some novel explicit filtered backprojection (FBP) type inversion formulae for the attenuated x-ray transform over curves in the two-dimensional unit disc in cases of known transmission coefficient. The formulae we present involve complexification of the vector fields generating the photon transport in the medium. This tomographic problem is useful in the nuclear medical imaging modality SPECT and has also arisen in the problem of determining the interior permittivity and permeability parameters of a conductive body from external Maxwell measurements.

LIOR HORESH
IBM TJ Watson Research Center

Optimal design in medical inversion

Coauthors: Eldad Haber, Luis Tenorio

In the quest for improving inversion capabilities design, vast attention has been devoted to effective solution of the problem under various regularization configurations. Nevertheless, questions such as optimal configuration of data acquisition or more generally any other controllable parameters of the apparatus and process (e.g. regularization) were mostly overlooked. While design for well-posed problems has been extensively studied in the past years, very little consideration has been givento its ill-posed counterpart. This stands in contrast to the fact that many real-life problems we challenge are of such nature. In this talk we shall describe some of the intrinsic difficulties associated with design for ill-posed inverse problems, lay out a coherent formulation to address them and finally demonstrate the importance of design for medical imaging problems.

JOHN M. HUDSON
University of Toronto

Functional Imaging of Cancer Using Contrast-Enhanced Ultrasound

Coauthors: Ross Williams, Brendan Lloyd, Laurent Milot, Mostafa Atri, Georg A. Bjarnason, and Peter N. Burns

Contrast enhanced ultrasound imaging offers a unique method to quantify the microvascular haemodynamics of tissue and cancers. This is achieved by exploiting the ability of the contrast agent (microbubbles) to be disrupted and preferentially detected with contrast specific imaging techniques. The procedure, known as Disruption-Replenishment, uses a clinical ultrasound system to disrupt the freely flowing microbubbles within the imaging scan plane with a short burst of high intensity ultrasound. This creates a regional void of tracer that will re-fill at a rate dependent upon the flow velocity, morphology, and blood volume of the feeding vasculature. In order to extract useful information from the time-intensity refill curves, we have developed a generalized model of replenishment that accounts for the details of the flow system under study (i.e. velocity distribution, fluid volume, vascular structure etc.) in addition to the influence of the ultrasound system used to make the measurement and its interaction with the circulating microbubble population. The model is used to generate parameter-enhanced radiological images of the microcirculation from which a variety of quantitative statistics can be calculated and used to monitor cancer therapy. In relation to a clinical anti-angiogenic trial for renal cell carcinoma, we have shown that microbubble dynamics can be used to selectively filter small vessel flow from large vessel flow in order to isolate the microvessels that might be preferentially targeted by anti-angiogenic treatments.

NUUTTI HYVNEN
Aalto University, Finland

Electrical impedance tomography with two electrodes

Electrical impedance tomography is a noninvasive imaging technique for recovering the conductivity distribution inside a body from boundary measurements of current and voltage. In this talk, we consider impedance tomography in the special case that the measurements are carried out with two electrodes that can be moved along the boundary of the (two-dimensional) object of interest. Two different types of data are considered: The backscatter data is obtained by using a small probe consisting of two electrodes for driving currents and measuring voltage differences subsequently at various neighboring locations on the boundary of the object. The sweep data is gathered by fixing the location of one electrode and measuring the voltage difference required for maintaining a unit current as a function of the position of the other. A reconstruction algorithm for locating conductivity

inhomogeneities in homogeneous background from such data sets is introduced and tested numerically.

HANNA JANKOWSKI
York University

Confidence Regions and Means of Random Sets using Oriented Distance Functions

Coauthors: Larissa Stanberry

Image analysis frequently deals with shape estimation and image reconstruction. The objects of interest in these problems may be thought of as random sets, and one is interested in fi

nding a representative, or expected, set. We consider a definition of set expectation using oriented distance functions and study the properties of the associated empirical set. Conditions are given such that the empirical average is consistent, and a method to calculate a confidence region for the expected set is introduced.

The proposed methodology was motivated by the problem of skin-boundary reconstruction in a mammogram image, and we illustrate our methods in this setting.

TIMOTHY D. JOHNSON
University of Michigan, Department of Biostatistics

Predicting Treatment Efficacy by Quantitative MRI via a Bayesian Joint Model

Coauthors: Jincao Wu

The prognosis for patients with high-grade gliomas is poor, with a median survival of one year. Treatment efficacy is typically assessed three to four months post therapy. However, our colleagues hypothesize that quantitative MRI can assess treatment efficacy three weeks after therapy starts, thereby allowing salvage treatments to begin earlier. The purpose of this work is to build a predictive model of treatment efficacy using qMRI data and to assess its performance. The outcome is one-year survival status. We propose a joint, two-stage Bayesian model. In stage I, we smooth the image data with a multivariate spatio-temporal pairwise difference prior. In stage II, summary statistics from stage I enter a generalized non-linear model (GNLM) as predictors of survival status. We use the probit link and a multivariate adaptive regression spline basis. Through model performance comparisons we find that we are able to acheive higher overall correct classification rates by accounting for the spatio-temporal correlation in the images and by allowing for a more complex and flexible decision boundary provided by the GNLM.

SESSION SPEAKER ABSTRACTS 1.3

DAVID KOFF
McMaster University

Rewards and Challenges in Adoption of Diagnostically Acceptable Irreversible Compression

As the increasing volume and size of medical images offsets the decreasing cost of storage, and as the implementation of regional Digital Images repositories allows access to exams region wide, there is a need for lossy compression to speed image transmission on limited bandwidth and save on storage costs. Compression ratios have been recommended for approved compression methods JPEG and JPEG2000 in National Standards but there are still quality issues to be solved to allow for large scale adoption and implementation of Diagnostically Acceptable Irreversible Compression.

JASON LERCH
Hospital for Sick Children

Detecting small changes in the brain with structural MRI

While the investigation of anatomy in studies of brain development and neurological or neuropsychiatric disorders is older than the field of brain imaging itself, recent studies have shown that even subtle differences due to learning can be detected using modern imaging hardware and sophisticated image processing techniques. In this talk I will present methods on how to analyze structural imaging data for detecting subtle alterations in neuroanatomy, with a particular focus on registration based techniques. Applications to both human and mouse data as well as simulated results will be discussed.

SHUO LI
GE Healthcare and Univ. of Western Ontario

Mathematics of Cardiac Image Segmentation and Registration

Major recent advances in the mathematics have led to great improvement in the automated cardiac segmentation and registration methods. Different real time and practical tools have been invented to handle the complexity in cardiac images especial in Magnetic Resonance Images. With the focus on the applied math and its application, a short review will be presented followed by an intensive discussion on the future development by leveraging the strength of advanced mathematics.

XITENG LIU
York University

System compression: theory and application

Coauthors: Hongmei Zhu, York University; Paul Babyn, Saskantoon Hospital Region.

Data in large quantity such as image or video data may be compressed to reduce its quantity for efficient storage and transmission. High efficiency lossy data compression is realized by locating and eliminating the redundancy, or say unessential elements, of the data set. Similarly, a linear system in large volume can be compressed through locating and eliminating its unessential elements - linear equations. The notion of system compression (SC) is related to compressed sensing (CS). One major difference between CS and SC is the requirement of randomness. CS paradigm emphasizes on randomness. Partial samples are randomly taken from the whole signal. As a result, the performance of reconstruction is random too. Reconstruction failures often occur. By contrast, in SC paradigm, partial samples are selectively taken from whole signal, in correspondence with the formation of system matrix, so that the matrix have certain desirable mathematical properties which may guarantee the stable success of signal reconstruction.

YINGLI LU
Sunnybrook Health Science Centre

Automated Analysis of Infarct Heterogeneity on Delayed Enhancement Magnetic Resonance Images

Coauthors: Perry Radau, Kim Connelly, Graham Wright

This presentation introduces an automated infarct heterogeneity analysis method for cardiac delayed enhancement magnetic resonance images(DE-MRI). Delayed enhancement magnetic resonance imaging (DE-MRI) is an imaging method for identifying myocardial infarct (MI). Two popular methods for determining the threshold values for the infarct core and gray zones on IR-GRE images have been proposed previously: standard deviation(SD) method and full-width at half-maximum (FWHM) method. For both methods, three contours are necessary: epicardial, endocardial and remote healthy myocardium region. Manual drawing of these contours is time consuming and suffers from high inter-observer and intra-observer variability.

This talk addresses the following key question: Is there a reproducible and reliable automated infarct heterogeneity analysis method? Using graph cuts method, this research yields a more reproducible measure of infarct core and gray zone as it is less sensitive to noise and does not require manual endocardial and remote region contour to segment out the blood pool, infarct core and gray zone.

WEIJING MA
University of Toronto

Active B1 Imaging Using Polar Decomposition Method

Coauthors: Nahla Elsaid, Dinghui Wang, Tim P. DeMonte, Adrian I. Nachman and Michael L. Joy

A novel way of measuring the radiofrequency B1 field is presented. It uses an MRI based method called Polar Decomposition Radio-frequency Current Density Imaging (PD-RFCDI). Unlike the conventional B1 mapping techniques that only measure the magnitude of B1, the proposed approach also measures the phase of B1.

In order to verify the validity of this novel method, the conventional double angle B1 mapping method was used to obtain the magnitude of B1 information of the same phantom. Both results show similar varying pattern across the phantom, which is consistent with previous B1 simulations. This research shows that PD-RFCDI is a useful tool of detecting B1. The phase information of B1 can be used for radio-frequency conductivity computation.

ALEXANDER MAMONOV
University of Texas at Austin

Resistor networks and optimal grids for electrical impedance tomography with partial boundary measurements

Coauthors: Liliana Borcea, Vladimir Druskin, Fernando Guevara Vasquez

We present methods to solve the partial data Electrical Impedance Tomography (EIT) problem numerically. Our methods regularize the problem by using sparse representations of the unknown conductivity on adaptive finite volume grids known as the optimal grids. The discretized problem is reduced to solving the discrete inverse problems for resistor networks. Two distinct approaches implementing this strategy are presented. The first approach uses the results for the full data EIT with circular resistor networks. The optimal grids for such networks are essentially one dimensional objects, which can be computed explicitly. We solve the partial data problem by reducing it to the full data case using the theory of extremal quasiconformal mappings. The second approach is based on pyramidal resistor networks. The optimal grids in this case are computed using the sensitivity analysis of both the continuum and the discrete EIT problems. Numerical results show two main advantages of our approaches compared to the traditional optimization-based methods. First, the inversion based on resistor networks is much faster than any iterative algorithm. Second, we are able to reconstruct the conductivities of ultra high contrast, which usually presents a challenge to inversion methods.

ANDREAS MANDELIS
Center for Advanced Diffusion-Wave Technologies, Department of Mechanical and Industrial Engineering, University of Toronto

The biomedical photoacoustic radar imager: Principles, signal-to-noise ratio, contrast and resolution

Coauthors: Bahman Lashkari and Sergey Telenkov

The talk will present the photoacoustic (PA) imaging (chirped) radar (or sonar) with respect to physical and instrumentation/signal generation and processing principles. A review of experimental and theoretical results obtained in our laboratory will demonstrate the instrumental capabilities for specific PA tissue imaging applications. Distinct features of the PA radar include excellent signal-to-noise ratio and efficiently suppressed baselines compared to pulsed laser sources, underscoring the high potential of this technique for depth-selective imaging of deep lying tissue chromophores. Our results demonstrate that submillimeter depth-selective photoacoustic imaging can be achieved without nanosecond pulsed laser systems by appropriate modulation of a continuous laser source and a signal processing algorithm adapted to specific parameters of the photoacoustic response. Furthermore, imaging contrast will be compared with the pulsed laser method. The application of nonlinear frequency modulation instead of the standard linear frequency chirps was investigated and its effects on signal to noise ratio (SNR), contrast and image resolution will be discussed. In addition to the image produced by the amplitude of the cross-correlation between input and detected signals, the phase of the correlation signal was used as a filter of the PA amplitude combined with linear or nonlinear frequency chirps. It was demonstrated that the phase signal can effectively filter the amplitude image and greatly improve its contrast. The experimental results with a high-frequency transducer exhibit more than 10 and 8 times contrast enhancement using nonlinear and linear chirps, respectively. Concomitant improvements in SNR and image resolution were also observed.

ELENA S DI MARTINO
University of Calgary

Wall stress and flow dynamics in abdominal aortic aneurysms

Coauthors: Alessandro Satriano

Abdominal aortic aneurysms (AAA) are characterized by the dilation of the aorta associated with degradation of the vessel wall. The natural history, in the absence of treatment, is the progressive enlargement of the aneurysm and eventually its rupture, an event that carries a very high mortality (up to 90

JOYCE R. MCLAUGHLOIN
Rensselaer Polytechnic Institute

Viscoelastic models for tissue: Theoretical results for the forward problem

Coauthors: Ashley Thomas, Rensselaer Polytechnic Institute Jeong-Rock Yoon, Clemson University

We consider viscoelastic models that have the property of finite propagation speed and frequency dependent wave speeds. We establish theoretical properties for these systems in 3D. We also discuss plane strain and plane stress approximating systems in 2D.

HATEF MEHRABIAN
Department of Medical Biophysics, University of Toronto

Application of independent component analysis (ICA) to identify and separate tumor arterial input function (AIF) in dynamic contrast enhanced-MRI

Coauthors: Chaitanya Chandrana, Ian Pang, Rajiv Chopra and Anne L. Martel

Investigating image intensity change in each pixel in dynamic contrast enhanced (DCE)-MRI data enables separation of its various tissue types based on their differences in contrast uptake. Pharmacokinetic (PK) modeling of tumor tissue is commonly used to extract physiological parameters (i.e. Ktrans and ve) from the concentration-time curves of the contrast agent in different spaces. In a two compartmental PK model the concentration-time curve of the feeding blood vessels or arterial input function (AIF) is required. This intravascular signal is inseparable from the signal from the extravascular extracellular space (EES) due to low resolution of the data and other imaging issues such as partial volume effect and intravoxel dephasing. Since direct measurement of these quantities is not possible in the tumor, some assumptions are made to approximate these concentration curves. Independent component analysis (ICA) has the potential to separate the AIF from the DCE-MRI of the tumor. We have performed a validation study using tissue mimicking phantoms and in-vivo VX2 tumors in a rabbit model to assess the performance of ICA in separating tumor AIF. The results demonstrated the efficiency of the ICA in identifying and separating the tumor AIF in DCE-MRI which may lead to more accurate measurement of PK parameters.

OLEG MICHAILOVICH
Department of ECE, University of Waterloo

Fast and accurate HARDI and its application to neurological diagnosis

Coauthors: Yogesh Rathi

The advent of diffusion MRI (dMRI) has led to the development of qualitatively new methods of interrogating the white matter of the brain. High angular resolution diffusion imaging (HARDI) constitutes a particularly important instance of dMRI, which offers a more accurate delineation of local diffusion patterns as compared to diffusion tensor imaging, while having considerably milder acquisition requirements as compared to the case of diffusion spectral imaging. Unfortunately, the clinical value of HARDI still remains limited, mainly because of the problem of prohibitively long acquisition times required to complete HARDI scans. Moreover, as the acquisition of HARDI data requires repetitive measurements from the same volume of interest using a number of diffusion-encoding gradients, the problem of acquisition times is known to aggravate with an increase in their number.

A possible solution to the above problem can be formulated based on the theory of compressed sensing (CS). Particularly, the fact that HARDI signals admit sparse representation in terms of spherical ridgelets can be exploited to substantially reduce the number of diffusion-encoding gradients required for their reconstruction. Moreover, the accuracy of HARDI reconstruction can be further improved by supplementing the CS estimation by additional constraints enforcing spatial regularity and positive valuedness of the diffusion signals.

The resulting HARDI signals can be used to estimate their associated orientation distribution functions (ODFs) - the functions which quantify the likelihood of water molecules to diffuse in a certain spatial direction. Such ODFs, in turn, can be considered to be the members of a statistical manifold, which can be properly metrized. In this talk, based on the above formalism, we will introduce a method for embedding the recovered ODFs into a finite dimensional Euclidean space. Since the latter offers a variety of efficient methods for discriminant analysis, the embedding will allow analyzing the diffusion data using simple and readily available means. As a practical example, the application of HARDI to diagnosis of first episode (FE) schizophrenia will be demonstrated. Moreover, we will show that the diagnostic accuracy of this method remains high even when the HARDI sampling is reduced to as few as 20 gradients per voxel.

AMIR MORADIFAM
University of Toronto

Conductivity imaging in the presence of perfectly conducting and insulating inclusions from one interior measurement

Coauthors: Adrian Nachman and Alexandru Tamasan

We consider the problem of recovering an isotropic conductivity outside some perfectly conducting or insulating inclusions from the interior measurement of the magnitude of one current density field $|J|$. We prove that the conductivity outside the inclusions, and the shape and position of the perfectly conducting and insulating inclusions are uniquely determined by the magnitude of the current generated by imposing a given boundary voltage. We also establish a connection between the above problem and the uniqueness of the minimizers of weighted least gradient problem $F(u) = \int_\Omega a|\nabla u|$ with $u|_{\partial\Omega} = f$.

UMBERTO MORBIDUCCI
Politecnico di Torino

Visualization and Quantification of Blood Flow in the Human Aorta. From in vivo 4D Phase Contrast MRI to Subject-Specific Computational Hemodynamics

The human aorta is the major vessel that transports blood pumped by the left ventricle to the systemic circulation. The complex hemodynamics that are observed in the human aorta partially originate in the complicated geometry. The other reason for the observed complexity is that the thoracic aorta is the site in the healthy cardiovascular system where laminar-turbulent transitional flows are present. There is substantial evidence that aortic segments that appear to be exposed to abnormal flow are more prone to the onset and development of vascular pathology. In the past, the majority of the studies on the subject focused primarily on wall shear stress (WSS)-based descriptors as quantitative indicators of disturbed flow. Only recently the interest in the role played by the bulk flow, in particular by the onset and decay of helical patterns in the pathophysiology of the human aorta has grown dramatically. This is the consequence of the emerging awareness that aortic hemodynamics, an intricate process that involves a continuous re-organization of bulk flow structures, could play a primary role in the optimization of fluid transport processes in the cardiovascular system, aimed at obtaining efficient perfusion, in the regulation/alteration of mass transfer and in being atheroprotective/susceptible. In the last decades, the PC MRI technique has become the prevalent imaging technique for non-invasive and detailed in vivo quantification of the aortic flow, allowing for the possibility of acquiring time-dependent data sets that are necessary to perform reliable and local hemodynamic characterization. Due to its features, PC MRI has provided insight into the hemodynamics of the aorta in humans, where it has been used to illustrate clinical

physiopathological findings. However, two main limitations arise from using PC-MRI measurements to fully characterize the aortic flow. The first one is that 4D flow patterns may be overlooked if only visualization tools are used. All of the in vivo observations of aortic flow topologies associated with common physiological and pathological findings that are available in the literature are based on qualitative visual evaluation, and the mechanistic role that these emerging flow features play in aorta hemodynamics remains unclear. Aiming to overcome this limitation, we present the results of in vivo helical flow quantification in ostensibly healthy human aortas, performed employing 4D PC-MRI. Our study is aimed at identifying common characteristics in healthy aortic flow topology in terms of its helical content. Technically, a method for helical flow quantification, which has been developed to reveal the global organization of blood flow, was applied to the datasets from healthy volunteers, making use of tools developed for computational fluid dynamics. In particular, we mapped the patterns of the transient flowin the human aortic arch in detail and quantified helical structures. This quantitative approach allowed us to rank the behavior of flowing blood and identify emerging physiological bulk flow features.

The second limitation is that while in vivo direct measurements of blood velocities and flow rates in aorta are affordable and accurate, direct in vivo WSS quantification is still a challenge. By coupling medical imaging and computational fluid dynamics (CFD) it is possible to computationally reconstruct the time-varying blood flow patterns in anatomically realistic model, thus obtaining the WSS distribution. Recently, PC-MRI has emerged as an effective tool for providing noninvasively and concurrently accurate vascular geometries for CFD simulations and quantitative data on blood flow rates, which can be used to specify realistic boundary conditions (BCs). In this context, it is clear that the direct imposition of individual PC-MRI measured flow rates waveforms as BCs in patient-specific simulations should be preferred. However, the imposition of subject-specific measured flow waveforms at boundaries is not straightforward, mainly due to the mass conservation constraint, which is required in hemodynamic simulations but is not guaranteed by in vivo measurements. Assumptions regarding BCs can affect the solutions of the equations governing blood flow. In particular, different inflow/outflow boundary conditions in domains with multiple outlets may lead to a variation of WSS even at regions located away from the terminal vessels. For this reason, different strategies in combining outlet BCs could lead to different simulated hemodynamics. Here we also analyze the influence of different possible strategies of applying PC-MRI measured flow rates on image-based hemodynamic models of the human aortas. Flow simulations were carried out applying different schemes for treating BCs at outlets and three common WSS-based indicators of abnormal flow were considered and the sensitivity of these indicators to the outlet treatment strategy was evaluated. Moreover, here we also present our findings about e the influence of assumptions regarding the velocity profile at the inlet section of ascending aorta, incorporating the 4D PC-MRI measured velocity profiles within the computational models. The final aim is to describe the impact of different strategies in combining mea-

sured BCs on WSS and, by identifying proper sets of BCs, eliminate a potential source of errors and uncertainties in blood flow simulations in human aortic arch.

JOHN C MOSHER
Cleveland Clinic Epilepsy Center

Imaging and Localizing Neural Sources from MEG Data

Magnetoencephalography (MEG) measures the extremely weak quasistatic magnetic field outside the scalp generated by neural activity within the brain; electroencephalography (EEG) measures the scalp potentials from the same activity. The forward problem is the calculation of the external fields given an elemental source within the brain, for which the solution is analytic for spheres and more generally solved using numerical methods for tessellated shapes. Because the fields are nearly static, the forward models are specializations of the Newtonian potential measured from a distance, and therefore the inverse solution is ambiguous, without the imposition of strong models. In practice, the fields are measured at a few hundred sites about the upper hemisphere of the head, in the presence of substantial environmental and biological noise, and sampling rates and filtering protocols restrict the bandwidth to about 100 Hz, recorded on the order of ten minutes. Magnetic resonance images are used as anatomical basis sets on which to project most of the present day functional solutions. We review the basics of the acquisition systems and forward modeling, then focus on the inverse modeling approaches used to process these large spatiotemporal data matrices.

ALEJANDRO MURUA
Universit de Montral

Functional connectivity exploration with the Potts and random cluster models

Exploratory analysis based on clustering methods may elucidate interconnectivity in brain responses associated to complex activation paradigms such as epileptic seizures and drug studies. We have used a method based on the Potts model clustering and the random cluster model to find interconnected regions under the resting-state and finger-tapping paradigms. One key advantage of our method is its ability to consider spatial constraints of the data through prior graph edges. We are also exploring the use of the Potts model to modulate the false discovery rate of active voxels. Potts model clustering is a powerful kernel-based clustering method. We have built on the work of Blatt, Wiseman and Domany (1996) who, borrowing from known algorithms in physics, used Potts models as a general tool for data clustering. One of the crucial steps in Potts model clustering is the estimation of the temperature of the Potts density. We present a Bayesian version of our model based on a prior for the temperature derived from random graph theory.

Part of this work has been done in collaboration with Nicolas Wicker, Universit de Strasbourg and Institut de Gntique et de Biologie Molculaire et Cellulaire; Larissa Stanberry, University of Washington, Werner Stuetzle, University of Washington (Seattle), and Dietmar Cordes, University of Colorado (Denver).

JESSICA L. M. PAVLIN
McMaster University

Determining a Flow Profile from Multi-Scale Phase Contrast Angiographic MRI Data

Coauthors: Christopher K. Anand, Maryam Moghadas

Magnetic Resonance Imaging (MRI) detects changes of magnetic spin of nuclei (mostly protons) through the application of external magnetic fields. Changes of spin depend foremost on the density of water, but also on the local chemical environment and the motion of the tissue. Phase Contrast Angiography (PCA) uses changes resulting from balanced spatially linear variations in magnetic field strength to produce variations in the angle of the magnetization proportional to the velocity. As the field variation increases, so too does the sensitivity of the data to changes in velocity, however higher variations cause the angle of the spinning protons to wrap around making it impossible to differentiate the signals of fast and slow spinning protons because of aliasing in the velocity dimension. When formulated as an objective function, we have to choose between a convex objective with a very shallow minimum (and resulting uncertainty in the presence of noisy data) or non-convex objective with multiple narrow minima, effectively converting some of the uncertainty into discrete uncertainty resulting from the multiple minima. Conceptually, we propose to combine a series of data recruited from low and high field variation experiments, the lower field variation data can be used to guide the solver in detecting the true densities and velocities from the results of the high field variation data. Concretely, we will show how this information can be combined into a family of objectives which can be solved using a continuation approach. Additionally, a priori information about the properties of blood and its flow pattern is used to regularize the problem and further reduce the inaccuracies caused by noise.

NATALIYA PORTMAN
McConnell Brain Imaging Centre, Montreal Neurological Institute

The Modelling of Biological Growth: a Pattern Theoretic Approach

This presentation will take you for a journey from the beginnings of computational anatomy to mathematical representations of biological laws of growth. I will explore evolution and the power of mathematical ideas that allow biologically meaningful interpretation and understanding of images of natural shapes. More precisely, I will focus on a pattern theoretic model for a biological growth called GRID (Growth as Random Iterated Diffeomorphisms). It was first introduced by Dr. Ulf Grenander in 2005 in response to the need to study growth and development of human anatomy based on a sequence of images. The GRID model represents a modification of growth models employed in the field of computational anatomy, acknowledging that diffeomorphic transformations induced by growth are dependent on genetic controls within an organism. The genetic control is expressed by a probability law which governs spatial-temporal patterns of cell decisions (cell division/death, enlargement) in such a way that the image of an initial organism becomes continuously transformed into the image of a grown organism. I will then demonstrate the GRID-based inference algorithm developed in my doctoral thesis that automatically estimates growth characteristics of an organism directly from image data. An example of larval growth of the Drosophila wind disc as seen in confocal micrographs of Wingless gene expression patterns will be considered. Overall, with implementation of the GRID model one can gain a new insight into the growth-induced shape generation process as controlled by the genes. Namely, one can reveal spatial-temporal patterns of intensity of cell divisions hidden deeper in given observations of growth.

KUI REN
Department of Mathematics, University of Texas at Austin

Numerical solution of inverse Helmholtz problems with interior data

We investigate numerically an inverse problem of the Helmholtz equation where the objective is to reconstruct both the refractive index and absorption coefficient from interior energy data. It is well-known that one set of interior data is enough to reconstruct one of the coefficients. We show here numerically that with data collected from carefully-chosen multiple set of illuminations, one can reconstruct both coefficients stably.

GABRIEL RILLING
University of Edinburgh

Optimized model-based undersampling and reconstruction for dynamic MRI based on support splitting. Application to phase contrast MRI carotid blood flow imaging.

Coauthors: Yuehui Tao, Mike Davies, Ian Marshall

Traditional approaches to accelerated dynamic MRI (UNFOLD, k-t BLAST, PARADIGM) are based on k-t lattice sampling. The underlying signal model is that most pixels in the MRimage are (nearly) static while only one or a few regions of interest (ROI) are dynamic. In the y-f domain (Fourier dual of the k-t domain) this model is a special case of sparse model insofar as y locations not corresponding to the ROIs have zero content for non-zero f. When the k-t lattice sampling strategy is optimized for a particular y-f support – estimated e.g. using training data – high quality reconstructions can be obtained. However, since k-t lattice sampling corresponds to tiling in the y-f domain, the achievable acceleration factor is limited by the packability of the support.

In order to bypass that limitation we observe that the dynamic MRI sequence can be split into two parts – the static image on the one hand, the dynamic ROI(s) on the other hand – whose y-f supports are individually much more packable than the initial y-f support. For each of these parts, a k-t lattice sampling strategy can be designed that allows a high quality reconstruction with limited interference from the other part. Compared to traditional single k-t lattice approaches, this allows higher acceleration factors with little degradation of the quality.

The sampling strategy for the dynamic part can also be designed to cope with unknown ROI locations. This can be achieved thanks to the multi-coset sampling theory which has been shown to be near-optimal for such a multi-ROIs model. Given the multi-coset samples, detection of the ROIs can be achieved either by an exhaustive search or greedy algorithms. Once the dynamic ROIs are detected, the whole dynamic MRI sequence can be robustly estimated by solving a regularized least-squares problem.

The proposed sampling and reconstruction strategy is illustrated on the problem of phase contrast carotid blood flow imaging. In this application, the y-f support is very sparse but has a low packability. Traditional approaches are therefore limited to rather low acceleration factors (about 2x). We show that using the support splitting approach, good quality reconstructions can be obtained at up to 8x acceleration. Our simulations also show that this approach outperforms the k-t SPARSE compressed sensing based method in this application.

ERIK L. RITMAN
Mayo Clinic College of Medicine, Rochester MN USA

Spectral X-ray Imaging - Implications for Attenuation and Scatter-based Tomography.

Coauthors: Diane R. Eaker (Mayo Clinic College of Medicine,Rochester MN USA) Steven M. Jorgensen (Mayo Clinic College of Medicine,Rochester MN USA) Cynthia H. McCollough (Mayo Clinic College of Medicine,Rochester MN USA)

Recent development of solid-state x-ray high resolution imaging arrays that provide x-ray photon count and discriminate photon energies are becoming available for micro-CT and likely for clinical CT in the near future. This has implications for reducing image noise down to the photon count level and for elimination of beam hardening artifacts. This also has potential for expanding the imaging repertoire by providing multi-energy discrimination of various naturally occurring (e.g.,calcium, iodine, iron) and purposely introduced (e.g.,gadolinium, barium, gold) elements as well as increased contrast of soft tissues by virtue of coherent scatter imaging which can be achieved at one angle (instead of the usual range of angles) to the illuminating x-ray beam. This presentation will include some examples of these capabilities as well as the challenges presented by the detector characteristics and image processing involved. REFERENCES 1. Jakubek J. Semiconductor Pixel detectors and their applications in life sciences. Journal of Instrumentation 2009;4: 1-18. DOI: 10.1088/1748-0221/4/03/P03013. 2. Roessl E, Proksa R. K-edge imaging in x-ray computed tomography using multi-bin photon counting detectors. Physics in Medicine and Biology 2007;52(15):4679-4696. 3. Frey EC, Wang X, Du Y, Taguchi K, Xu J, Tsui BMQW. Investigation of the use of photon counting x-ray detectors with energy discrimination for material decomposition in micro-computed tomography. Medical Imaging 2007: Physics of Med Imaging. Proc of SPIE 2007;65100:65100A-165100A-11. 4. Butzer JS, Butler APH, Bones BJ, Cook N, L Tlustos L. Medipix Imaging Evaluation of data sets with PCA. IEEE 2008;978-1-4244-2582-2/08. 5. Butler APH, Anderson NG, Tipples R, Cook N, Watts R, Meyer J, Bell AJ, Melzer TR, Butler PH. Bio-medical X-ray imaging with spectroscopic pixel detectors. Nucl Instr and Methods in Physics Res A. 2008;591(1):141-146. 6. Eaker DR, Jorgensen SM, Butler APH, Ritman EL. Tomographic imaging of coherent x-ray scatter momentum transfer distribution using spectral x-ray detection and polycapillary optic.Proc. SPIE, Developments in X-ray Tomography VII 7804:78041O-178041O-7, 2010.

BERNHARD ROSS
Department of Medical Biophysics, University of Toronto

Identifying brain networks of coherent oscillations with MEG

Applying beamformer source analysis to the neuromagnetic signal recorded with magnetoencephalography (MEG) results in a four dimensional data set of brain activity in space and time. MEG has highest resolution in the time domain and the signal can be described by time series of activities at a set of discrete sources within the brain volume. Synchrony between oscillations at different brain areas, measured as coherence, has been suggested as a mechanism of connectivity within wide range networks. However, cortico-cortical coherence is compromised by the limited spatial resolution of the source analysis. This presentation introduces first a method for separating event-related coherence from apparent coherence resulting from spatial filtering and second a test for signal detection based on circular statistics. The principle of the method is demonstrated with Monte-Carlo simulations, and the detection of event related coherence is applied to human MEG data. In healthy young participants, listening to rhythmic auditory stimuli during MEG recording, we identified a brain network involving auditory and sensorimotor areas. The interpretation is that synchronous beta oscillations play a role in auditory-motor integration, facilitating auditory cued rhythmic movements.

ROSALIND J. SADLEIR
University of Florida

Imaging conductivity changes deep in the brain

Coauthors: Te Tang, Florida State University Michael D. Weiss, University of Florida Zijun Meng, Kyung Hee University Atul Minhas, Kyung Hee University Eung Je Woo, Kyung Hee University

Many existing techniques for imaging brain function or processes are restricted to imaging surface or peripheral changes. We have recently proposed and tested methods for imaging conductivity changes as a result of activity. We have found that these techniques are robust and feasible for imaging deep changes. In this talk I will give examples of applications and approaches we have used thus far, and and outline strategies for future improvements.

ALEXEY SAMSONOV
Department of Radiology, University of Wisconsin, Madison

A Novel Iterative Thresholding Algorithm for Compressed Sensing Reconstruction of Quantitative MRI Parameters from Insufficient Data

Coauthors: Julia Velikina

Quantification of MR parameters using analytical models of MRI signal often offers a unique and important perspective onto tissue micro environment compared to the traditional visualization of human anatomy by MRI. Examples of quantitative MRI (qMRI) techniques are T1 and T2 relaxometry and methods based on diffusion weighting contrast. The estimation of qMRI parameters requires acquisition of multiple datasets at different values of pulse sequence parameters (control parameters). As a result, quantitative MRI typically incurs a several-fold increase in scan time compared with conventional imaging.

Quantitative MRI offers an additional, parametric, dimension, similar to time variable in dynamic imaging. The standard two-step qMRI procedure reconstructs images for each value of the control parameter separately and then fits them to a model equation. Such an approach fails to exploit dependencies between images in the parametric dimension which are implied by the underlying physical model, hence, it does not utilize fully the power of a priori knowledge. Several methods making use of the physical model and resulting inter-image dependencies in the parametric dimension were proposed so far to accelerate quantitative measurements. Unfortunately, many of them lack robustness in practical imaging situations where imaging artifacts and deviation from anticipated analytical model may be significant. We propose a novel algorithm that utilizes knowledge of physical signal model within compressed sensing framework for robust accelerated quantitative MRI. The algorithm was demonstrated with T2/T1 relaxometry data and provided significant imaging acceleration.

CHRISTOPH SCHWARZBACH
University of British Columbia, Vancouver

Computational tools for microwave imaging some finite element aspects

Coauthors: Eldad Haber (University of British Columbia, Vancouver)

High contrast in electrical permittivity and conductivity motivates the investigation of electromagnetic methods for medical imaging, for instance for breast cancer detection. A straightforward approach to modelling the spatial distribution of these parameters is the assumption of piecewise constant values, defined on a moderately fine tessellation of the volume under investigation by hexahedra or tetrahedra. We study here the solution of the 3-D forward problem for monofrequency microwave tomography using finite elements, based on the above mentioned tessellation. Furthermore, we seek to reconstruct the spatial distribution of permittivity and conductivity of an overparameterized model by

a regularised output least squares approach. Our model assumption, piecewise constant coefficients, allows for simplifications of the forward solver which eventually lead to an overall faster imaging algorithm. The model assumption also requires special care when the regularisation operator is derived for unstructured meshes within the finite element framework.

GREIG SCOTT
Dept Electrical Engineering, Stanford University

The Physical Basis of RF Electrical Properties Contrast Imaging by MRI

MRI is unique in its ability to quantify and map RF magnetic fields in vivo at the Larmor frequency, but the simplified signal equation is a product of left(LCP) and right(RCP) circularly polarized RF magnetic field terms. The possibility of creating contrast from the radio frequency electrical properties of tissue by MRI was first proposed and demonstrated almost two decades ago. In recent years, the focus has turned to creating quantitative images of RF conductivity and permittivity of tissue using a variety of approximations, and even an estimation of the RF power.

To recover these properties, the Helmholtz equation is analyzed in terms of LCP and RCP terms, but MRI RF field mapping can only map a transmit field (LCP) relative to an implicit receive (RCP) field. To estimate vector field components, the zero divergence of magnetic fields must be used, and approximations for a dominant Bo directed RF electric field/current density may be needed based on RF coil/antenna geometry. Simplified pulse sequences that use only phase information for conductivity, or amplitude information for permittivity become possible when certain expanded Helmholtz terms can be neglected. Finally, most field analysis uses spatial derivative operations, but it is also possible to build in the field equations using a simplified form of the Kottler integral equations. This presentation will provide an overview of these approximations and future directions for reconstruction and contrast generation of RF electrical properties by MRI.

JIN KEUN SEO
Department of Computational Science and Engineering, Yonsei University, Seoul 120-749, Korea

Inverse Problems in Medical Imaging: Electrical Property Imaging using MRI

Last two decades, much researches in biomedical imaging area deal with electromagnetic or mechanical property imaging instead of anatomical imaging since they manifest structural and pathological conditions of the tissue providing valuable diagnostic information. The corresponding objectives are in visualizing cross-sectional image reconstructions of admittivity, susceptibility, shear modulus distributions inside the human body. This

talk focuses on electrical property imaging modalities which require interdisciplinary research incorporating mathematical theories, inverse problems and image reconstruction algorithms, image processing (denoising, segmentation, compressed sensing), numerical analysis and error estimates, MR physics and experimental techniques.To achieve these objectives, we need to set up a mathematical framework using the constitutive relation, related physical principles, and available measurement techniques, and it must be taken into account the well-posedness and uncertainties in boundary conditions and material characterizations. It is often necessary to make various simplifications of reality with sacrificing physical details so that the simplified model is manageable and holds key information to be aimed. In this talk, we briefly discuss these issues from its mathematical framework to human experiments via error analysis.

SHAWN SHADDEN
Illinois Institute of Technology

Transport studies of patient specific hemodynamics: Methods of modeling and characterization

This talk will focus on the study of advection-related processes in cardiovascular flow. It is widely accepted that local blood flow conditions can greatly influence the development and progression of many vascular diseases. Furthermore, proper diagnosis of flow conditions can be essential in properly assessing vascular disease progression, or evaluating different treatment options. Major obstacles in this area of research include being able to obtain realistic and relevant blood flow information (modeling), and being able to comprehend the complex, transport-related processes at work (characterization). We will discuss a framework that notably combines a dynamical systems approach to studying transport, with computational fluid dynamics and medical imaging, to obtain unique insights into blood transport problems. This framework takes a unique perspective to understanding blood flow, by shifting the paradigm from a shear-centric view of hemodynamics to a more complete appreciation and understanding of the biomechanical aspects of blood flow, while providing the tools needed to make such understandings possible.

MICHAEL B SHARPE
Princess Margaret Hospital, University of Toronto

Advancements in Radiation Therapy Treatment Planning and Optimization

Cancer is a leading cause of disability and mortality affecting the lives of many Canadians. Ionizing radiation is a potent therapeutic agent and its role in treating cancer was established and applied almost immediately after the discovery of x-rays. Radiation therapy

has been an important option in the control of cancer for over one hundred years. Every so often, advancements in engineering, computation, medical imaging, treatment planning, and control theory have converged to change how we view radiation therapy. From technological shifts, important concepts have emerged, including intensity-modulation, and image-guidance. Contemporary radiation therapy strategies build on these concepts, and now are applied within an extensive framework of machines and computing resources supporting teamwork among staff highly trained in a number of medical and technical specialties.

This presentation will review the principles of modern radiation therapy; including, intensity modulated radiation therapy (IMRT), target localization using image-guidance. The discussion will include experience in the clinical implementation of advanced technologies and some of the implications for the continuing development of radiation therapy technology and processes.

JOHN G. SLED
Hospital for Sick Children

Growth Dynamics in the Mouse

The mouse as a model organism provides tremendous opportunities for learning the functions of genes and for constructing complex models of human diseases. Morphology, as revealed by 3D imaging, has proven particularly sensitive for dectecting abnomal phenotypes caused by genetic mutations in in-bred mice and therefore provides a means to infer gene function. However, the interpretation of these data can be complex as phenotypic differences manifest as perturbations to the normal developmental trajectory. Moreover, the resolution limitations of current in vivo imaging technologies motivate one to infer population-based growth dynamics from cross-sectional rather than longitudinal data. In this presentation, we examine computational approaches to infer growth dynamics in the embryonic and immature mouse as well as in the microcirculation of the murine placenta.

MICHAEL SMITH
University of Calgary

Moving the best ideas from 1985s constrained reconstruction techniques into 2011s compressed sensing reconstruction

With the recent availability of efficient algorithms for non-linear optimizations, there has been an explosion of interest in applying compressive sensing (CS) techniques in various engineering applications. A key concept behind MR compressed sensing is the gathering of reduced k-space data sets. This concept can be traced back to super-resolution reconstruction (SR) algorithms of 1985 which were an attempt to improve upon the even

earlier techniques of partial Fourier transform reconstruction. In this paper, we demonstrate how many successful processes and validation technique from super-resolution can be adapted to compressed sensing reconstruction to considerable advantage. We examine (i) the importance of ensuring that the simulated data used to validate and tune CS algorithms matches the characteristics of experimental data and (ii) techniques to improve the appearance of CS images used for diagnostic purposes. We propose the adaption of two existing SR techniques for use in CS reconstruction (iii) by using a k-space approach to generating a sparser data set by modeling the edges of the data rather the data itself, and (iv) combining the TERA SR algorithm with CSs sparse sampling regime to remove issues surrounding the truncation of k-space data.

BOJANA STEFANOVIC
Sunnbrook Research Institute

In vivo imaging of cerebral hemodynamics with two photon fluorescence microscopy

Coauthors: Liis Lindvere, Adrienne Dorr, David Chartash, John G. Sled

The present talk will discuss our recent work on the assessment of stimulation induced changes in the brain microvascular network in vivo. We employ time series two photon laser scanning microscopy data of the microvessels in the primary somatosensory cortex of anesthetized rodents during electrical stimulation of the forepaw. A semi-automated, multi-scale, model based algorithm is employed for segmentation of the intravascular space over time, followed by generalized linear modeling to evaluate the spatiotemporal pattern of changes in vessels calibers elicited in this vascular bed by the functional stimulus. We observe a highly heterogeneous changes in the capillaries, with the preponderance of dilatations occurring on the level of cortical penetrating vessels. Consistent with mesoscopic modalities, net response is that of dilatation, with peak radii changes of 5into neurovascular network reactivity.

STERGIOS STERGIOPOULOS
Senior Defence Scientist, Defence R&D Canada Toronto, 1133 Sheppard Ave West, Toronto, Ontario, M3M 3B9

Advanced Signal Processing for Non-Invasive Medical Diagnostic System Applications

Coauthors: Yi-Ting Shen

Introduction: The material of this presentation emerged from the authors most recent investigations in implementing defense oriented research from sonar and radar system applications into non-invasive medical diagnostic R&D to address difficult diagnostic problems and delivery of health care in very remote areas. Thus, this material bring together

some of the most recent theoretical developments on advanced signal processing; in order to provide a glimpse on how modern technology can be applied to the development of current and next generation real time medical diagnostic systems. The first part will focus on advances in digital signal processing algorithms and on their implementation in PC-based computing architectures that can provide the ability to produce real time systems that have capabilities far exceeding those of a few years ago. It included also a generic concept for implementing successfully adaptive schemes with near-instantaneous convergence in 2-dimensional (2-D) and 3-dimensional (3-D) array of sensors, such as planar, circular, cylindrical and spherical arrays of sensors. The second part focuses on the emerging medical technologies in the areas of non-invasive tomography imaging, monitoring vital signs and addresses topics on recent advances on image segmentation, registration and fusion techniques for 3D/4D ultrasound and other tomography imaging modalities.

Methods: For real time 3D ultrasound imaging the proposed approach is to implement 3D adaptive beamformers in portable ultrasound imaging systems, that can improve image resolution for low frequency planar array probes. Along these lines, Defence R&D Canada (DRDC) has allocated significant investment to develop an advanced, fully-digital 4D (3D-spatial + 1D-temporal) ultrasound imaging technology for improving image resolution and facilitating auto-diagnostic applications to detect non-visible internal injuries, based on the volumetric imaging outputs provided by a 4D ultrasound imaging system that includes: 1) a 32x32 sensor planar array ultrasound probe with a fully digital data acquisition peripheral; 2) a portable ultrasound computing architecture consisting of a cluster of DSPs and CPUs; 3) adaptive 3D beamforming algorithms with volumetric visualization, including fusion and automated segmentation capabilities; and 4) the implementation of a decision-support process to provide automated diagnostic capabilities for non-invasively detecting internal injuries and facilitate image guided surgery.

Results and Conclusion: Results of our study at this point have demonstrated that our fully digital 3D/4D ultrasound imaging system provides far superior image resolution compared with commercially available portable units. Our DRDC imaging system holds much promise in preparing the grounds for the "next-generation" fully digital ultrasound imaging technology.

MARSHALL S. SUSSMAN
University Health Network (UHN), Toronto, Ontario

A Novel Method for Motion Correction in Cardiac MRI

High-quality magnetic resonance images (MRI) typically require data acquisitions lasting anywhere from several seconds to several minutes. Over this time period, significant physiologic motion may occur. In cardiac imaging, motion is caused by both the beating of the heart, as well as respiration. As a result of this motion, the heart will be in different

positions at different times in the scan. This will cause inconsistencies in the data; giving rise to errors in the images reconstructed from this data.

Many techniques have been developed to minimize motion-related MRI errors. In general, these techniques utilize a subset of the MR data to periodically monitor anatomic motion throughout the scan. This information is used to either directly correct for the motion, or alternatively to identify data acquired during periods of minimal motion. A major challenge with all of these techniques is that the type of information provided by the MR data subset is very limited often a simple 1D projection of the anatomy. From this limited information, it is often difficult to accurately correct for the complex, 3D, deformable motion of the heart. In this presentation, we will discuss a novel method for identifying periods of minimal displacement in MR imaging of the heart. It will be shown that this technique is applicable to motions of almost arbitrary complexity.

SERGEY TELENKOV
Center for Advanced Diffusion Wave Technologies, MIE, University of Toronto, 5 King's College Road, Ontario M5S 3G8, Canada

Frequency-Domain Photoacoustics: Specifics of Signal Processing and Image Reconstruction

It was demonstrated that spatially-resolved photoacoustic (PA) imaging can be accomplished using relatively long intensity-modulated laser excitation as opposed to short-pulse imaging mode. Although this method is very attractive for design of portable clinical instrumentation, it requires different approach to signal detection and image reconstruction. This presentation discusses problems of the frequency-domain PA technique and possible solutions pertinent to spatially-resolved imaging of optical contrast in biological tissues.

FERNANDO GUEVARA VASQUEZ
University of Utah

Uncertainty quantification in resistor network inversion

Coauthors: Liliana Borcea and Alexander V. Mamonov

We present a method for finding the electrical conductivity in a domain from electrical measurements at the boundary. Our method consists of two steps. In the first step we find a resistor network that fits the data and then we estimate the conductivity from the resistors by interpreting the network as a finite volumes discretization of the problem. We show through a Monte Carlo study that our discretization of the conductivity reduces the uncertainty in the reconstructions, as compared to a conventional discretization. We review recent developments on extensions of resistor network inversion to other setups in two dimensions.

J.L. PEREZ VELAZQUEZ
Hospital for Sick Children and University of Toronto

The clinical and basic significance of studying fluctuations of brain coordinated activity

Coauthors: V. Nanadovic, A. Teitelbaum, R. Wennberg, L. Garcia Dominguez

Experimental evidence and considerations about the basic and clinical implications of the study of the variability in brain signals will be presented. More specifically, most of the presentation will centre on the possible usefulness of the quantification of spatio-temporal variability of the brain synchronization patterns in patient prognosis after traumatic brain injury, in finding precursors of seizures in epileptiform activity, and in classifying (diagnosing?) subjects with autism. Some general considerations of more theoretical nature will be discussed, specifically related to the upper or lower bounds to the variability in nervous system activity for the individual to be adaptable and viable, and the relation to pathologies.

JULIA VELIKINA
University of Wisconsin - Madison, USA

Application of Temporally Constrained Compressed Sensing for High Spatial and Temporal Resolution Magnetic Resonance Imaging

Coauthors: Kevin Johnson (University of Wisconsin), Steven Kecskemeti (University of Wisconsin), Charles Mistretta (University of Wisconsin), Patrick Turski (University of Wisconsin), Alexey Samsonov (University of Wisconsin)

Many clinical applications necessitate a limited scan time for dynamic MRI acquisition, e.g. due to breath hold or contrast passage. This often restricts attainable spatial and temporal resolution, limiting potential diagnostic or research applications. To reconstruct significantly undersampled time frames at clinically desired spatial/temporal resolution a number of approaches have been proposed, including compressed sensing (CS). CS reconstruction from incomplete data relies on the assumption that the underlying signal has a sparse representation in some basis. Typically, CS utilizes spatial sparsity of the image itself or its discrete gradient. However, in time-resolved imaging, the level of spatial sparsity may not be sufficient to support the required high accelerations, leading to residual artifacts and loss of spatial resolution. We will discuss a way to use spatio-temporal correlations in the image series as a means to achieve high accelerations without loss of spatial resolution / SNR and without compromising waveform fidelity. We evaluate the performance of the proposed temporally constrained compressed sensing approach in such clinical applications as contrast-enhanced intracranial angiography and cardiac perfusion imaging.

ALESSANDRO VENEZIANI
Department of Mathematics and Computer Science, Emory University, Atlanta (GA) - USA

An Integrated Morphology+CFD Statistical Investigation of Parent Vessel in Cerebral Aneurysms

Coauthors: Tiziano Passerini, Laura M. Sangalli, Simone Vantini, Marina Piccinelli, Susanna Bacigaluppi, Luca Antiga, Edoardo Boccardi, Piercesare Secchi

It is widely accepted that hemodynamics plays a relevant role in initiation, progression and eventually rupture of brain aneurysms. Several works actually point out how the geometry and consequently the blood flow in the aneurysm are related to the evolution of this pathology. However, the underlying mechanism need still to be identified and explained. The accomplishment of this task is anticipated to detect possible morphological indexes to be used for a prognostic purpose. Geometrical landmarks could support the decision making of doctors that need to decide whether it is convenient to operate or not.

In this talk we give a contribution in this direction with two distinctive features, one refers to the specific subject of our investigation, the other one to the data analysis methods adopted.

1) The focus of our study is on the geometry of the vessel hosting the aneurysm rather than on the sac itself.

2) Variety and complexity of the data at hand demand for sophisticated statistical methods. With "data" here we mean both geometry and fluid dynamics. In particular, under the category of geometrical features we consider different quantities of the parent vessels (e.g. radius, curvature, tortuosity); hemodynamical quantities are in particular the Wall Shear Stress (WSS) along the parent vessel and its axial gradient. These quantities are regarded as stochastic functions of the axial coordinate along the vessel. To extract patterns from such a heterogeneous aggregate of informations we resorted to an advanced statistical technique, the Functional Principal Component Analysis (FPCA). This method allows to identify the part of the data set relevant for our purpose, which is the correlation to the rupture.

The workflow behind the present work consists therefore of three components:

i) robust extraction of the vessel morphology from rotational angiographies; ii) numerical simulation of the blood flow and post-processing quantities (CFD - Computational Fluid Dynamics); iii) FPCA analysis of the aggregated data.

In this talk I will address these steps and present results obtained following this approach on a data set (52 patients) collected at the Hospital Ca' Granda, Niguarda in Milan (Italy), whithin the collaborative framework called ANEURISK, granted by the Politecnico di Milano Foundation with the support of SIEMENS Medical Solutions, Italy. The results identify possible landmarks for the assessment of a rupture risk index.

This research is partially supported by The Brain Aneurysm Foundation in the frame-

work of the project "Computational and Statistical Analysis of Brain Aneurysm Morphology&Hemodynamics".

ALESSANDRO VENEZIANI
Department of Mathematics and Computer Science, Emory University, Atlanta (GA) - USA

4D Image-Based CFD Simulation of a Compliant Blood Vessel

Coauthors: Marina Piccinelli, Tiziano Passerini, Lucia Mirabella, Eldad Haber

Numerical simulation of fluid-structure interaction (FSI) in the arterial system is a challenging and time consuming procedure because of the intrinsic heterogeneous nature of the problem. Moreover, in patient-specific simulations, modeling of the vascular structure requires parameter identification still difficult to accomplish. On the other hand, new imaging devices provide time sequences of the moving vessel of interest. When one is interested only in the blood dynamics in the compliant vessel, a possible alternative to the full fluid-structure interaction simulation is to track the vessel displacement from the images and then to solve the fluid problem in the moving domain reconstructed accordingly. We present an example of this image-based technique. We describe the steps necessary for this approach (image acquisition and 3D geometric reconstruction, motion tracking, computational fluid dynamics (CFD) simulation) and present some results referring to an aortic arch and a validation of the proposed technique vs. a traditional FSI simulation in a carotid bifurcation.

This work places itself in the framework of a strong integration between data (images/measures) and simulations that is likely to introduce a significant improvement in the reliability of cardiovascular numerical mathematics.

This work has been supported by the EMORY URC Project "Image Based Fluid-Structure Interaction Simulations in Computational Haemodynamics".

YOGESH CHINTA VENKATESWARAO
McMaster University

Sparse Sampling of Velocity MRI

Coauthors: Dr. Christopher Anand

The standard MRI is being used to image objects at rest. In addition to standard MRI images,

which measure tissues at rest, Phase Contrast MRI can be used to quantify the motion of blood

and tissue in the human body. The current method used in Phase Contrast MRI is time

consuming. The development of new trajectories has minimized imaging time, but creates

subsampling errors. The proposed method uses regularization of velocities and proton densities

to eliminate errors arising from k-space undersampling.

RAGINI VERMA
University of Pennsylvania

Analyzing Diffusion MRI Based "Connectivity" for Diagnosis

The talk will present a brief overview of diffusion imaging (tensor and higher order models). It will cover various issues involved in analyzing diffusion data with the aim of conducting large population studies as well as creating markers of "connectivity" from the population that best characterize the pathology. The talk will briefly discuss statistical and machine learning methods employed in such studies.

IRENE VIGNON-CLEMENTEL
INRIA Paris-Rocquencourt, France

From imaging and hemodynamic data to patient-specific simulations of Glenn to Fontan conversion

Coauthors: Jeffrey Feinstein, Tain-Yen Hsia, Alison Marsden, Francesco Migliavacca

Single-ventricle defects are a class of congenital heart diseases that leave the child with only one operational pump, requiring the systemic and the pulmonary circulations to be placed in series through several operations performed during young childhood. The last procedure (the Fontan palliation) artificially connects both venae cavae to the pulmonary arteries, which improves oxygeneration of the child at the cost of blood flowing passively into the lungs. Numerical simulations may be used to investigate the nature of the flow and its connection to post-operative failures and sources of morbidity. However they heavily rely on boundary condition prescrip- tion. We present our recent work on predictive patient-specific modeling of the Fontan conversion. Patient-specific preoperative models are developed based on clinical data. Results include a sensitivity analysis of several hemodynamics factors to the input data. In addition, previous studies have demonstrated that the geometry plays an important role in Fontan hemodynamics. A novel Y-shaped design was recently proposed to improve upon traditional designs, and results showed promising hemodynamics. In this study, we show how geometry and boundary conditions affect the performance of these virtual surgical designs. In particular, we investigate if and how the inferior vena cava flow (which contains an important biological factor) can be optimally distributed amoung both lungs. We also present an outlook on how multiscale

simulations can be predictive. Numerical issues related to patient-specific simulations will be briefly discussed.

DINGHUI WANG
Keller Center for Imaging Innovation, Barrow Neurological Institute, Phoenix, AZ, USA

Radio Frequency Current Density Imaging with a 180-Degree Sample Rotation

Coauthors: Michael L.G. Joy, Weijing Ma, Tim P. DeMonte and Adrian I. Nachman

Biological tissues are generally conductive and knowing the current distribution in these tissues is of great importance in theoretical and practical biomedical applications. Based on magnetic resonance imaging (MRI), radio frequency current density imaging (RF-CDI) measures current density distributions at the Larmor frequency of the magnetic resonance (MR) imager. RF-CDI computes the applied Larmor frequency current density, J, from the non-invasively measured magnetic field, H, produced by J. However, the previous method for RF current density reconstruction could only compute one component of J. Moreover, this reconstruction required an assumption about H, which may be easily violated in biomedical applications. We propose a new reconstruction method for RF-CDI to fully reconstruct all three components of J without relying on any assumption of H. The central idea of our approach is to rotate the sample by 180 degrees in the horizontal plane to collect adequate MR data to compute one component of J. Furthermore, this approach can be extended to reconstruct the other two components of J by one additional sample orientation in the horizontal plane. Using simulations and experiments, we have demonstrated for the first time the feasibility of imaging the magnitude and phase of all components of a radio frequency current density vector field. In addition, the reconstruction of the complex conductivity of biological tissues becomes possible due to measurement of the complete H vector field.

Z. JANE WANG
ECE Dept., University of British Columbia, Canada

fMRI Signal Processing Methods for Brain Connectivity Modeling

Coauthors: Junning Li, Aiping Liu and Martin McKeown

There have been revolutions in neuroimaging technologies that can non-invasively probe the brain at different temporal and spatial scales, such as functional MRI (fMRI) and electroencephalogram (EEG). With the recent revolution in fMRI neuroimaging techniques, there is greater recognition of the vital role signal processing techniques can play for modeling brain connectivity. While there has been significant progress, there are still a number of challenges associated with inferring brain connectivity from fMRI signals that

require special exploration. In this talk, we focus on developing novel, fundamental signal processing and graphical models for accurately inferring brain connectivity from fMRI data by addressing key challenges, including sparsity, error control in learning network structures and group analysis to deal with inter-subject variability. A real fMRI case study in Parkinson's disease suggests that the proposed brain connectivity modeling approach demonstrated relative normalization of brain connectivity due to L-dopa medication.

QIONG WU
McMaster University

A Semi-Definite, Nonlinear Model for Optimizing k-Space Sample Separation in Parallel Magnetic Resonance Imaging

Coauthors: Christopher Anand

Parallel MRI, in which Fourier (k-Space) is regularly undersampled, is critical for imaging speed. In our approach, a semi-definite model is built to optimize the pattern of regular data sampling to minimize noise in the reconstructed image. To solve the model, a bi-level strategy is applied.

YUAN XU
Department of Physics, Ryerson University

Ultrasound methods to image the electrical/electrokinetic properties of biomaterials

Coauthors: Ozkan Doganay

We propose a novel method to combine ultrasound and electromagnetic waves to image and characterize tissues by further investigating a new effect: the physiological-level Electric-field Induced Mechanical Changes (EIMC) in soft tissues (Doganay and Xu, JASA-EL V128, P261-267, 2010). We found that the application of a DC or a low-frequency AC electric field (at physiologically safe levels) to various types of soft biological tissues can induce mechanical changes, including strain and deformation, in the samples. We have also shown that the EIMC can be monitored by commercial ultrasound instruments. Our preliminary results have suggested that EIMC is an electrokinetic phenomenon (motion of particles and fluids under the influence of an electric field) and is related to the fixed charge density in the sample. Although electrokinetic phenomena have been widely studied in solutions, gelatin, cell cultures, and some special tissues such as cartilage (due to the large fixed charge density in these tissues extracellular matrix), it is the first time that the electrokinetic phenomena have been observed and imaged both from the inside and at the surface of various soft tissues. EIMC depends on the chemical composition and conductivity of the samples. Therefore, EIMC-based imaging methods

have the potential to measure the electric/electrokinetic properties of biological tissues non-invasively.

JONG CHUL YE
Korea Advanced Institute of Science and Technology

Compressive MUSIC for diffuse optical tomography using joint sparsity

Coauthors: Ok Kyun Lee, Jong Min Kim, Yoram Bresler

Diffuse optical tomography (DOT) is a sensitive and relatively lowcost imaging modality that reconstructs optical properties of a highly scattering medium. However, due to the diffusive nature of light propagation, the problem is severely ill-conditioned and highly nonlinear. Even though nonlinear iterative methods have been commonly used, they are computationally expensive especially for three dimensional imaging geometry. Recently, compressed sensing theory has provided a systematic understanding of high resolution reconstruction of sparse objects in many imaging problems; hence, the goal of this paper is to extend the theory to the diffuse optical tomography problem. The main contributions of this paper are to formulate the imaging problem as a joint sparse recovery problem in a compressive sensing framework and to propose a novel noniterative and exact inversion algorithm that achieves the l0 optimality as the rank of measurement increases to the unknown sparsity level. The algorithm is based on the recently discovered generalized MUSIC criterion, which exploits the advantages of both compressive sensing and array signal processing. A theoretical criterion for optimizing the imaging geometry is provided, and simulation results confirm that the new algorithm outperforms the existing algorithms and reliably reconstructs the optical inhomogeneities when we assume that the optical background is known to a reasonable accuracy.

XIAHAI ZHUANG
University College London

A Registration-Based Atlas Propagation Framework for Automatic Whole Heart Segmentation

Extracting anatomical information of the heart can be important for the development of new clinical application, as well as the planning and guidance of cardiac interventional procedures. To avoid inter- and intra-observer variability of manual delineation, it is highly desirable to develop an automatic segmentation method such as from cardiac MRI. However, automating this process is complicated, particularly by the large shape variation of the heart between subjects. To achieve this goal, we employ a registration-based atlas propagation framework where a novel technique, locally affine registration method, is proposed to tackle the challenge of large shape variations.

Locally affine registration method (LARM) is an attractive registration alternative for applications where a single global affine transformation cannot provide enough accuracy, while a nonrigid registration would incorrectly affect the local topology, such as due to the large shape variability of the heart anatomy. In the automatic whole heart segmentation framework, LARM globally deforms the heart image but locally maintains the shape of the predefined substructures, such as the four chambers and the major vessels. Such an approach is able to avoid local optima during the optimization of the global transformation and eventually provides a good initialization of substructures for the follow-up nonrigid registration to achieve an accurate and robust refinement.

The talk will also show a validation study where 37 pathological MR data were used and some extension works.

LILI GUADARRAMA BUSTOS
Laboratoire de Mathematiques, Universite Paris-Sud 11. France

Transient Wave Imaging

We study Elasticity imaging by the use of the acoustic radiation force of an ultrasonic focused beam to remotely generate mechanical vibrations in organs.

We provide a solid mathematical foundation for this transient technique and design accurate methods for anomaly detection using transient measurements.

We consider transient imaging in a non-dissipative medium. We develop anomaly reconstruction procedures that are based on rigorously established inner and outer time-domain asymptotic expansions of the perturbations in the transient measurements that are due to the presence of the anomaly.

Using the outer asymptotic expansion, we design a time-reversal, Kirchhoff-, MUSIC- imaging technique for locating the anomaly. Based on such expansions, we propose an optimization problem for recovering geometric properties as well as the physical parameters of the anomaly.

In the case of limited-view transient measurements, we construct Kirchhoff- and MUSIC- algorithms for imaging small anomalies. Our approach is based on averaging of the limited-view data, using weights constructed by the geometrical control method; It is quite robust with respect to perturbations of the non-accessible part of the boundary. Our main finding is that if one can construct accurately the geometric control then one can perform imaging with the same resolution using partial data as using complete data.

ALEX MARTINEZ
University of Toronto

Simulation of Magnetic Resonance Imaging using Oscillatory Quadratures

Coauthors: Luca Antiga (Orobix Srl and Mario Negri Institute), David Steinman (University of Toronto)

Magnetic resonance imaging (MRI) has become one of the leading modalities for non-invasive anatomical imaging. However, there are many independent parameters that control an MRI scan and many physical phenomena that affect the quality and accuracy of the acquired image. Studying the causes and effects of these phenomena is difficult, because MRI facility availability is scarce and operating time is costly. Computational simulation is MRI has become an attractive alternative, but can suffer from extensive

simulation times. Moreover simulations are usually based on structured, Cartesian grids, which must be very dense in order to adequately resolve anatomically realistic objects.

An alternative approach has been suggested in which the MRI signal equation, which represents the volumetric integration of a magnetized object modulated by a sinusoidally varying field, can be solved exactly over objects defined by an unstructured grid of linear tetrahedral elements [1]. If an object can be segmented into regions over which each a constant magnetization can be assumed, the signal for these regions can be converted, via the divergence theorem, into the result of a surface integration over linear triangles [2]. In either case, however, the number of simplexes, and hence the CPU time, required to resolve the curved boundaries of realistic objects, can be prohibitive.

The present work focuses on the use of quadratic triangulations, which have been shown to offer significant reductions in the number of simplexes required to discretize complex objects [3], but which require numerical rather than exact integration of the signal equation. Due to the oscillatory terms in the signal equation, conventional Gaussian quadratures can be costly, as the number of points needed in each dimension is proportional to the maximum spatial frequency in the simulation. Instead, we consider here the novel use of highly oscillatory quadratures, for which the number of integration points *decreases* with increasing frequency. Specifically, in the numerical steepest descent (NSD) approach [4], the path between the integration limits is deformed using the method of stationary phase, but instead of trying to find an asymptotic estimate of the integral afterwards, the new integral is evaluated using Gaussian quadrature. This method can then be applied recursively for integrals of n dimensions.

For a given number of integration points the NSD approach can be expected to yield lower errors compared to Gaussian quadrature. However, preliminary estimates suggest that each NSD quadrature point require 3-4 times the number of operations compared Gaussian quadrature. Moreover, NSD requires special handling for some combinations of simplex and spatial frequency orientations [4]. We intend to demonstrate whether the perceived benefits of oscillatory vs. conventional quadratures for simulating MRI are outweighed by these extra computational costs.

References:

1. Truscott KJ and Buonocore MH. Simulation of tagged MR images with linear tetrahedral solid elements. J Magn Reson Imaging 2001;14:336-340.

2. Antiga L and Steinman DA. Efficient MRI simulation via integration of the signal equation over triangulated surfaces. Proc Int Soc Magn Reson Med 2008;16:489.

3. Simedrea P, Antiga L, Steinman DA. FE-MRI: Simulation of MRI using arbitrary finite elements. Proc Int Soc Magn Reson Med 2006:14:2946.

4. Huybrechs D and Vandewalle S. The construction of cubature rules for multivariate highly oscillatory integrals. Math Comp 2007; 76:1955-1980. *The authors thank Dr.*

Huybrechs for valuable assistance.

ALEX MARTINEZ
University of Toronto

Simulation of Magnetic Resonance Imaging using Oscillatory Quadrature Methods

Coauthors: Luca Antiga (Orobix Srl and Mario Negri Institute), David Steinman (University of Toronto)

Magnetic resonance imaging (MRI) has become one of the leading modalities for non-invasive anatomical imaging. However, there are many independent parameters that control an MRI scan and many physical phenomena that affect the quality and accuracy of the acquired image. Studying the causes and effects of these phenomena is difficult, because MRI facility availability is scarce and operating time is costly. Computational simulation is MRI has become an attractive alternative, but can suffer from extensive simulation times. Moreover simulations are usually based on structured, Cartesian grids, which must be very dense in order to adequately resolve anatomically realistic objects.

An alternative approach has been suggested in which the MRI signal equation, which represents the volumetric integration of a magnetized object modulated by a sinusoidally varying field, can be solved exactly over objects defined by an unstructured grid of linear tetrahedral elements [1]. If an object can be segmented into regions where a constant magnetization can be assumed, the signal for these regions can be converted, via the divergence theorem, into the result of a surface integration over linear triangles [2]. In either case, however, the number of simplexes, and hence the CPU time, required to resolve the curved boundaries of realistic objects, can be prohibitive.

The present work investigates the use of quadratic triangulations, which have been shown to offer significant reductions in the number of simplexes required to discretize complex objects [3], but which require numerical rather than exact integration of the signal equation. Due to the oscillatory terms in the signal equation, conventional Gaussian quadratures can be costly, as the number of points needed in each dimension is approximately proportional to the maximum local spatial frequency in each quadratic triangle. We are investigating different methods to evaluate this integral including methods for which the number of integration points *decreases* with increasing frequency. Specifically, in the numerical steepest descent (NSD) approach [4], the path between the integration limits is deformed using the method of stationary phase, but instead of trying to find an asymptotic estimate of the integral afterwards, the new integral is evaluated using Gaussian quadrature. This method can then be applied recursively for integrals of n dimensions.

Preliminary results show that in 3 dimensions, using a surface mesh with an element size of approximately 1 mm with a MR image field of view of 40 by 80 mm and a spatial

resolution of 1 mm, in the elements where we can currently apply NSD, NSD can integrate the oscillatory term of the 2 dimensional surface signal equation for quadratic triangular elements with appreciably lower errors than Gaussian quadrature for the same number of quadrature point evaluations. This is the case depending on the required maximum error and k-space location. However the time ratio between Gaussian quadrature and NSD for the same amount of quadrature point evaluations was not taken into account. Current investigations also focus on the handling of stationary points [4], which can arise for some combinations of simplex and spatial frequency orientations.

References:

1. Truscott KJ and Buonocore MH. Simulation of tagged MR images with linear tetrahedral solid elements. J Magn Reson Imaging 2001;14:336-340.

2. Antiga L and Steinman DA. Efficient MRI simulation via integration of the signal equation over triangulated surfaces. Proc Int Soc Magn Reson Med 2008;16:489.

3. Simedrea P, Antiga L, Steinman DA. FE-MRI: Simulation of MRI using arbitrary finite elements. Proc Int Soc Magn Reson Med 2006:14:2946.

4. Huybrechs D and Vandewalle S. The construction of cubature rules for multivariate highly oscillatory integrals. Math Comp 2007; 76:1955-1980.

MIHAELAPOP
Sunnybrook Research Institute, Toronto

Experimental framework to parameterize 3D MR image-based computer models of electrophysiology in heterogeneous infarcted porcine hearts

Coauthors: Maxime Sermesant (INRIA, France) Tommaso Mansi (Siemens Corporate Research, Princeton, USA) Sudip Ghate (Sunnybrook Research Institute, Toronto) Jean-Marc Peyrat (Siemens Molecular Imaging, Oxford, UK) Jen Berry (Sunnybrook Research Institute, Toronto) Beiping Qiang (Sunnybrook Research Institute, Toronto) Elliot McVeigh (Johns Hopkins University, USA) Eugene Crystal (Sunnybrook Research Institute, Toronto) Graham Wright (Sunnybrook Research Institute, Toronto)

Mathematical modelling, high-resolution imaging and electrophysiology experiments are needed to better understand how tissue heterogeneities contribute to the genesis of arrhythmia in hearts with prior infarction (a major cause of sudden cardiac death). The purpose of this work was to globally parameterize a 3D magnetic resonance MR image-based computer model of electrophysiology (EP) constructed using a pre-clinical pig model of chronic infarct. The computer heart model was built from high-resolution ex-vivo 3D MRI scans. Diffusion weighted MRI was used to estimate myocardial anisotropy (i.e.,

fiber directions) and heterogeneities (healthy zone, dense scar and border zone, BZ). We used a simple mathematical model based on reaction-diffusion equations, and calculated the propagation of action potential (AP) after application of stimuli (with location and timing replicating precisely the stimulation protocol used in the experiment). Specifically, the mathematical parameters were globally fit by zone (i.e., the three zones derived from heterogeneous MRI maps); this step was performed using characteristics of AP waves measured ex-vivo (using 2D optical fluorescence imaging). Then, these fitted parameters were further used as input to the 3D computer model to replicate in-vivo EP studies, under pacing or arrhythmia induction. Our results showed a better agreement between experiments and simulations, when these customized parameters were used instead of literature values. Future work will focus on constructing the model from in-vivo MR images and translating the model into clinical applications.

DINORA MORALES
Universidad Politcnica de Madrid

Spatial clustering analysis of functional magnetic resonance imaging data

Coauthors: Concha Bielza, Pedro Larraaga

Functional magnetic resonance imaging (fMRI) allows the brain function detection by measuring hemodynamic changes related to neuronal activity given stimulus or task. The central problem in the analysis of fMRI is the reliable brain activated detection. One way is to compute a statistical map and the spatial dependence among voxels are making during inference form it. Clustering techniques have been applied to statistical map based on extent of activation cluster after intensity thresholding or taking into account contextual information clustering. In this paper we focus on the spatial information of fMRI to detect the brain activity taking into the spatial contiguity constraints using the neighbourhood expectation maximization algorithm with four and eight neighbourhood configurations. The neighbourhood expectation minimization algorithm was applied to Alzheimer's disease fMRI study.

NARGOL REZVANI
Department of Computer Science, University of Toronto

A Polyenergetic Iterative Reconstruction Framework for X-Ray Computerized Tomography

Coauthors: D. A. Aruliah, Kenneth R. Jackson

While most modern x-ray CT scanners rely on the well-known filtered back-projection (FBP) algorithm, the corresponding reconstructions can be corrupted by beam-hardening artifacts. These artifacts arise from the unrealistic physical assumption of monoenergetic

x-ray beams. To compensate, we discretize an alternative model directly that accounts for differential absorption of polyenergetic x-ray photons. We present numerical reconstructions based on the associated nonlinear discrete formulation incorporating various iterative optimization frameworks.

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FIELDS

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Department of Athletics and Recreation
55 Harbord Street, Phone: (416) 978-3437
Please see Members Liaison, Rm. 330 to purchase a day pass for the Athletic Centre at $8.50 each.

Building Hours

The doors of the Institute are unlocked between 9:00 am and 5:00 pm, Monday to Friday. If you require access after hours please see the Members Liaison, Room 330. When entering or leaving the building after hours, please **do not let people who are unfamiliar to you enter the building**. Visitors who are allowed access will have keys to enter the building.

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Local faxing is available in Room 345.
To receive a fax at this machine the number is (416) 348-9385.

Fire Safety

Should a fire alarm sound; you are required to leave the building immediately. Stairwells are located at the NW and NE corners of the building on the third and fourth floors, the front staircase and the NE corner on the second floor. Please familiarize yourself with these exits. Do not use the elevator to exit the building when a fire alarm is sounding.

Library

The main library for the University of Toronto is Robarts Library, at 130 St. George, on the northwest corner of Harbord and St. George. The hours of operation are as follows; Monday through Thursday 8:30 am to 11:00 pm, Friday 8:30 am-6 pm, Saturday 9:00 am- 5:00 pm, & Sunday 1:00 pm-6:00 pm.
The Math and Statistics Library is located in Room 6141 of the Bahen Centre, at 40 St. George Street (open 9:00am-5:00 pm Monday through Friday).

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Instructors: Andrei Krokhin, Jaroslav Nesetril, Ross Willard, Ryan O'Donnell, Venkatesan Guruswami

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Toronto Probability Seminar

Toronto Quantum Information Seminar

COMMERCIAL INDUSTRIAL MATHEMATICS PROGRAM SEMINARS

PRMIA RiskManagement Seminars
Fields Industrial Optimization Seminar
Seminar Series on Quantitative Finance

WORKSHOPS AND SPECIAL EVENTS SUPPORT BY FIELDS

June 20-24, 2011
Fields-MITACS Conference on the Mathematics of Medical Imaging
hosted by the Fields Institute
held at the University of Toronto

June 27-29, 2011
Conference in Number Theory
Carleton University

June 27-July 8, 2011
Séminaire de mathématique supérieures, Metric Measure Spaces:Geometric and Analytic Aspects
held at Université de Montréal
Co-sponsored by CRM, Fields, MSRI and PIMS

July 4-August 26, 2011
Fields-MITACS Undergraduate Summer Research Program
Fields Institute

July 6-9, 2011
Conference on Transcendence and L-functions
Fields Institute

July 11-13, 2011
Coxeter Lectures (Summer Thematic Program on the Mathematics of Constraint Satisfaction)
Moshe Y. Vardi, Rice University

July 11-15, 2011
SciCADE 2011, International Conference on Scientific Computational and Differential Equationsb
Hosted by the Fields Institute
Held at the University of Toronto

July 25-29, 2011
International Conference on Applied Mathematics, Modeling and Computational Science, AMMCS 2011
Sir Wilfrid Laurier University
Supported by the Fields Institute

July 25-29, 2011
Conference on Blaschke Products and their Applications
University of Toronto Campus

July 26-29, 2011
Conference in Harmonic Analysis and Partial Differential Equations (in honour of Eric Sawyer)
Fields Institute

August 2-4, 2011
Workshop on Positivity
Hosted by the Fields Institute
Held at the University of Toronto

August 3-10, 2011
Banach Algebras Conference 2011
University of Waterloo

August 8-12, 2011
o-minimal Structures and Real Analytic Geometry Retrospective Workshop
Fields Institute and the University of Toronto Campus

August 8-12, 2011
Conference on Quantum Computing and Quantum Control
A Joint Fields-CQIQC Conference
Fields Institute

August 10-12, 2011
23rd Canadian Conference on Computational Geometry
University of Toronto Campus

August 11-12, 2011
Workshop on Selected Areas in Cryptography (SAC 2011)
Ryerson University

August 16-25, 2011
Workshop on Arithmetic and Geometry of K3 surfaces and Calabi-Yau threefolds
Fields Institute and University of Toronto

August 21-24, 2011
Fields-MITACS Workshop on Probabilistic Methods in Wireless Networks
Carleton University

September 9-11, 2011
Brock International Conference in Number Theory
Brock University, St. Catherines, Ontario

October 5-6, 2011
Distinguished Lecture Series in Statistical Science
Jerome H. Friedman, Department of Statistics, Stanford University
Fields Institute

October 14-16, 2011
Workshop on Category Theoretic Methods in Representation Theory
University of Ottawa

November 4-6, 2011* (tentative)
Research Colloquium on Mathematics Education and Climate Change
University of Ottawa

FIELDS

INSTITUTE PROFILE 2.3

The Fields Institute is a research facility in the mathematical sciences. The Institute's mandate includes programs devoted to research in the mathematical sciences, advancement in mathematics education, enhanced graduated and post-doctoral training opportunities, and developing partnerships with industry to encourage technology transfer.

Mathematicians from business, industry and financial institutions, can come together to carry out research and formulate problems of mutual interest, and to provide a supportive and stimulating environment for mathematics innovation and education.

Founded in 1992, the Fields Institute was initially located at the University of Waterloo. The Fields Institute officially opened at its 222 College Street location on the campus of the University of Toronto on November 17, 1995. The building The Fields Institute occupies was designed specifically to accommodate its research functions and activities by Toronto architects Kuwabara Payne McKenna Blumberg.

The Institute is named for Canadian mathematician John Charles Fields (1863-1932), whose will established the International Medal for Outstanding Discoveries in Mathematics, now known as the Fields Medal.

ACTIVITIES AT THE INSTITUTE

The Fields Institute environment is designed to support and enhance a large spectrum of mathematical activities such as research in pure and applied mathematics, statistics, computer science, and a bread spectrum of other disciplines including engineering, mathematical biology, theoretical physics, economics and mathematical finance, telecommunications, and medicine.

Research activities of the Institute bring together prominent mathematicians from Canada and around the world for periods of intensive collaborative research on topics of current importance. Unique courses, seminars, and other activities off Canadian and international graduate students and postdoctoral fellows access to world leaders in their fields and give private sector mathematical scientists access to the latest developments. Programs are selected by the Scientific Advisory Panel, an independent group of leading Canadian and international mathematicians.

OUR FACILITIES

Office space is available for 80 mathematicians and postdoctoral fellows from Canada and abroad. The facilities include a 100 seat lecture theatre, two smaller seminar room, computing stations and many spaces that are conducive to informal exchanges.

PUBLICATIONS

The Fields Institute publishes two book series with the American Mathematical Society, The Monograph Series and the Communications Series. The monograph series features high-quality research monographs and lecture notes in mathematics and applications of mathematics in science, engineering and industry. The communications volumes are conference proceedings of research and survey articles. As of July 1, 2004, there are 20 volumes in the FIM series and 41 in the FIC series. Both series, monograph and communications, are available through the AMS On-Line Bookstore.

Publications in both series often result from activities at the Institute, but we encourage all authors of books to consider publishing with us. Our publishing program with the AMS affords authors the advantages of wide distribution and advertising, high quality and low cost of published material, and a guarantee that all volumes will remain long in print.

All Monographs and Communications volumes are available for purchase from the American Mathematical Society On-line Bookstore - www.ams.org/cgi-bin/bookstore/bookpromo/fimseries

CALL FOR PROPOSALS 2.4

Thematic and Focus Program Proposals
The Fields Institute solicits proposals for a variety of programs in areas of current research interest in the mathematical sciences:
(1) Major thematic programs, six months in length.
(2) Thematic or focus programs, from one to two months in length to run concurrently with our major thematic programs. We are interested, in particular, in two-month summer programs of an interdisciplinary nature.
Deadlines for submission of letters of intent or proposals are March 15 and September 15 of each year

Scientific Activity Proposals
Proposals for general scientific activity, such as workshops, seminars, conferences and summer schools which do not fall within the scope of the main programs. The proposals are due by October 15, February 15 and June 15 of each year and decisions will be announced shortly afterwards.

CRM-Fields-PIMS Prize
The Centre de recherches mathématiques (CRM) and the Fields Institute for Research in Mathematical Science and the Pacific Institute for Mathematics Sciences solicit nominations for this joint prize in recognition of exceptional achievement in the mathematical science. Nominations for the CRM-Fields Prize should reach the Institute by November 1.

Lecture Series
The Fields Institute Coxeter Lecture Series (CLS), the Distinguished Lecture Series (DLS), and the Distinguished Lecture Series in Statistical Science (DLSS) are intended to bring a leading international mathematician in the field of the thematic program of the Institute to give a series of three lectures. Proposals and nominations and should be received by September 15 or March 15.

Fields Institute Fellows
The Fields Institute is soliciting nominations for Fields Institute Fellows. These are awarded in recognition of outstanding contributions to the Fields Institute and its activities. The deadline for nominations is February 15 each year.

Postdoctoral Fellowships
These fellowships provide an opportunity to spend a period of at least one year engaged in research and participating in the research activities of the Institute. Qualified candidates who have recently completed a PhD in an area related to the upcoming thematic program are encouraged to apply. Deadline for applications is December each year.

Visiting Members of the Fields Institute
Applications are invited to be a visiting member at the Fields Institute. While a member at the Institute, it is expected that you will carry out your own research, participate in the activities related to your interests and collaborate with other visiting members. Applications are accepted on an ongoing basis.

Research Immersion Fellowship
This program supports individuals with high potential to re-enter an active research career after an interruption for family responsibilities. To qualify, candidates must have been in a postdoctoral or faculty position at the time their active research career was interrupted. The duration of the career interruption should be at least one year and no more than eight years.

For detailed information regarding the proposal process and criteria please see:
www.fields.utoronto.ca/proposals/

PUBLICATIONS 2.5

All Fields publications can be viewed in the Fields library and purchased at the reception desk, free of shipping costs.

Monographs

Brauer Type Embedding Problems - Arne Ledet, *Texas Tech University* - AMS, 2005, 171 pp., List: US$52, AMS Members: US$42

Lectures on Automorphic L-functions - James W. Cogdell, *Oklahoma State University*, Henry H. Kim, *University of Toronto*, and M. Ram Murty, *Queen's University* - AMS, 2004, 283 pp.
List: US$79, AMS Members: US$63

Efficient Graph Representations - Jeremy P. Spinrad, *Vanderbilt University* - AMS, 2003, 342 pp., List: US$95, AMS Members: US$76

Meromorphic Functions and Linear Algebra - Olavi Nevanlinna, *Helsinki University of Technology* - AMS, 2003, 136 pp.
List: US$49, AMS Members: US$39

Coloring Mixed Hypergraphs: Theory, Algorithms and Applications - Vitaly I. Voloshin, *Moldovan Academy of Sciences* - AMS, 2002, 181 pp., List: US$49, AMS Members: US$39

Lectures on Monte Carlo Methods - Neal Madras, *York University* - AMS, 2002, 103 pp., List: US$30, AMS Members: US$24

Lectures on Algebraic Model Theory - Bradd Hart and Matthew Valeriote, *McMaster University*, Editors - AMS, 2002, 111 pp., List: US$30, AMS Members: US$18

Large Deviations - Frank den Hollander, *Nijmegen University* - AMS, 2000,
List: US$49, AMS Members: US$39

Lectures on Operator Theory - B. V. Rajarama Bhat, *Indian Statistical Institute*, George A. Elliott, *University of Toronto*, and Peter A. Fillmore, *Dalhousie University*, Editors - AMS, 2000, 323 pp., List: US$69, AMS Members: US$55

Ordered Exponential Fields - Salma Kuhlmann, *University of Saskatchewan* - AMS, 2000, 166 pp., List: US$50, AMS Members: US$30

Communications

Representations of Algebras and Related Topics - Ragnar-Olaf Buchweitz, *University of Toronto*, and Helmut Lenzing, *University of Paderborn*, Editors - AMS, 2005, 396 pp., List: US$109
AMS Members: US$87

Asymptotic Methods in Stochastics: Festschrift for Miklós Csörgö - Lajos Horváth, *University of Utah*, and Barbara Szyszkowicz, *Carleton University*, Editors – AMS, 2004, 530 pp., List: US$129
AMS Members: US$103

Difference and Differential Equations - Saber Elaydi, *Trinity University*, Gerry Ladas, *University of Rhode Island*, Jianhong Wu, *York University*, and Xingfu Zou, *Memorial University of Newfoundland*, Editors - AMS, 2004, 438 pp, List: US$119
AMS Members: US$95

Galois Theory, Hopf Algebras, and Semiabelian Categories - George Janelidze, *Razmadze Mathematical Institute of the Georgian Academy of Sciences*, Bodo Pareigis, *University of Munich*, and Walter Tholen, *York University*, Editors – AMS, 2004, 570 pp., List: US$129, AMS Members: US$103

High Primes and Misdemeanours: Lectures in Honour of the 60th Birthday of Hugh Cowie Williams - Alf van der Poorten, *Centre for Number Theory Research*, and Andreas Stein, *University of Illinois at Urbana-Champaign*, Editors - AMS, 2004, 392 pp., List: US$110, AMS Members: US$88

Representations of Finite Dimensional Algebras and Related Topics in Lie Theory and Geometry - Vlastimil Dlab, *Carleton University*, and Claus Michael Ringel, *Universität Bielefeld*, Editors - AMS, 2004, 479 pp., List: US$119, AMS Members: US$95

Vertex Operator Algebras in Mathematics and Physics - Stephen Berman, *University of Saskatchewan*, Yuly Billig, *Carleton University*, and Yi-Zhi Huang and James Lepowsky, *Rutgers University*, Editors - AMS, 2003, 249 pp., List: US$75, AMS Members: US$60

Continued overleaf...

Monographs

Shape, Smoothness and Invariant Stratification of an Attracting Set for Delayed Monotone Positive Feedback - Tibor Krisztin, *University of Szeged, Bolyai Institute*, Hans-Otto Walther, *Universität Giessen*, and Jianhong Wu, *York University* - AMS, 1999, 245 pp., List: US$72, AMS Members: US$43

Quasicrystals and Discrete Geometry - Jirí Patera, *Centre de recherches mathématiques, Université de Montréal*, Editor - AMS, 1998, 289 pp., List: US$83, AMS Members: US$50

Introduction to Homotopy Theory - Paul Selick, *University of Toronto, ON, Canada* - AMS, 1997, 188 pp., List: US$51, AMS Members: US$41

Lifting Solutions to Perturbing Problems in C*-Algebras - Terry A. Loring, *University of New Mexico* - AMS, 1997, 165 pp.
List: US$46, AMS Members: US$28

Bordism, Stable Homotopy and Adams Spectral Sequences - Stanley O. Kochman, *York University* - AMS, 1996, 272 pp.
List: US$51, AMS Members: US$41

C*-Algebras by Example - Kenneth R. Davidson, *University of Waterloo* - AMS, 1996, 309 pp.
List: US$62, AMS Members: US$50

Multiplicative Galois Module Structure - A. Weiss, *University of Alberta* - AMS, 1996, 95 pp., List: US$41, AMS Members: US$25

Riemannian Geometry - Gérard Besson, *Institut Fourier*, Joachim Lohkamp, *Institute des Hautes Etudes Scientifiques*, Pierre Pansu, *University of Paris-Sud, Orsay*, and Peter Petersen, *University of California, Los Angeles* - AMS, 1996, 115 pp., List: US$48
AMS Members: US$38, Sale Price: US$24

Communications

Calabi-Yau Varieties and Mirror Symmetry - Noriko Yui, *Queen's University*, and James D. Lewis, *University of Alberta*, Editors - AMS, 2003, 367 pp., List: US$110, AMS Members: US$88

Valuation Theory and Its Applications, Volume II - Franz-Viktor Kuhlmann, Salma Kuhlmann, and Murray Marshall, *University of Saskatchewan*, Editors - AMS, 2003, 459 pp., List: US$119, AMS Members: US$95

Novel Approaches to Hard Discrete Optimization - Panos Pardalos, *University of Florida*, and Henry Wolkowicz, *University of Waterloo*, Editors - AMS, 2003, 181 pp., List: US$62, AMS Members: US$50

Dynamical Systems and Their Applications in Biology - Shigui Ruan, *Dalhousie University*, Gail S. K. Wolkowicz, *McMaster University*, and Jianhong Wu, *York University*, Editors - AMS, 2003, 268 pp.
List: US$79, AMS Members: US$63

Symplectic and Contact Topology: Interactions and Perspectives - Yakov Eliashberg, *Stanford University*, Boris Khesin, *University of Toronto*, and François Lalonde, *Université de Québec à Montréal*, Editors - AMS, 2003, 199 pp., List: US$64
AMS Members: US$51

Numerical Methods and Stochastics - T. J. Lyons, *University of Oxford*, and T. S. Salisbury, *York University*, Editors - AMS, 2002, 121 pp.
List: US$49, AMS Members: US$29

Valuation Theory and Its Applications, Volume I - Franz-Viktor Kuhlmann, Salma Kuhlmann, and Murray Marshall, *University of Saskatchewan*, Editors - AMS, 2002, 449 pp., List: US$119, AMS Members: US$71

Differential Equations and Dynamical Systems - A. Galves, *Universidade de São Paulo*, J. K. Hale, *Georgia Institute of Technology*, and C. Rocha, *Instituto Superior Técnico*, Editors - AMS, 2002, 353 pp., List: US$99, AMS Members: US$59

Mathematical Physics in Mathematics and Physics: Quantum and Operator Algebraic Aspects - Roberto Longo, *University of Rome II*, Editor - AMS, 2001, 451 pp., List: US$119
AMS Members: US$71

A complete listing of all of our publications, including earlier editions, can be found at www.ams.org/cgi-bin/bookstore/bookpromo/fimseries & www.ams.org/cgi-bin/bookstore/bookpromo/ficseries

COLLEGE STREET

Asean Restaurant
416-598-2895
257 College Street

Burger King Restaurants
416-591-9999
267 College Street

College Grill Ltd
416-260-0576
177 College Street

Druxy's Famous Deli Sandwiches
416-586-0242
191 College Street

Einstein Cafe & Pub
416-597-8346
229 College Street

O'Grady's Tap & Grill
416-596-0327
171 College Street

Pita Pazzaz Mars
416-977-7482
101 College Street

Pita Pit Inc
416-586-0202
235 College Street

McCAUL STREET

Al's Fish & Chips
416-351-8722
105 McCaul Street

Gypsy Hungarian Restaurant
416-598-1650
109 McCaul Street

McDonald's
416-977-6607
109 McCaul Street

UNIVERSITY AVENUE

Druxy's Famous Deli Sandwiches
416-260-2184
610 University Avenue

Earl's Bistro
416-595-0700
700 University Avenue

Fallone's Deli Plus
416-977-1961
700 University Avenue

Tim Hortons Donuts
416-585-2914
610 University Avenue

SPADINA AVENUE

Chung King Szechwan Restaurant
416-593-0101
428 Spadina Avenue

Lucky Dragon
416-598-7823
418 Spadina Avenue

New Ho King
416-595-1881
416 Spadina Avenue

Saigon Palace Restaurant
416-968-1623
454 Spadina Avenue

Subway Sandwiches and Salads
416-925-6020
656 Spadina Avenue

Thai Bangkok Restaurant
416-598-4701
412 Spadina Avenue

All restaurants are within 1 km of the Medical Sciences Auditorium

vegetarian only expensive choice

BALDWIN STREET

Bocca on Baldwin
416-348-0731
26 Baldwin Street

Bodega Restaurant
416-977-1287
30 Baldwin Street

Cafe La Gaffe
416-596-2397
24 Baldwin Street

Eating Counter
416-977-7028
23 Baldwin Street

Fujiyama Japanese Restaurant
416-596-1913
49 Baldwin Street

The Gateways of India
416-340-0404
19 Baldwin Street

Hana Korea Restaurant
416-979-9453
45 Baldwin Street

Hua Sang Seafood Restaurant
416-596-1628
41 Baldwin Street

Jodhpore Club Indian Restaurant
416-598-2502
33 Baldwin Street

John's Italian Caffe
416-596-8848
27 Baldwin Street

Kolbeh A Taste of Persia
416-597-8296
160 Baldwin Street

Kon-Nichi-Wa Japanese Restaurant
416-593-8538
31 Baldwin Street

Kowloon Dim Sum Restaurant
416-977-3773
5 Baldwin Street

Margarita's Fiesta Room
416-977-5525
14 Baldwin Street

Matahari Grill
416-596-2832
39 Baldwin Street

One on Mahal
416-599-6565
23 Baldwin Street

Sambuca Grill Inc
416-595-6277
21 Baldwin Street

Sushi Ya
416-260-3188
20 Baldwin Street

Thai Paradise
416-351-1368
35 Baldwin Street

Tuscany Cafe
416-971-4432
45 Baldwin Street

Vegetarian Haven
416-977-1640
17 Baldwin Street

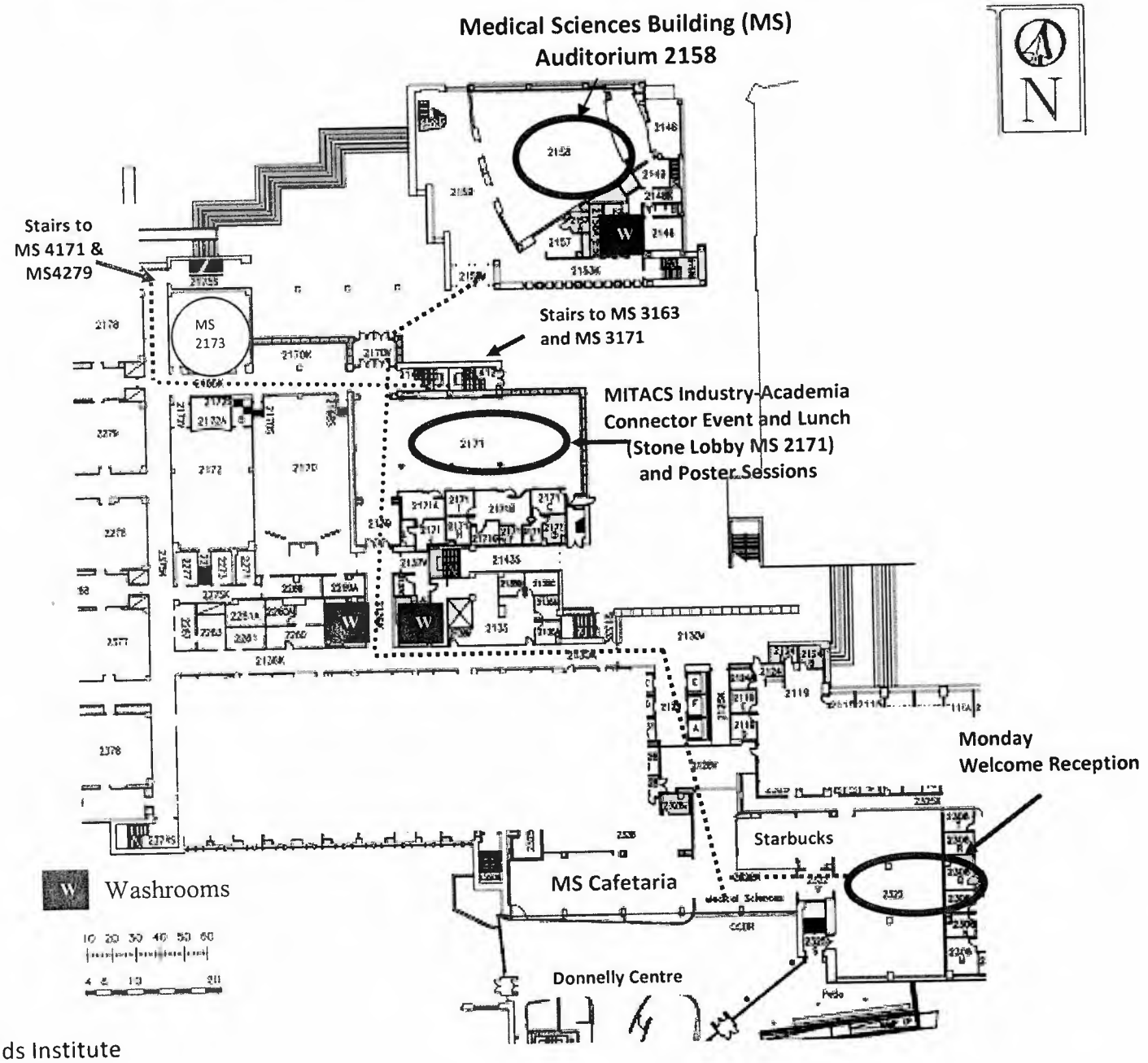
Wah Sing Seafood Restaurant
416-599-8822
47 Baldwin Street

All restaurants are within 1 km of the Medical Sciences Auditorium

vegetarian only expensive choice

FIELDS

MAP OF CAMPUS 3.2



Fields Institute
222 College

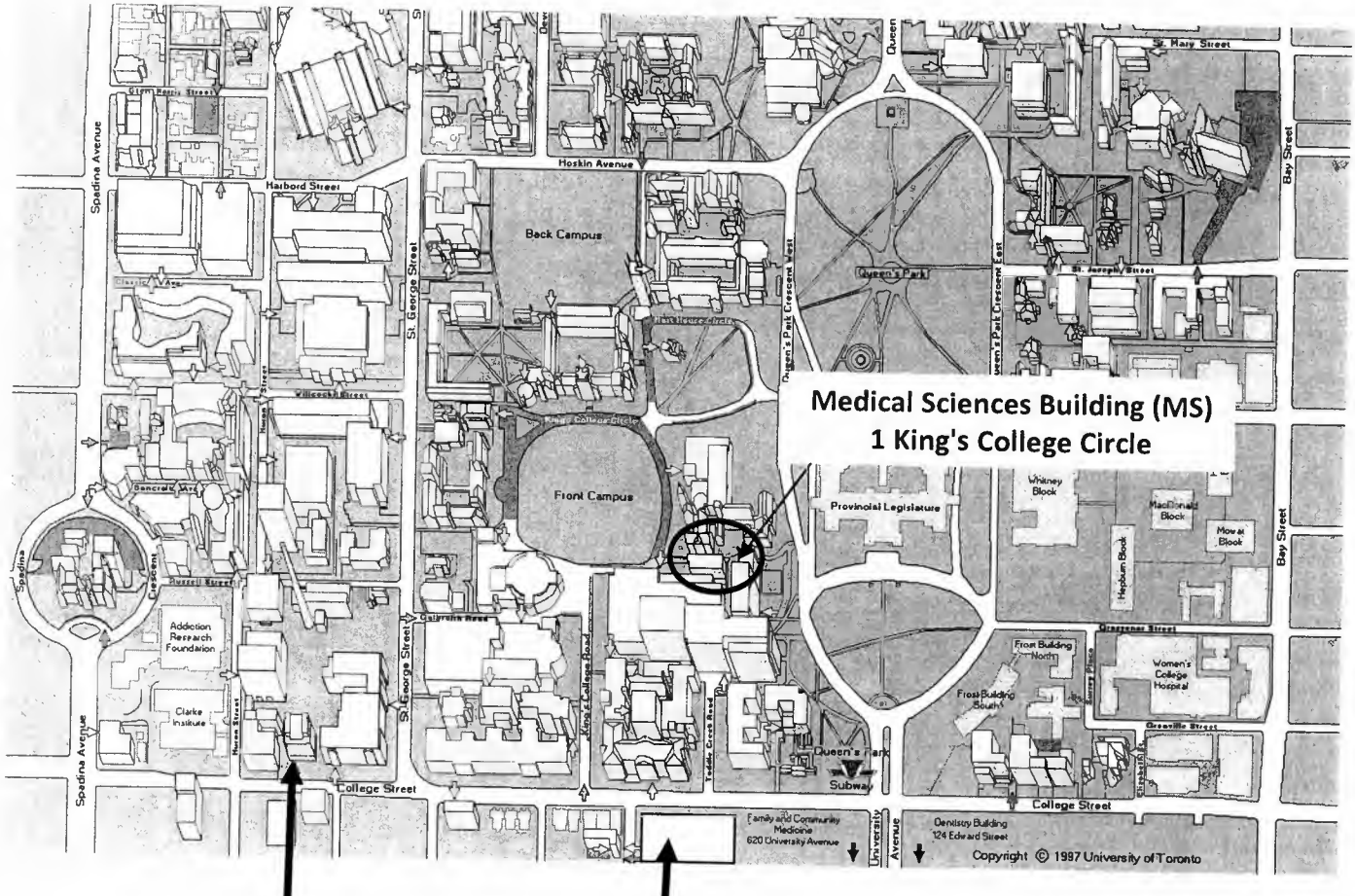
College Street

Health Sciences
155 College Street

The Medical Sciences Building is also accessible through the Donnelly Centre to the south.

FIELDS

MAP OF CAMPUS 3.2



The Fields Institute (FI)
222 College Street

Health Sciences (HS)
155 College Street