IC1

Mathematical Challenges in Magnetic Resonance Imaging (mri)

Magnetic resonance imaging (MRI) requires solutions to (at least) two inverse problems. The first problem is the design of radio frequency (RF) pulses that excite the spins in a certain slice or volume according to a prescribed pattern. The second problem is the reconstruction of 2D, 3D, or 4D images from the measured data. Both of these problems can be solved with simple Fourier transform methods in some cases, but there are interesting applications, including functional MRI (fMRI), where more advanced methods based on more accurate physical models are beneficial. These usually require iterative optimization methods. This talk will first review the problems and traditional solutions, and then will describe some more recent advanced methods. Along the way I will identify some open mathematical challenges in this field.

Jeffrey Fessler
University of Michigan
fessler@umich.edu

IC2

First Twenty Years of Total Variation In Image Processing and Analysis (Inventor's Perspective and Critique)

Total Variation measure for the functions of one variable, and the related properties, were established by C. Jordan in 1881. A consistent geometrical extension to the functions of two-variable was developed by A. Kronrod in 1950. In order to address the smooth solutions only limitations of the classical Tichonov regularization theory for ill-posed problems, particularly as it applies to the image restoration problems, L. Rudin in his 1987 work, has postulated that: Images belong and can be modeled in the space of functions of bounded total variation BV(R2) . In the same work a first example of a BV imbedding of the solution for a discontinuous image enhancement problem was constructed through a non-linear PDE Shock-Filter. Thus, the new field of non-linear PDEs for image processing was initiated. In 1989 report delivered to US Government, the author and his two collaborators demonstrated a new variational computational framework, where imaging solutions were derived via Minimization of TV functional, subject to the noise statistical constraints. This work had to wait until 1992 to appear in public. Also, in 1989 Mumford and Shah have proposed a novel variational approach to image segmentation problem. The classical Mumford-Shah functional, while important on its own merits, is not equivalent to the Min(TV) problem, does not yield a straightforward Euler-Lagrange minimization algorithm, imposes special geometrical constraints on the way the boundaries can intersect each other, and it is not a straight-forward generalization of Tichonov Regularization theory as the TV approach is. The above minimizing 2-D Total Variation functional yielded a novel Euler-Lagrange equation with piece-wise smooth solutions to image denoising and deblurring. A simple Min(TV) concept forced the solution to be in BV space, but not necessary to be in the class C8, which would happen with the classical regularization. Ever since, the Min(TV) principle is being faithfully followed, in thousands of publications, with no or little change to the variatonal principle. The multitude of applications is an indication of an apparent success for the first twenty years of the TV-based methods. Citations show real practical applications to the fields of optical, electro-optical, acoustic image processing, 3-D image analysis, data compression, CT/MRI and other bio-medical imaging, fluid mechanics, circuits design, scattering and electromagnetic inverse problems, DNA and Chromosomes image analysis, seismic tomography, material science, etc. As a practicing image processor, the author has spent last twenty years applying advanced algorithms (anything that works) to imaging problems arising in forensic/security and other video gathering fields. Image quality is critical here, as the identification depends on it. TV based image restoration showed to be superior to the classical Tichonov regularization. The following practical observation however can be made: most bad quality images were not satisfactory recoverable by any of the state of the art image processing techniques. In this talk, we will examine such practical examples and consider the causes. We will question whether the blind following of the original principle of TV minimization is the best way to fight ill-posedness in image processing.

Leonid Rudin
Cognitech, Inc.
lenny@cognitech.com

IC3

Are Future Advances in Seismic Imaging Going to Be Incremental from Here on Out?

Rapid advances in computing power have brought us to the point where essentially all "classical" methods of imaging the subsurface of the Earth with sounds waves are feasible and even practical. Coupled with new techniques in acquiring seismic reflection data, these algorithms are creating high-quality images of subsurface structures for hydrocarbon exploration and production. I'll show a few examples of complex imaging projects where our "classical" methods recent advances are working well. Given those successes, it is worth asking the question: Are we really at the end game, where all remaining advances will be incremental and we merely surf the wave of increasing computer power using known methods? I think not, as there are still geological structures that do not yield useful seismic reflection images, and many other situations where the quality of those images is insufficient in fundamental ways. I'll discuss what I see as some of the most difficult remaining problems in reflection seismology and how we might approach solving those problems.

John Etgen
British Petroleum
John.Etgen@bp.com

IC4

Advanced Signal Processing for Ultra-Wideband Synthetic Aperture Radar (sar)

Ultra-wideband SAR in the VHF and UHF bands is commonly used for foliage-penetration applications, i.e. standoff detection of objects concealed in forest. The currently main limiting factor is the strong backscattering obtained from dense forests. The talk will discuss possibilities to improve detection performance. One possibility which will be discussed is to improve resolution by increasing the integration angle. Another possibility which will be discussed is to use bistatic scattering geometries. The challenges for the signal processing will be outlined and possible solutions described.

Lars Ulander
Swedish Defense Research Agency, Sweden
lars.ulander@foi.se

IC5

Qualitative Features of the Minimizers of Energies and Implications on Modelling

We address all applications that are solved by minimizing an energy function combining a data-fidelity and a regularization term. Energy functions are classically defined either from a PDE standpoint or in a Bayesian estimation framework. Our approach is to characterize the essential features exhibited by the minimizers of such energies as a function of the shape of the energy. For instance, the recovery of homogeneous regions, textures and edges, the processing of outliers or spikes, the obtaining of sparsity, are shown to be determined by some attributes of the energy relevant to its (non)smoothness or its (non)convexity. Our point of view provides a framework to address rigorously the problem of the choice of energies for image reconstruction and invokes a new understanding of modelling.

Mila Nikolova
Centre de Mathématiques et de Leurs Applications (CMLA)
ENS de Cachan, CNRS
nikolova@cmla.ens-cachan.fr

IC6

Foundations of Compressed Sensing

We will give an introduction to the emerging field of Compressed Sensing. The main objective of this new paradigm in signal processing is to capture a signal with the smallest number of measurements. We shall emphasize ways to decide what are the best sensing systems and describe how to construct near optimal systems.

Ronald DeVore
Department of Mathematics
University of South Carolina
devore@math.sc.edu

IP0

Past President's Address: whydomath

One of the extraordinary and most satisfying features of mathematics is a kind of technology transfer that occurs when ideas developed in one field of mathematics apply equally well, and oftentimes in unlikely ways, in fields outside of mathematics. Katherine Socha and I have been leading a SIAM effort to develop a multimedia website, named whydomath, which will feature many success stories about the application of mathematics and computational science. The website, aimed at a freshman / popular science level, will be introduced at this meeting. Ultimately, whydomath will consist of many nodes, each one telling a story where the mathematical sciences has already proved instrumental in advancing an area of general societal interest, perhaps by being the foundation for a multi-billion dollar industry or, perhaps, just by providing the framework for unexpected advancement in another field. We want to highlight many of the ways in which the mathematical sciences have added value. In part the purpose of this talk is to present the website. But there is a more important goal: to challenge members of the SIAM community to help tell these stories.

Marty Golubitsky
University of Houston
mg@math.uh.edu

IP0

John Von Neumann Lecture: The Effect of Local Features on Global Expansions

Global expansions, such as Fourier expansions, form the basis of many approximations which are successfully used in a wide variety of applications. Fourier expansions are used in applications ranging from medical CT scans, which are based on the Fourier expansion coefficients of an image, to spectral methods which are widely used to simulate complicated flows. While methods based on global approximations converge exponentially when the underlying function and all its derivatives are smooth, they lose accuracy in the presence of discontinuities. The term "Gibbs phenomenon" refers to the fact that the presence of a local discontinuity degrades the global convergence of such methods, although this fact was first pointed out by Albert Michelson. Over the years, a variety of techniques have been developed to alleviate or overcome the Gibbs phenomenon. These techniques include filtering (in the physical space as well as in the transform plane) and reprojections (re-expansing the numerical solution in a different basis). In this talk, we will present the history of the Gibbs phenomenon, and review the recent literature concerning overcoming of this phenomenon, including a discussion of methods for edge detection, which allow us to determine the location of the discontinuities.

David I. Gottlieb
Brown University
Div of Applied Mathematics
dig@cfm.brown.edu

IP0

W. T. and Idalia Reid Prize in Mathematics Lecture

To follow.

Max Gunzburger
Florida State University
School for Computational Sciences
gunzburg@scs.fsu.edu

IP0

The AWM-SIAM Sonia Kovalevsky Lecture: A Noisy Adiabatic Theorem: Wilkinson Meets Schrdinger's Cat

The adiabatic theorem gives conditions that guarantee that a system defined by Schrdinger's equation remains in its ground state when started in its ground state and evolved slowly. Realistically, such systems are subject to perturbations in the initial condition, systematic time-dependent perturbations in the Hamiltonian, coupling to low-energy quantum systems, and decoherent time-dependent perturbations in the Hamiltonian. Using Wilkinson-style perturbation analysis, we derive bounds on the effects of these perturbations. This is joint work with Michael J. O'Hara.

Dianne P. O'Leary
University of Maryland, College Park
Department of Computer Science
oleary@cs.umd.edu

IP0

I.E. Block Community Lecture: Stylish Mathemat-

ics

All too often we see mathematics and the arts as two sides of the science/humanities coin. In this talk we'll see a place in which the two come naturally together in exciting new research. For in today's world in which almost all aspects of life are brought to the common medium of the computer, it is now possible to quantify and extract the style of an artist via computation. Examples are gleaned from the literary, visual, and dance arts, and include applications to the problem of authentication as well as to the more general problem of quantifying one's personal style. Taken together, this body of work shows just how "stylish" mathematics can be!

Daniel Rockmore
Dartmouth College
daniel.rockmore@dartmouth.edu

JP1
The Heat Equation with Us Forever

What good comes from applying the heat equation to a digital image? The obvious answer is nothing: the heat equation just mixes colors and blurs images. Likewise could a solution to the Laplace equation produce decent images? Again, the a priori answer is no since a solution to the Poisson equation is smooth, and hence results in blurriness. Contradicting this doxa, I'll show that long-pursued aims in image processing and in image analysis are solved with the simplest linear PDEs: the heat equation and the Poisson equation. Three examples are treated. All three are basic questions about images and their perception. Thus, one could do a crash course in image processing with just the Laplacian. In the talk I'll go over such a course. The first problem is shape recognition. A recent algorithm invented by David Lowe gives an wonderfully complete solution. At its core lies the heat equation. The second example is Land's retinex theory, which delivers optimally contrasted images. Lo and behold the restored image is the solution of a Poisson equation! My third example is image denoising. Untold methods have been suggested for this puzzling problem, including all sorts of nonlinear heat equations. Yet the problem is elegantly solved by the heat equation.

Jean-Michel Morel
ENS Cachan
morel@cmla.ens-cachan.fr

CP1
A New Multiphase Image Segmentation and Its Application to Partial Volume Calculation

Multiphase image segmentation via Modica-Mortola phase transition is essentially a different way from Mumford-Shah model. The original model assumes the image to be piecewise constant. In this paper, it is extended to Gaussian-distribution-like image, and is then applied to partial volume segmentation of human brains. Unlike those existing EM based method where partial volume is computed pointwisely, the new method computes the partial volume phasewisely.

Fuhua Chen
Department of Mathematics
University of Florida
fuhua@math.ufl.edu

Yunmei Chen
University of Florida
yun@math.ufl.edu

Hemant Tagare
Yale University
hemant.tagare@yale.edu

CP1
Joint Image Segmentation and Registration: An Explicit Solution Using an LMMSE Estimator

We consider the problem of natural image segmentation based on the elastic registration of a deformable template. We show that the original highly nonlinear problem can be represented by an equivalent *linear system* in the deformation parameters, biased by the unknown image background. The first two moments of the linear system are calculated using a Bayesian framework. Classical linear methods are then employed to estimate the deformation parameters, providing an explicit solution for the joint segmentation and registration problem. The applicability of the method is demonstrated on natural images.

Gilad Cohen, Joseph Francos
Ben Gurion University
Electrical & Computer Engineering Department
cogil@ee.bgu.ac.il, francos@ee.bgu.ac.il

CP1
A Graph Cut Based Active Contour Without Edges Model for the Segmentation of Vector Valued Images

This work presents an extension of our previous work Graph cut optimization of the Mumford-Shah functional. It proposes a discrete formulation of the Chan-Vese segmentation model for vector valued images. It proves the graph representability of the discrete energy function and optimizes it using graph cuts. The model preserves the advantages of Chan-Vese model vis-a-vis robustness to topology changes and noise. Meanwhile, It is much faster because graph cuts minimizes the energy function in a polynomial time. Our technique is more reliable. It is not sensitive to initialization as graph cuts optimize the function globally.

Noha Y. El-Zehiry
Computer Engineering and Computer Science Department
University of Louisville
nyelze01@louisville.edu

Prasanna Sahoo
Mathematics Department
University of Louisville
sahoo@louisville.edu

Adel Elmaghraby
Computer Engineering and Computer Science
University of Louisville
adel@louisville.edu

CP1
A Combined Segmentation and Registration Framework with a Nonlinear Elasticity Smoother

We present a new non-parametric registration method. The shapes to be registered are implicitly modelled with

level set functions and the problem is cast as an optimization problem combining a matching criterion borrowed from the segmentation model proposed by Chan and Vese and a nonlinear elasticity-based smoother on the displacement vector field. This modelling is twofold: first, in a way, registration is jointly performed with segmentation since guided by the segmentation process and secondly, the use of a nonlinear elasticity-type regularizer allows large deformations.

Carole Le Guyader
IRMAR
INSA de Rennes, France
carole.le-guyader@insa-rennes.fr

Luminita A. Vese
University of California, Los Angeles
Department of Mathematics
lvese@math.ucla.edu

CP1
Image Segmentation Based on the Statistical Variational Formulation Using the Local Region Information

We propose a variational segmentation model based on statistical information of an image. The model consists of a local region-based energy and a global region-based energy in order to handle misclassification with an assumption that an image is a mixture of two Gaussian distributions. We find a local ambiguous region where misclassification might happen due to a small difference between two Gaussian distributions. We design a local region-based energy in order to reduce the misclassification.

Chang-Ock Lee
Department of Mathematical Sciences
KAIST
colee@kaist.edu

Sung Ha Park
KAIST
sungha_06@kaist.ac.kr

Jooyoung Hahn
Department of Mathematical Sciences, KAIST
JooyoungHahn@kaist.ac.kr

CP1
A Landmark Based Nonlinear Elasticity Model for Mouse Atlas Registration

This work is devoted to the registration of gene expression data to a neuroanatomical mouse atlas in two dimensions. We use a non-linear elasticity regularization model, allowing large deformations guided by an intensity-based data fidelity term and by landmarks. We overcome the difficulty of minimizing the nonlinear elasticity functional by introducing an additional variable $v = \nabla u$, where u is the displacement. Thus, in the obtained Euler-Lagrange equations, the non-linearity is no longer in the derivatives of the unknown, u. Experimental results show gene expression data mapped to a mouse atlas for a standard L2 data fidelity term in the presence of landmarks.

Tungyou Lin
UCLA
tungyoul@math.ucla.edu

Ivo D. Dinov
UCLA
Center for Computational Biology
ivo.dinov@loni.ucla.edu

Luminita A. Vese
University of California, Los Angeles
Department of Mathematics
lvese@math.ucla.edu

CP1
Poster Presentation and Open Discussion

Session Participants
.
.

CP1
Morphological Multimodal Image Registration

Since the gradients for different images of the same object are parallel at each point we use the norm of the outer product of the gradients as a measure of the difference of multimodal images. We minimize this functional instead of mutual information in 2D and 3D multimodal image registration, using regularization by Sobolev norms or the elastic energy. We present results among others for the registration of MR images to a brain atlas.

Kristian Witsch, Claudia Frohn-Schauf, Dominik Loechel
Universitat Dusseldorf
Angewandte Mathematik
witsch@am.uni-duesseldorf.de, frohn@am.uni-duesseldorf.de, loechel@am.uni-duesseldorf.de

CP2
An Efficient Reconstruction Method for Band-Limited Images Using Nonperiodic Sampling Sets

In this presentation, we introduce a new reconstruction method for band-limited images. The sampling sets in our theory are union of shifted lattices. Therefore our method employs nonperiodic sampling sets. An image could be reconstructed via a recursive reconstruction algorithm from its samples provided the sampling sets and the spectrum of the image satisfy certain compatibility conditions. We will explain these conditions and compare the speed of reconstruction using periodic sampling with our method.

Hamid R. Behmard
Western Oregon University
behmarh@wou.edu

CP2
Direct Reconstruction in Electrical Impedance Tomography Using The D-Bar Method and Finite Differences

The d-bar method, introduced in the context of EIT by Nachman, is able to generate quantitatively accurate reconstructions of the complex permittivity within a two-dimensional medium. Isaacson, Mueller, and Siltanen developed and implemented a practical implementation of this method, testing it on data from a circular chest phantom. We extend this work, showing that the d-bar equation can be implemented using the finite-difference method, with a low degree of computational complexity. Results are

shown for a circular test phantom as well as for analytically derived data generated in the case of a layered medium.

Gregory Boverman
Rensselaer Polytechnic Institute
boverg@rpi.edu

David Isaacson
RPI
isaacd@rpi.edu

CP2

An Exact Solution to the Cone Beam Transform for Orbits Satisfying the Sufficiency Conditions, Proof of a Fourier Theorem for the Cone Beam Transform, and the Use of Invertible Transformations of Cone Beam Projections to Facilitate Phantom Synthesis.

We derive a solution of the Cone Beam Transform for a wide selection of cone beam vertex trajectories and detector orientations that satisfies the Tuy-Grangeat sufficiency conditions. This solution has similarities to the Colsher filter for 3D PET reconstruction. The result of this analysis is that an exact solution emerges for both the short-body problem and long body problem. We analyze a large family of orbits, including the spherical helical and cylindrical helical trajectories with the detector always facing the sphere of support. The planar circular orbit is a limiting case of both of these classes. We also analyze the classical helical trajectory, or long body problem of the commercial the X-ray tomograph, in which the detector orientation is perpendicular to the long axis of support, and has a limited polar acceptance angle. We demonstrate the solution by accurately reconstructing the three-dimensional Shepp-Logan phantom with typical X-ray contrast range. The algorithms are efficient, exhibiting a numerical complexity of $O\left(N_{orbit}N^3\right)$, where N_{orbit} is the number of vertices and N^3 is the number of voxels in the reconstruction. We also derive data transformations that allow the generation of cone beam projections for translated and rotated ellipsoids from the projections of a uniform, centered sphere with unit radius. We show that these operations are invariant under the dot product. We also derive a theorem linking the Fourier transform of the object to the Fourier transform of the cone beam data. We use the transformational tool for the dot product to generate Cartesian Fourier components for a phantom consisting of two nested concentric spheres. Key words: Integral Transforms, Inverse Problems, Cone Beam Transform, Tuy-Grangeat sufficiency condition, Colsher filter.

William G. Hawkins
University of Arizona
Bimadida Tomo, Co.
hawkins_44143@yahoo.com

David Rohler
Plexar Associates, Inc.
dprohler@plexar.com

CP2

Bayesian Signal Restoration and Mumford-Shah Functional

Inverse problems are related to solving quantities that cannot be measured directly. In Bayesian inversion theory the problem is formulated as a statistical inference problem based on stochastic models of indirect measurements and a priori information. In this setting the solution is the posterior probability distribution. In this presentation we discuss the connections between the Mumford-Shah functional and hierarchical statistical inverse problems.

Tapio Helin
Helsinki University of Technology
tapio.helin@tkk.fi

Matti Lassas
Helsinki University of Technology
Finland
matti.lassas@tkk.fi

CP2

Issues and Examples of Reverse Time Migration

Simple 3D models are used to investigate the effects of issues in reverse time migration, such as constant density and constant impedance migration. Such simplifications decrease migration quality but enhance computational efficiency. Realistic 2D synthetics from the Gulf of Mexico is used for migration with original and own generated synthetics. I conclude that it is the synthetics/data quality that determines the final image quality. Numerical dispersion during migration often have minimal impact.

Stig O. Hestholm
Shell Exploration and Production Inc.
Stig.Hestholm@shell.com

CP2

Optimization Strategies for Formation and Reconstruction of Digital Holography Images

Lens-less Fourier transform digital holography is a powerful method for multi-aperture and three-dimensional active imaging at long ranges. Distorted imagery resulting from phase aberrations due to optical system misalignments and atmospheric turbulence can be corrected using digital phase masks. We present an overview of the image formation method and describe optimization strategies for determining phase corrections, illustrated by results from laboratory and field test data.

Thomas Hoft, Joseph Marron, Nathan Seldomridge,
Taylor Grow
Lockheed Martin Coherent Technologies
thomas.a.hoft@lmco.com, joe.marron@lmco.com,
nathan.seldomridge@lmco.com, taylor.grow@lmco.com

Richard Kendrick
Lockheed Martin Advanced Technology Center
rick.kendrick@lmco.com

CP2

Bayesian Multiresolution Method for Local X-Ray Tomography

A Bayesian multiresolution model for local tomography is proposed. In this model a wavelet basis is used to present tissue structures and the prior information is modeled in terms of Besov norms. The proposed wavelet-based multiresolution method is used to reduce the number of unknowns in the reconstruction problem by abandoning fine-scale wavelets outside the region of interest (ROI). This multiresolution model allows significant reduction in the

number of unknowns without the loss of reconstruction accuracy inside the ROI. The feasibility of the proposed method is tested with two-dimensional (2D) examples of local tomography in dental radiology.

Ville P. Kolehmainen, Kati Niinimäki
Department of Physics
University of Kuopio
Ville.Kolehmainen@uku.fi, kati.niinimaki@uku.fi

Samuli Siltanen
Tampere University of Technology
samuli.siltanen@tut.fi

CP2

Exploiting Multiple Scattering for Improved Seismic Image Illumination: A Series Approach

Standard one-way approximations to the wave equation do not allow waves to propagate perpindicular to the designated preferred direction. In seismic experiments, where these approximations are commonly used, data are collected only along the top of the region of interest. This, along with a single scattering assumption, limits the illuminated region. Using a series aproach, we show that including multiply scattered waves illuminates additional structure, with particular improvement in imaging the underside of structures.

Alison Malcolm
MIT
amalcolm@mit.edu

Bjorn Ursin
Norwegian University of Science and Technology
bjorn.ursin@ntnu.no

Maarten V. de Hoop
Purdue University
mdehoop@purdue.edu

CP2

Poster Presentation and Open Discussion

Session Participants
.
.

CP2

Inverse Scattering Using Finite Elements and Gap Reciprocity

we consider the inverse scattering problem of determining the shape of one or more objects embedded in an inhomogeneous back-ground from Cauchy data measured on the boundary of a domain containing the objects in its interior. We use the reciprocity gap functional method. We provide analysis to support the method, and also describe implementation issues. Numerical examples are given showing the performance of the method.

Jiguang Sun
Dept. of Applied Mathematics and Theoretical Physics
Delaware State Univeristy
jsun@desu.edu

Peter B. Monk
Department of Mathematical Sciences
University of Delaware
monk@math.udel.edu

CP3

Faster Object Tracking Via "URV" Updates

Template tracking refers to the problem of tracking an object through a video sequence using a template. The aspect of template tracking that we are interested in is the problem of updating the template.The method of updating the template using both recent frames, to account for appearance changes, and also the initial template, to eliminate drift, was suggested by Matthew et. al. (The Template Update Problem). The update strategy proposed by Matthew et. al. requires computation of the principal components (PCs) of the augmented image matrix at every iteration; since the PCs correspond to the left singular vectors of image matrix ($m \times n$), we suggest using URV *updates* as an alternative to computing PCs *ab initio* at every iteration. Since updating the PCs has a complexity $O(mn)$ as opposed to $O(mn^2)$ complexity of computing the PCs from scratch, our method offers significant speed gains.

Jesse L. Barlow
Penn State University
Dept of Computer Science & Eng
barlow@cse.psu.edu

Anupama Chandrasekhar
Pennsylvania State University
anupama.psu@gmail.com

CP3

Fast Nonlocal Mean Filtering

In the recent years local and nonlocal adaptive filtering schemes have shown to produce surprisingly excellent results in image processing. The fundamental assumption for this success is the idea that a single image has enough redundant information to boost its signal to noise ratio. These new neighborhood methods are able to filter the noise away without destroying the underlying geometry. Following this trend, we present a denoising algorithm which is a rewriting of the recently proposed nonlocal mean filter. It builds on the decomposition property of neighborhood filtering to offer a fast parallel and vectorized implementation in contemporary shared memory computer architectures while reducing the theoretical computational complexity of the original filter. In practice, our approach is ten to hundred orders of magnitude faster (runs in milliseconds for medium sized images) than a serial, non–vectorized implementation and it scales linearly with the image size. We demonstrate our method in images obtained in cryomicroscopy which are typically extremely noisy, with signal to noise ratios much lower than one. We also apply it to high resolution MRI showing its capability to keep filament type structures which are very important in the assessment of diseases. We believe our approach brings nonlocal neighborhood filtering to a full realization making it truly practical for end users.

Alexandre Cunha
California Institute of Technology
cunha@caltech.edu

Jerome Darbon
UCLA
jerome@math.ucla.edu

Tony Chan
University of California. Los Angeles
chan@math.ucla.edu

Stanley J. Osher
University of California
Department of Mathematics
sjo@math.ucla.edu

CP3

Mumford-Shah Regularizer with Contextual Feedback

We present a simple and robust feature preserving image regularization by letting local region measures to modulate the diffusivity. The purpose of this modulation is to disambiguate low level cues in early vision. We interpret the Ambrosio-Tortorelli approximation of the Mumford-Shah model as a system with modulatory feedback and utilize this interpretation to integrate high level information into the regularization process.

Erkut Erdem
M.E.T.U.
Dept. of Computer Engineering
erkut@ceng.metu.edu.tr

Sibel Tari
Middle East Technical University
stari@metu.edu.tr

CP3

Nonlinear Subdivision for the Handling of Manifold Valued Data

Manifold valued data can be processed in a multiscale fashion using nonlinear subdivision schemes. We show how to define and analyze these multiscale transforms and how to encompass directionality into a nonlinear subdivision scheme, following a shearlet-inspired approach introduced by G. Kutyniok and T. Sauer for the linear case.

Philipp Grohs
TU Graz, Institute of Geometry
grohs@geometrie.tuwien.ac.at

CP3

A Nonlinear Structure Tensor with Diffusivity Matrix Composed of Image Gradient

We propose a nonlinear partial differential equation (PDE) for regularizing a tensor which contains the first derivative information of an image such as strength of edges and a direction of the gradient of the image. Unlike a typical diffusivity matrix which consists of derivatives of a tensor data, we propose a diffusivity matrix which consists of the tensor data itself, i.e., derivatives of an image. This allows directional smoothing for the tensor along edges which are not in the tensor but in the image. That is, a tensor in the proposed PDE is diffused fast along edges of an image but slowly across them. Since we have a regularized tensor which properly represents the first derivative information of an image, the tensor is useful to improve the quality of image denoising, image enhancement, corner detection, and ramp preserving denoising. We also prove the uniqueness and existence of solution to the proposed PDE.

Jooyoung Hahn
Department of Mathematical Sciences, KAIST
JooyoungHahn@kaist.ac.kr

Chang-Ock Lee
Department of Mathematical Sciences
KAIST
colee@kaist.edu

CP3

Image Restoration Using Bounded Variation and Sobolev Spaces of Negative Differentiability

We recover an unknown image from a blurry and noisy image f. We approach this problem by minimizing a regularized functional and finding solutions of the form u+v, where u is cartoon found in the space of bounded variation and v is texture found in a Sobolev space of negative differentiability so that we will not only recover an unknown image but also find a cartoon texture decomposition capturing more details in natural images.

Yunho Kim
Department of Mathematics
UCLA
yuno1123@math.ucla.edu

Luminita A. Vese
University of California, Los Angeles
Department of Mathematics
lvese@math.ucla.edu

CP3

Pde Based Image Compression in Real Time

We implement a image compression scheme based on image inpainting using different kinds of diffusion models. The arising PDEs are solved by an efficient multigrid solver in case of linear homogeneous diffusion and by a multilevel scheme applying inexact lagged diffusivity in case of nonlinear isotropic and anisotropic diffusion. We consider real world and medical data sets, and show that it is possible to decompress more than 25 frames per second of size 320x240 with a Cell processor.

Harald Koestler
University of Erlangen-Nuremberg
harald.koestler@informatik.uni-erlangen.de

CP3

Nonlocal Similarity Image Filtering

We exploit the recurrence of patches at different locations, orientations and scales in an image to perform denoising and interpolation. While previous methods based on "nonlocal filtering' identify corresponding patches only up to translations, we consider more general similarity transformations. Due to the additional computational burden, we break the problem down into two steps: First, we extract affine invariant descriptors at each pixel location; second, we search for similar patches by matching descriptors. The descriptors used are inspired by SIFT features, whereas the similarity search is solved via the minimization of a cost function adapted from local denoising methods. Our method compares favorably with existing denoising and interpolation algorithms as tested on several datasets.

Yifei Lou
University of California Los Angeles

yflou@math.ucla.edu

Paolo Favaro
Heriot-Watt University
Edinburgh, UK
p.favaro@hw.ac.uk

Stefano Soatto
UCLA
Computer Science Department
soatto@cs.ucla.edu

CP3
Poster Presentation and Open Discussion

Session Participants
.
.

CP3
Error Bound for Numerical Methods for the ROF Image Smoothing Model

The Rudin-Osher-Fatemi variational model has been extensively studied and used in image analysis. There have been several very successful numerical algorithms developed to compute the minimizer of the discrete version of the ROF energy. We study the convergence of solutions of discrete total variation models to the solution of the continuous model. We use the discrete ROF energy with a symmetric discrete TV operator and obtain an error bound between the minimizer for the discrete ROF model with a symmetric TV operator and the minimizer for the continuous ROF model.

Jingyue Wang, Bradley Lucier
Department of Mathematics
Purdue University
jwang@math.purdue.edu, lucier@math.purdue.edu

CP4
Identification of Velocity Fields for Geophysical Fluids from a Sequence of Images

We consider the assimilation of satellite images, within the framework of data assimilation in geophysical systems. Based on the constant brightness assumption, we define a nonlinear functional measuring the difference between two consecutive images, the first one being transported to the second one by the unknown velocity. By considering a multiscale approach and a Gauss-Newton minimization algorithm, we can estimate the entire velocity fields at a high frame rate and then assimilate these pseudo-observations.

Didier Auroux, Jérôme Fehrenbach
University of Toulouse
auroux@mip.ups-tlse.fr, fehren@mip.ups-tlse.fr

CP4
Parametric Estimation of Deforming Objects

We consider the problem of estimating the geometric deformation (rigid or elastic) of an object, with respect to some reference observation on it. Existing solutions, set in the standard coordinate system imposed by the measurement system, lead to high-dimensional, non-convex optimization problems. We propose a novel framework that employs a set of non-linear functionals to replace this originally high dimensional problem by an equivalent problem that is linear in the unknown transformation parameters. The proposed solution is unique and exact. It is applicable to any transformation regardless of its magnitude. Empirical results on estimating the location and orientation of a human head will be presented.

Rami R. Hagege
Ben Gurion Univesity - Beer Sheva Israel
hagege@ee.bgu.ac.il

Joseph Francos
Ben Gurion University
Electrical & Computer Engineering Department
francos@ee.bgu.ac.il

CP4
Monitoring Earth's Surface Dynamics with Optical Imagery

Despite the increasing availability of high quality optical satellite images, continuous monitoring of Earth's surface changes is still of limited use due to technical limitations. To overcome these limitations, we have devised a processing chain to accurately orthorectify and coregister sets of pushbroom images, which, associated with a precise correlation technique, allows for the measurement of ground deformations with accuracy on the order of 1/20 of the pixel size. Applications related to earthquake ground deformations, ice flow, landslides, and sand dune migration are presented.

Sebastien Leprince, Francois Ayoub
California Institute of Technology
leprincs@caltech.edu, fayoub@gps.caltech.edu

Etienne Berthier
CNRS-LEGOS, Toulouse, France
etienne.berthier@legos.obs-mip.fr

Pablo Muse
California Institute of Technology
muse@gps.caltech.edu

Christophe Delacourt
IUEM, Université de Bretagne Occidentale,
Plouzané, France
christophe.delacourt@univ-brest.fr

Jean-Philippe Avouac
California Institute of Technology
avouac@gps.caltech.edu

CP4
A Realtime Algorithm for the Identification and Measurement of Highly Irregular Elliptical Shapes

The proposed algorithm computes an approximation ellipse E_i which best fits to an irregular shape S_i with

$$\oint_{E_i} xdy - ydx = \oint_{S_i} xdy - ydx, \qquad i = 1, 2, 3, \ldots \quad (1)$$

by processing only the

$$1\times(b_{min}-1), 2\times(b_{min}-1), 3\times(b_{min}-1), \ldots, \left\lfloor \frac{ImageWidth}{b_{min}-1} \right\rfloor$$

vertical lines of the image, without loss of accuracy, where b_{min} parameter corresponds to the minimum semi-minor axis of the examinable ellipses. Furthermore, for achieving realtime results, various optimization techniques and an OLS statistical model are used. Concluding, a comparison takes place with the NASAs Goddard IDL program library for ellipse fitting.

Christos Liambas, Constantine Tsouros
Aristotle University of Thessaloniki
Christos.Liambas@gmail.com, tsouros@auth.gr

CP4

New Approach of Time-Frequency Analysis

Usually, one computes local frequency spectrum of a signal in a time interval and then makes analysis on this local spectrum. We propose a new approach in which, after computing the local spectrums in all intervals, the transform coefficients at the same frequency in all intervals are rearranged into one group. Then, make analysis on this group. Whole analysis goes on while frequency changes. Experiment results show new approach improves nearly 30% image compression performance.

Xiteng Liu
University of South Carolina
xiteng@yahoo.com

CP4

Poster Presentation and Open Discussion

Session Participants
.
.

CP4

Identification of Multiscale Aspects of Images with Applications to Turbulence

Mathematical aspects of a purely meshless method for identifying generalized level crossing scales from experimental laser images of multiscale flows are presented and demonstrated. We generalize the standard one-dimensional concept of level crossing scale to multidimensional fields by identifying the shortest distance from random locations, within a reference region, to the nearest level crossing locations. This approach is useful for purely meshless identification of generalized level crossing scales in multiscale images in various phenomena.

Jennifer Shockro, Aaron Freeman, Fazlul Zubair, Siarhei Piatrovich, Haris Catrakis
University of California, Irvine
jshockro@uci.edu, freemana@uci.edu, fazlul.zubair@gmail.com, siarheicka@gmail.com, catrakis@gmail.com

CP5

Noise Modeling and Pde-Based Denoising for Magnetic Resonance (mr) Imagery

The noise in magnetic resonance (MR) imagery has been described by the Rician distribution in the MR literature; however, none of PDE-based denoising models have addressed noise characteristics of MR images appropriately. This article introduces a new noise model and its corresponding PDE-based denoising algorithm for MR imagery. The new model can be implemented easily by adjusting the constraint term in conventional PDE-based models and turns out to improve effectiveness.

Aisha A. Alwehebi, Seongjai Kim
Department of Mathematics and Statistics
Mississippi State University
aaa92@msstate.edu, skim@math.msstate.edu

CP5

Identification of Nerves in Ultrasound Scans Using a Modified Mumford-Shah Model and Prior Information

Ultrasound scans have many important clinical applications in medical imaging, one of which is locating nerves. The goal of this paper is to acquire an efficient image segmentation algorithm which identifies nerves in ultrasound scans. A new region based variational model is proposed using a modified Mumford-Shah model and prior information based on the distance function. The preliminary numerical results with an application to healthy human neck ultrasound images show the effectiveness of the suggested algorithm.

Jung-Ha An
Mathematics Department
California State University, Stanislaus
jan@ima.umn.edu

Paul Bigeleisen
University of Pittsburg
bigeleisenpe@upmc.edu

Steven Damelin
Georgia Southern Unviersity
damelin@georgiasouthern.edu

CP5

Noise Removal and Structure Enhancement for Electron Tomography of Mitochondria

We review some recent progress in image enchancement aimed at improving mitochondrial images obtained from electron tomography. We propose: (*) an iterative method, based on the well established total variation (TV) approach to image processing, whereby we can obtain a good approximation to the true image, with minimum human intervention; (*) a new image smoothing and edge detection technique that employs a combination of nonlinear diffusion and bilateral filtering.

Peter Blomgren
San Diego State University
Department of Mathematics and Statistics
blomgren@terminus.sdsu.edu

Carlos Bazan
San Diego State University
Computational Science Research Center
carlos@carlosbazan.com

CP5

An Optimization Method for anterior vertebral body morphometry to enhance surgical devices

It is important to know the variability of shape of the anterior surface of vertebral bodies to ensure optimum congruence of surgical devices whilst minimising the stock sizes required. The surface of seventeen 5th Lumbar vertebrae were digitised and a hyperboloid surface model fitted to each. Statistical evaluation of the fitted parameters identified key aspects of morphological variability permitting a distractor device to be simplified. Acknowledgement: T Steffen, T Lussier, S Preston: McGill University, Canada

Francisco J. Casesnoves
Postgraduate Researcher Biomechanics Institute
The University of Nottingham, United Kingdom
francisco.casesnoves@gmail.com

CP5
Regularized Tissue Quantification from Incomplete Mri Data

Tissue fractions can be recovered from MRI images using the Moore-Penrose pseudo-inverse. Acquiring sufficiently many source images may be too time consuming for some applications. We show how tissue fractions can be recovered from partial k-space data, collected in a fraction of the time required for full images. We show how to regularize the inverse problem, to save time and improve quality. Numerical experiments predict 40% sample time and 60% noise reductions.

Mehrdad Mozafari
Computing and Software, McMaster University
mozafam@mcmaster.ca

Christopher Anand
McMaster University
anandc@mcmaster.ca

CP5
Characterization of Multi-Fiber Tissues for Diffusion Mri

With the development of diffusion magnetic resonance imaging (MRI) method such as high angular resolution diffusion imaging (HARDI), q-Ball imaging (QBI), more detailed tissue information can be achieved through the signal intensity data, especially in multiple fiber crossing cases. The talk will focus on the analysis of diffusion MRI data, and the algorithm of characterization of tissues with single or multiple crossing fibers from clinical data with noise, which could be applied on fiber orientation detection and reconstruction.

Yunmei Chen
University of Florida
yun@math.ufl.edu

Yuyuan Ouyang
Department of Mathematics, University of Florida
ouyang@math.ufl.edu

CP5
Poster Presentation and Open Discussion

Session Participants
.
.

CP5
An Iterative Active Contour Algorithm Applied to Heart Segmentation

A variant of the Chan-Vese model for image segmentation is used for heart segmentation. Our variant is based on a L^1–fidelity term and an iterative segmentation process. The iterative segmentation is an efficient alternative to the usual multiphase segmentation for identifying N regions and L^1–fidelity allows to segment in fewer steps. We will present 2D and 3D segmentations of the heart from CT images, and meshes generated from the segmentations.

Olivier Rousseau, Yves Bourgault
University of Ottawa
orous097@uottawa.ca, ybourg@uottawa.ca

CP5
Self-calibrating MIMO Reconstruction in Multichannel MRI

Self-calibrating reconstruction techniques for multichannel MRI such as GRAPPA aim to recover the full data for each channel from uniformly subsampled measurements. However, current schemes are heuristic and lack performance estimates. Formulating the problem as multiple-input multiple-output (MIMO) interpolation in shift-invariant spaces, we specify conditions satisfied by a distortion-free MIMO interpolator without prior knowledge of the channel transfer functions (so-called sensitivity maps). For practical implementation, we compute a finite-impulse-response approximation to the optimum MIMO interpolator.

Behzad Sharif
Univ of Illinois, Urbana-Champaign
ECE Dept, Coordinated Science Lab
sharif@uiuc.edu

Yoram Bresler
Univ of Ill @ Urbana-Champaign
Coordinated Science Laboratory
ybresler@uiuc.edu

MS1
Sparse Approximations in Image Processing

The search for the "best basis" (or even good enough) in which to approximate, to denoise, or, more generally, to analyze images has led to a flurry of activity in the construction of orthonormal, bi-orthogonal, and finally, redundant or overcomplete dictionaries. With these constructions, came heuristic algorithms for how best to use them in the nonlinear approximation and analysis of images. We will survey the combined efforts of the engineering, statistics, mathematics, and computer science communities to put these heuristics on solid theoretical footing, as well as their performance in practice. The final part of the tutorial will show how a number of these techniques are used in compressed sensing.

Anna Gilbert
Department of Mathematics
University of Michigan
annacg@umich.edu

MS2
Global and Approximate Optimization of Markov

Random Fields

I'll present some sufficient and necessary conditions for the applicability a maximum-flow approach ("graph-cuts") for the optimization of Markov Random Fields with pairwise interactions. Then I'll describe an approximation algorithm for the special case of the Total Variation with quasi-convex data fidelity terms with applications for Synthetic Aperture Radar Image Restoration. This is a joint work with L. Denis, M. Sigelle and F. Tupin.

Jerome Darbon
Mathematics
UCLA
jerome@math.ucla.edu

MS2
Analogue of the Total Variation Model in the Context of Geometry Processing

We propose a new variational model for surface processing. It is the natural analogue, in the context of geometry processing, of the total variation based image denoising model of Rudin, Osher, and Fatemi. In particular, it admits as solutions surfaces that may have discontinuities in their normals, and can reconstruct shapes with sharp ridges and corners. As the analogue of a perfectly well-posed image model, the proposed surface model differs from those based on ill-posed equations of image processing. Since the proposed geometry regularization is variational, it can be incorporated into a variety of applications, such as surface fairing, 3D object reconstruction from multiple viewpoints, or shape optimization. On the other hand, the numerical minimization of the proposed model seems to be challenging. Drawing on important previous work of geometers who were interested in extending certain classical theorems from smooth to polyhedral manifolds, we describe in detail a preliminary numerical implementation for the proposed model in the case of triangulated surfaces. Joint work with Matthew Elsey.

Selim Esedoglu
Department of Mathematics
University of Michigan
esedoglu@umich.edu

MS2
Efficient Reconstruction of Piecewise Constant Images Using Nonsmooth Nonconvexminimization

We consider the restoration of piecewise constant images where the number of the regions and their values are not fixed in advance, with a good difference of piecewise constant values between neighboring regions, from noisy data obtained at the output of a linear operator (e.g. a blurring kernel or a Radon transform). Thus we also address the generic problem of unsupervised segmentation in the context of linear inverse problems. The segmentation and the restoration tasks are solved jointly by minimizing an objective function (an energy) composed of a quadratic data-fidelity term and a nonsmooth nonconvex regularization term. The pertinence of such an energy is ensured by the analytical properties of its minimizers. However its practical interest used to be limited by the difficulty of the computational stage which requires a nonsmooth nonconvex minimization. Indeed, the existing methods are unsatisfactory since they (implicitly or explicitly) involve a smooth approximation of the regularization term and often get stuck in shallow local minima. The goal of this paper is to design a method that efficiently handles the nonsmooth nonconvex minimization. More precisely, we propose a continuation method where one tracks the minimizers along a sequence of approximate nonsmooth energies $\{J_\epsilon\}$ the first of which being strictly convex and the last one the original energy to minimize. Knowing the importance of the nonsmoothness of the regularization term for the segmentation task, each J_ϵ is nonsmooth and is expressed as the sum of an ℓ_1 regularization term and a smooth nonconvex function. Furthermore, the local minimization of each J_ϵ is reformulated as the minimization of a smooth function subject to a set of linear constraints. The latter problem is solved by the modified primal-dual interior point method which guarantees the descent direction at each step. Experimental results are presented and show the effectiveness and the efficiency of the proposed method. Comparison with simulated annealing methods further show the advantage of our method.

Michael Ng
Hong Kong Baptist University
Department of Mathematics
mng@math.hkbu.edu.hk

Mila Nikolova
Centre de Mathématiques et de Leurs Applications (CMLA)
ENS de Cachan, CNRS
nikolova@cmla.ens-cachan.fr

MS2
Stochastic Continuation. Opening New Horizons to Solving Difficult Optimization Problems

We introduce a new class of hybrid algorithms which combines the theoretical advantages of simulated annealing (SA) with the practical advantages of deterministic continuation. We call this class of algorithms stochastic continuation (SC). SC inherits the finite-time convergence properties of generalized SA under fairly mild assumptions, and it can be successfully applied to inverse problems involving challenging optimization tasks. Our numerical experiments about piecewise constant signal reconstruction indicate that SC substantially outperforms SA.

Marc C. Robini, Isabelle Magnin
CREATIS
INSA Lyon
marc.robini@creatis.insa-lyon.fr,
isabelle.magnin@creatis.insa-lyon.fr

MS3
Overcomplete Dictionary Design based on Empirical Risk Minimization

In this study, we present a new approach for dictionary learning. The central idea is based on minimization of the empirical risk, given some training models. We present a mathematical formulation and an algorithmic framework to achieve this goal. The proposed framework offers incorporation of non-injective and nonlinear operators, which allows the data and the recovered parameters to reside in different spaces. We test our algorithm and show that it yields optimal dictionaries for diverse problems.

Lior Horesh
Department of Mathematics
Emory University
horesh@mathcs.emory.edu

Eldad Haber
Emory University
Dept of Math and CS
haber@mathcs.emory.edu

MS3
Learning Dictionaries for Sparse Independent Vector Analysis (shiva)

We consider the problem of learning overcomplete dictionaries over spaces having independence between subspaces, each with dimension generally greater than one. Projecting a signal onto the subspaces yields component vectors that are statistically independent of each other while having dependent components. Multivariate generalized Gaussian scale mixtures are used to model the statistical properties of the subspaces. An EM algorithm is derived to update the density location and scale parameters, while MAP and Variational Bayes algorithms are used to update the dictionary.

Ken Kreutz-Delgado
Electrical and Computer Engineering
University of California, San Diego
kreutz@bali-1.ucsd.edu

Jason Palmer
ECE Dept. & Swartz Center for Computational Neuroscience
University of California, San Diego
japalmer@ucsd.edu

MS3
Overcomplete Dictionary Design Using Matching Pursuit and Restricted Coding

We present an algorithm for learning overcomplete dictionaries which are capable of representing image or other data succinctly using a sparse set of elements. Typically, sparse code vectors are unconstrained or non-negative. However, in many applications it is desirable to have bounded signal representations, and our algorithm allows such bounds, e.g. $[0, 1]$, even approaching the binary case, with accuracy comparable to non-negative coding. Computational efficiency is achieved by using matching pursuit for sparse coding.

Joseph Murray
Brain and Cognitive Sciences
MIT
murrayjf@mit.edu

MS3
Dictionary Design Using Sparse Bayesian Learning

Given a fixed dictionary of features, sparse Bayesian learning offers a powerful means of finding sparse representations that naturally extends to handle constraints such as non-negativity or bounded activation. SBL can also be supplemented with simple update rules for re-estimating the features, which makes it an attractive candidate for dictionary design. This leads to a principled, noisy version of sparse component analysis. Additionally, this process can be leveraged to efficiently learn sparse orthogonal transforms.

David Wipf
Biomagnetic Imaging Lab
University of California, San Francisco
david.wipf@mrsc.ucsf.edu

MS4
Decoding Brain Activity in Natural Environments

Very recently, fMRI has been used to infer subjective experience and brain states of subjects immersed in natural environments. These environments are rich with uncontrolled stimuli and resemble real life experiences. Conventional methods of analysis of neuroimaging data fail to unravel the complex activity that natural environments elicit. We describe a new method that yields a low dimensional embedding of the fMRI data. The embedding provides a representation of the cognitive activity. We learn a set of time series that are implicit functions of the cognitive activity, and we predict the values of these times series in the future from the knowledge of the fMRI data only. We present experiments conducted with the datasets of the 2007 Pittsburgh Brain Activity Interpretation Competition.

Francois G. Meyer
University of Colorado
USA
fmeyer@colorado.edu

MS4
Computational Models of Biological Shapes

We present novel computational models of multi-dimensional elastic shapes developed within the framework of Riemannian geometry and discuss various applications to the analysis and visualization of biological shapes, in particular, the anatomy of the human brain. We construct shape spaces equipped with Riemannian structures that encode the resistance offered by a shape to infinitesimal deformations by stretching and bending. Global shape dissimilarities are quantified by geodesic distances and geodesic deformation fields allow us to develop localization tools to identify the regions where the most significant morphological differences occur. Geodesic interpolations enable us to visualize shape deformations and can be used in conjunction with the shape metric in the construction of mean shapes and anatomical atlases of the human brain. Among other applications, an atlas provides a common domain for the comparison of structural and functional data associated with different subjects. The Riemannian framework also allows us to develop stochastic models of shapes from observations, for example, to model normal anatomical variations, as characterized in a control group. We conclude with several illustrations, comparisons with a simpler model based on Sobolev metrics, and a discussion of future work.

Washington Mio
Department of Mathematics
Florida State University
mio@math.fsu.edu

MS4
Parallel Elastic Registration using Octrees

Image registration is a challenging problem for several reasons: the choice of the image similarity functional, the regularization, and the numerical solution of the chosen formulation. Here, we are interested in numerical algorithms for variational image registration. As a model problem, we consider 3D L^2 elastically-regularized registration. This is a nonlinear non-convex variational problem. We present a multigrid algorithm that can be applied to several other types of variational image registration formulations. In particular, we use two classical approaches in numerical PDEs: (a) Multigrid and (b) Adaptivity. In addition, we propose massively parallel algorithms for those problems. The proposed approach enables us to co-register high-resolution images. In general, adaptive techniques are complicated and incur large overheads. However, we show that octrees could be a perfect balance between flexibility and simplicity. We recently introduced a parallel geometric multigrid algorithm for finite elements on octree meshes that has scaled to billions of elements on thousands of processors.

George Biros
University of Pennsylvania
biros@seas.upenn.edu

Rahul Sampath
Mechanical Engineering
Univeristy of Pennsylvania
rahulss@seas.upenn.edu

MS4

Hippocampal Mapping with Intrinsic Surface Geometry

In this work we present a mapping algorithm for hippocampal surfaces based on the spectrum of the Laplacian-Beltrami operator. Using the eigen-functions of the Laplace-Beltrami operator, our algorithm automatically detects a set of landmark curves that are stable across population on hippocampal surfaces. After that, the map between surfaces is computed by minimizing the harmonic energy with these landmark curves as the boundary condition.

Yonggang Shi
LONI, CCB
UCLA School of Medicine
yshi@loni.ucla.edu

Paul M. Thompson
Department of Neurology
UCLA School of Medicine
thompson@loni.ucla.edu

Ivo D. Dinov
UCLA
Center for Computational Biology
ivo.dinov@loni.ucla.edu

Arthur Toga
UCLA
Laboratory of Neuro Imaging
toga@loni.ucla.edu

MS5

Three Dimensional Denoising and Detection in LIDAR Data

A recent advance in imaging technology is Flash lidar 3-D cameras.There are several primary choices when it comes to the selection of ways to process this type of three-dimensional data. We will discuss the data, along with several detection and denoising algorithms.

Frank Crosby
Naval Surface Warfare Center
Panama City
frank.crosby@navy.mil

MS5

Sonar Image Enhancement and Classification

The objective of the project is to develop enhancement and classification algorithms for sonar image. We present a MMSE Super-Resolution for Sonar Image Enhancement, which uses minimum mean squared error reconstruction filters to obtain a super resolved sonar image. We also discuss the MCM Classification using a classifier cascade to improve performance for classification of sonar image data.

Ryan Prendergast, Dung Vo, Sunhyoung Han, Nuno Vasconcelos
UCSD
rprender@ucsd.edu, d3vo@ucsd.edu, s1han@ucsd.edu, nuno@ece.ucsd.edu

Truong Nguyen
ECE, UCSD
nguyent@ece.ucsd.edu

MS5

Classification of Underwater Objects Using Synthetic Aperture Sonar Images and Waveforms

We discuss a new method to classify underwater objects using both underwater scenery images obtained by the Synthetic Aperture Sonar (SAS) system and its raw waveforms. Classification of objects solely using the SAS images is misleading due to the shape ambiguity. On the other hand, the raw sonar waveforms contain physical property of the object. Our proposed classification method combines the image-based information as well as time-frequency features of the raw sonar waveforms.

Naoki Saito, Bradley Marchand, Linh Lieu
Department of Mathematics
University of California, Davis
saito@math.ucdavis.edu, bmarchand@math.ucdavis.edu, llieu@math.ucdavis.edu

MS5

Synthesis of Pulse Waveforms with Optimal Correlation Functions

We introduce a method for the synthesis of pulse waveforms for synthetic aperture imaging with multiple transmitters. The pulses satisfy given time-bandwidth constraints, have narrow auto-correlation functions, and have neglegible cross-correlation functions for all lags. We leverage the simultaneous energy concentration property of the prolate spheroidal wave functions in order to ensure small pairwise cross-correlations, and develop an iterative algorithm that enforces the desired auto-correlation function on the resulting pulses. Numerical results are reported; significant improvements in correlation properties over that of commonly used waveforms are presented.

Ritesh Sood
UC Davis
rsood@ucdavis.edu

Hong Xiao
University of California at Davis
hxiao@ucdavis.edu

MS6

A Discriminative Approach for Transform Based Restoration

This work suggests a discriminative approach for wavelet denoising where a set of shrinkage functions (SFs) are designed to perform optimally (in a MSE sense) with respect to a given set of images. Using the suggested scheme a new set of SFs are generated which are shown to be different from the traditional soft/hard thresholding in the overcomplete case. These SFs are demonstrated to obtain the state-of-the-art denoising performance. As opposed to the descriptive approaches modeling image or noise priors are not required here and the SFs are learned directly from the example set. Thus, the framework enables the shrinkage operation to be customized seamlessly to a new set of restoration problems, such as: image de-blurring, JPEG artifacts removal, and different types of additive noise.

Yacov Hel-Or
School of Computer Science
The Interdisciplinary Center, Israel
toky@idc.ac.il

Doron Shaked
HP Labs Israel
doron.shaked@hp.com

MS6

Image Super-Resolution via Sparse Representation

In this talk, we address the problem of generating a super-resolution (SR) image from a single low-resolution input image. We approach this problem from the perspective of compressed sensing. The low-resolution image is viewed as downsampled version of a high-resolution image, whose patches are assumed to have a sparse representation with respect to an over-complete dictionary of prototype signal-atoms. The principle of compressed sensing ensures that under mild conditions, the sparse representation can be correctly recovered from the downsampled signal. We will demonstrate the effectiveness of sparsity as a prior for regularizing the otherwise ill-posed super-resolution problem. We further show that a small set of randomly chosen raw patches from training images of similar statistical nature to the input image generally serve as a good dictionary, in the sense that the computed representation is sparse and the recovered high-resolution image is competitive or even superior in quality to images produced by other SR methods.

Jianchao Yang, John Wright, Yi Ma
Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign
jyang29@uiuc.edu, jnwright@uiuc.edu, yima@uiuc.edu

MS6

Multidimensional Kernel Regression for Video Processing and Reconstruction

We introduce a novel framework for adaptive enhancement and upscaling of videos containing complex activities based on multidimensional kernel regression. In this framework, each pixel in the video sequence is approximated with a 3-D local (Taylor) series, capturing the essential local behavior of its spatio-temporal neighborhood. The coefficients of this series are estimated by solving a local weighted least-squares problem, where the weights are a function of the 3-D space-time orientation in the neighborhood. As this framework is fundamentally based upon the comparison of neighboring pixels in both space and time, it implicitly contains information about the local motion of the pixels across time. The proposed approach not only significantly widens the applicability of super-resolution methods to a broad variety of video sequences containing complex motions, but also yields improved overall performance.

Hiroyuki Takeda
UC Santa Cruz
htakeda@soe.ucsc.edu

Peyman Milanfar
Electrical Engineering
UC Sant Cruz
milanfar@ee.ucsc.edu

Matan Protter
The CS depoartment
The Technion, Israel
matanpr@cs.technion.ac.il

Michael Elad
Computer Science Department
Technion
elad@cs.Technion.AC.IL

Peter van Beek
Sharp Labs of America
pvanbeek@sharplabs.com

MS6

Image Processing with Manifold Models

In this talk I will study the manifold structure of sets of patches extracted from natural images. The local manifold constraint is chained into a global one since the whole image traces a smooth surface on the features manifold. We detail this manifold structure for various ensembles suitable for natural images and textures modeling. These manifolds offer a low-dimensional parameterization of geometric patterns that can be found in such datasets. One can use these manifold models in order to regularize inverse problems in signal and image processing. In this framework, one searches for a smooth surface traced on the feature manifold that matches the forward measurements. In the discrete setting, the manifold can be either known analytically or estimated from exemplars using a graph structure. Numerical simulations on inpainting and compressive sampling inversion show how such manifolds models bring an improvement for datasets with geometrical features.

Gabriel Peyre
CEREMADE
gabriel.peyre@ceremade.dauphine.fr

MS6

Learning to Classify

Sparse signal models have been the focus of much recent research, leading to (or improving upon) state-of-the-art results in signal, image, and video restoration. This work extends this line of research into a novel framework for image discrimination tasks, proposing energy formulations with both sparse reconstruction and class discrimination components, jointly optimized during dictionary learning. We present the mathematical and computational frameworks and provide some examples for texture segmentation, digit recognition, and scene classification. The work is joint with J. Mairal, F. Bach, J. Ponce, A. Zisserman (partially reported at CVPR '08), and some contributions from F. Rodriguez as well.

Guillermo Sapiro
University of Minnesota
Dept Electrical & Computer Engineering
guille@umn.edu

MS7

Recent Developments on the Qualitative Methods in Inverse Electromagnetic Scattering Theory

Inverse scattering theory has been a particularly active area in applied mathematics for the past twenty five years. The aim of research in this field has been to not only detect but also to identify unknown objects through the use of acoustic, electromagnetic or elastic waves. Mathematically, such problems lead to nonlinear and severely ill-posed equations. Until a few years ago, essentially all existing algorithms for target identification were based on either a weak scattering approximation or on the use of nonlinear optimization techniques. In recent years alternative methods for imaging have been developed which avoid incorrect model assumptions inherent in weak scattering approximations and, as oppose to nonlinear optimization techniques, do not require a priori information. Such methods come under the general title of qualitative methods in inverse scattering theory. This lecture will provide a review of the state of art of qualitative methods in inverse electromagnetic scattering theory. Numerical examples showing the practicality of these approaches to the problem of target identification will be given and finally some related open problems will be discussed.

Fioralba Cakoni
University of Delaware
cakoni@math.udel.edu

MS7

Edge Illumination and Imaging of Extended Reflectors

We use the singular value decomposition of the array response matrix to image selectively the edges of extended reflectors in a homogeneous medium. We show with numerical simulations in an ultrasound regime, and analytically in the Fraunhofer diffraction regime, that information about the edges is contained in the singular vectors for singular values that are intermediate between the large ones and zero. Our results confirm well-known experimental observations on the rank of the response matrix.

Fernando Guevara Vasquez
University of Utah
fguevara@math.utah.edu

Liliana Borcea
Rice University
Dept Computational & Appl Math
borcea@caam.rice.edu

George C. Papanicolaou
Stanford University
Department of Mathematics
papanico@math.stanford.edu

MS7

Distributed Sensor Imaging

A multi-step adaptive algorithm for imaging with distributed sensor networks is presented. The sensors record the impulse response of the unknown background medium with and without the scatterers to be imaged. The signal difference is used to image the scatterers with a three step algorithm. First, the decoherence frequency is estimated using adaptive coherent interferometry (CINT), with uniform illumination. CINT is a smoothed and stable form of travel-time migration, and performs well in an unknown complex background. Second, the CINT images are optimized with a selective subspace algorithm based on the singular value decomposition. Third, the strength of the illumination by the sensors is optimized. The algorithm is explored with numerical simulation in 2D, in a region with many background scatterers.

George C. Papanicolaou
Stanford University
Department of Mathematics
papanico@math.stanford.edu

MS7

Some Estimates for the Helmholtz Equation that commute with Dilations and Translations

In 1975, Agmon introduced weighted L^2 estimates for the Schroedinger (Helmholtz) equation to study scattering and spectral theory. These estimates are rotationally invariant and very general. However, they do not scale as simply as the underlying Helmholtz equation. We give up the generality and the rotational symmetry, and instead prove estimates that depend on a choice of basis for $\mathbf{R}^n$, but use only L^p type norms without weights. The new estimates scale correctly under dilations and are translation invariant.

John Sylvester
Department of Mathematics
University of Washington
sylvest@u.washington.edu

MS7

Selective Array Imaging of Cracks in Random Media

We consider selective array imaging of cracks embedded in random media. It was shown recently that information about the edges of extended scatterers is contained in the singular vectors of the response matrix corresponding to singular values that are in the transition zone between the large ones and zero. Using this information the edges of extended objects can be imaged selectively. Here we apply this idea on selectively imaging the tips of cracks. The imaging method used is coherent interferometry that allows for statistically stable imaging in random media.

Chrysoula Tsogka
University of Crete and FORTH-IACM
University of Crete
tsogka@tem.uoc.gr

MS8

Topological Issues in Image Analysis: An Overview

This talk surveys some basic image analysis techniques benefiting from the use of topology. We discuss how topology is used successfully to address problems in imaging. We present topology-based methods for image enhancement, segmentation, and shape representation. Topology can be integrated as a constraint in any image analysis technique to force it to respect the topology. However, this poses a problem since imaging techniques operate at local level while topology is a global property.

Madjid Allili
Bishop's University
Sherbrooke, Canada
mallili@ubishops.ca

MS8

Fast Homology Algorithms with Applications to Image Analysis

Topological methods in image analysis in particular require very effficient homology algorithms. The classical homology algorithm with its O(n3) complexity is far too slow for the amount of data which needs to be processed in image analysis. In the talk some new homology algorithms will be presented together with experimental results and some theoretical estimates which indicate that these algorithms are much faster than other available algorithms. The talk will be concluded with examples of applications to image analysis in which the new algorithms have been successfully applied.

Marian Mrozek
Jagiellonian University, Krakow, Poland
marian.mrozek@uj.edu.pl

MS8

Topological Features for Image Segmentation

We describe a general framework for detecting topological features in static or time-dependent images based on the concept of contour tree. As an application, we demonstrate how it can be used to segment tubular organs such as airway trees or blood vessels from medical images. We also discuss other applications such as detection of certain types of contour behaviors in time-dependent data.

Andrzej Szymczak
Colorado School of Mines
Golden, CO, USA
aszymcza@mines.edu

MS8

Counting Branching Points in Images

The method of counting branches in linear structures will be presented. This method is based on cubical homology algorithms which can estimate the number of branches and their locations. As an application we present counting vessel branches in endoscopic pictures of colon mucosa. This is helpful in detecting some kinds of pathologies (colitis, polyps, vessel malformation, cancer). The proposed idea can be easily extended to three and higher-dimensional images, for example to analyze the structure of collagen fibers.

Marcin Zelawski
Jagiellonian University
Krakow, Poland
marcinz@dmt.com.pl

MS8

On the Local Behavior of Spaces of Natural Images

In this study we concentrate on qualitative topological analysis of the local behavior of the space of natural images. To this end, we use a space of 3 by 3 high-contrast patches $\mathcal{M}$ studied by Mumford et al. We develop a theoretical model for the high-density 2-dimensional submanifold of $\mathcal{M}$ showing that it has the topology of the Klein bottle. Using our topological software package *PLEX*, we experimentally verify our theoretical conclusions. We use polynomial representations to parameterize various subspaces of $\mathcal{M}$. We find the best-fitting embedding of the Klein bottle into the ambient space of $\mathcal{M}$. Our results are currently being used in developing a compression algorithm based on a Klein bottle dictionary.

Afra Zomorodian
Dartmouth College
Hanover, NH, USA
afra@cs.dartmouth.edu

MS9

Nonconvex Compressive Sensing

We will examine theoretical and numerical results demonstrating that replacing the convex optimization problems of compressive sensing with nonconvex ones allows sparse signals to be reconstructed from many fewer measurements. Surprisingly, very simple algorithms are able to reconstruct signals successfully, despite the huge numbers of local minima. We will see striking examples of the recovery performance of these algorithms under a variety of circumstances, and discuss the state of the underlying theory.

Rick Chartrand
Los Alamos National Laboratory
rickc@lanl.gov

MS9

Fast Discrete Optimizations for Sparse Approximations

Fast algorithms for total variation minimization and related variational problems have recently been developed. These methods involve reducing the problems to a set of independent binary models and solving, using efficient graph-cut based algorithms. This has led to remarkably fast algorithms for TV based denoising (Rudin-Osher-Fatemi) and other related problems. In this work we extend the scope of these fast algorithms to TV based sparse representation. This is a joint work with Stanley Osher (UCLA).

Jerome Darbon
Mathematics
UCLA
jerome@math.ucla.edu

MS9

Semismooth Newton and Active Set Methods for Sparse Reconstruction

The problem of sparse reconstruction by Basis Pursuit is equivalent to regularization of inverse problems with sparsity constraints. We will shortly describe regularizing properties and then employ a semismooth version of Newton's method to solve the related non-smooth minimization problem. This algorithm can be formulated as an active set method and we prove its local superlinear convergence. Besides this local result, the algorithm is—in some cases—robust to the initial value. Moreover, we discuss globalization strategies of the algorithms.

Dirk Lorenz
Center for Industrial Mathematics
University of Bremen
dlorenz@math.uni-bremen.de

Roland Griesse
Technical University Chemnitz
roland.griesse@mathematik.tu-chemnitz.de

MS9

Separable Approximation for Sparse Reconstruction

We discuss practical algorithms for large scale unconstrained optimization problems in which the objective consists of a smooth data-fitting term added to a regularization term, which is often nonsmooth and separable. We discuss several applications of the method, highlighting why it is particularly effective on compressed sensing problems.

Stephen J. Wright
University of Wisconsin
Dept. of Computer Sciences
swright@cs.wisc.edu

Mario T. Figueiredo
Instituto Superior Tecnico
Instituto de Telecomunicacoes
mario.a.t.figueiredo@gmail.com

Robert Nowak
University of Wisconsin
Electrical and Computer Engineering
nowak@ece.wisc.edu

MS10

Frame Potential and Wiener Amalgam Penalty Criteria for Classification

Experiments to compare spectral signatures illustrate that different classes are almost never orthogonal at the level of given data, whereas eigenmap methods provide processed orthogonal decompositions. For given data and kernel, we present an alternative to eigenmap methods. This alternative is a mathematical model to provide classification as well as noise reduction and numerical stability in the process. The non-orthogonal nature of regions and substances in classification leads to the use of frames. The construction of sparse representation frames by Wiener amalgam norms to replace eigenmap methods is accomplished through frame potential energy algorithms. Substantive numerical comparison between this method and existing procedures must be preceded by numerical progress for all methodologies.

John J. Benedetto, Wojtek Czaja, Matthew Hirn, Ioannis Konstantinidis, David Widemann
University of Maryland
College Park
jjb@math.umd.edu, wojtek@math.umd.edu, hirn@math.umd.edu, ixk@math.umd.edu, widemann@math.umd.edu

MS10

Segmentation and Inpainting Algorithms for Hyperspectral Data

Hyperspectral imagery (HSI) refers to data in the form of coregistered images of a scene, sampled at a multitude of frequencies of the electromagnetic spectrum. Such images are acquired by remote sensing operations and thus are typically two dimensional in space with up to several hundred bands in the spectral range. We discuss some of the challenges in dealing with hyperspectral imagery and how some ideas from variational based image processing can be used for basic applications related to HSI. We also discuss problems where variational methods may be time consuming and propose alternative solutions.

Andrea L. Bertozzi
UCLA Department of Mathematics
bertozzi@math.ucla.edu

MS10

Dimension Reduction and Analysis of High Dimensional Data

Recent innovations in commercial sensor technology such as hyperspectral and LIDAR systems have led to significant spatial and spectral resolution improvements thus providing the potential to analyze and exploit information in more effective ways. This talk discusses data-organizational techniques designed to facilitate the analysis and exploitation of high dimensional data and concludes with a discussion on future research direction for these problems.

Edward H. Bosch
NGA
bosche@nga.mil

MS10

Compression and Processing of Geospatial Data

We will discuss a geometry preserving image compression algorithm and its applications to path planning, line-of-sight and denoising of DTED data

Stanley Osher
Level Set Systems
ilevels310@earthlink.net

MS11

Selecting Good Fourier Measurements for Compressed Sensing

We consider the problem of constructing good Fourier compressed sensing matrices by selecting rows of the DFT matrix. While random selection produces good matrices with high probability, particular selections can result in failure to recover certain sparse signals. Using efficiently computable bounds on the admissible signal sparsity for a given sensing matrix, we propose a method to find universally good deterministic Fourier compressed sensing matrices, without compromising average performance.

Kiryung Lee
University of Illinois at Urbana-Champaign
klee81@uiuc.edu

Yoram Bresler
Univ of Ill @ Urbana-Champaign
Coordinated Science Laboratory
ybresler@uiuc.edu

MS11

Sparse Sampling and Exact Reconstruction of Signal Innovations: Theory, Algorithms and Applications

Consider the problem of sampling signals which are not bandlimited, but still have a finite number of degrees of freedom per unit of time, such as, for example, piecewise polynomial or piecewise sinusoidal signals, and call the number of degrees of freedom per unit of time the rate of innovation. Classical sampling theory does not enable a perfect reconstruction of such signals since they are not bandlimited. In this talk, we show that many signals with finite rate of innovation can be sampled and perfectly reconstructed using a rich variety of sampling kernels and fast reconstruction algorithms. The class of kernels that can be used includes functions satisfying Strang-Fix conditions, Exponential Splines, functions with rational Fourier transform and the sinc or Gaussian functions. Retrieval of such signals in noise is also considered. Lower bounds by Cramer-Rao are given, and an iterative algorithm due to Cadzow is shown to perform close to optimal over a wide range of signal to noise ratios. This indicates the robustness of the proposed methodologies. Finally, applications of such methods to image super-resolution and distributed video compression are presented.

Pier Luigi Dragotti
Imperial College
p.dragotti@imperial.ac.uk

Varit Chaisinthop
Imperial College London
varit.chaisinthop@imperial.ac.uk

MS11

Analog and Digital Sparse Approximation with Applications to Compressed Sensing

In the compressed sensing (CS) framework, the sampling phase is resource constrained, taking a small number of linear samples. However, the price paid for this simplicity is a computationally expensive reconstruction algorithm that forms a bottleneck in using the sensed data. We will present a sparse approximation framework that both unifies many of the recently proposed digital algorithms and introduces novel analog architectures that solve the same problems. We will demonstrate how these analog systems solve CS recovery problems orders of magnitude faster than current digital systems, at speeds limited only by the underlying hardware components.

Chris Rozell
Georgia Institute of Technology
crozell@ece.gatech.edu

MS11

Advances in Compressed Sensing for MRI

Recent developments in Compressive Sensing (CS) theory offer the potential for significant advances in diagnostic medical imaging, and especially magnetic resonance imaging (MRI). Here, we review some of the key works on the application of CS theory and its extensions to both single and multi-coil or parallel MR imaging and discuss practical benefits such as improved patient comfort, reduced susceptibility to physiological motion, and increased clinical throughput.

Joshua D. Trzasko
Mayo Clinic
trzasko.joshua@mayo.edu

MS12

Inverse Consistent Non-Rigid Image Registration in Radiation Therapy

We propose a inverse consistent deformable image registration model, which is applicable in imaging guided radiation therapy. This model minimizes two energy functionals coupled by a natural inverse consistent constraint. The energy functionals for forward and backward deformation fields are based on their smoothness measures and statistics of the source and target images. The AOS scheme and multi-resolution method are used to speed up the computation. The experimental results on synthetic images, and volumetric CT and MRI data indicate the improvement of the proposed model in robustness, accuracy and inverse consistency.

Yunmei Chen
University of Florida
yun@math.ufl.edu

Qingguo Zeng
PHD student at Department of Mathematics,
University of Florida
qingguo@math.ufl.edu

MS12

Image Super-resolution by Total Variation Regularization

We present a time-dependent convolutional model for super-resolution based on a constrained minimization of the total variation norm. The constraints consist of a set of linear integral equations relating the high resolution scale to the low resolution one through a convolution operator and a down-sampling operator. We propose an explicit algorithm and a Bregman iterative refinement procedure to improve spatial resolution. Numerical results include super-resolution of MRI data sets indicating good behavior of the algorithm.

Antonio Marquina
University of Valencia, Spain
marquina@math.ucla.edu

MS12

Direct Quantification of Three-dimensional Strain in the Heart Using zHARP

Magnetic resonance tagging has long been used to measure motion and estimate strain in moving tissues, particularly the heart. Until now, it has been necessary to use orthogonal images – e.g., short-axis and long-axis – and interpolating kernels between relatively sparse data. This talk describes a new approach to measuring 3D strain tensors from a single slice orientation without interpolation. The imaging protocol, imaging equations, and processing algorithms will be described. Experiments on phantoms and normal human subjects will be presented.

Jerry L. Prince
Johns Hopkins University
Electrical and Computer Engineering
prince@jhu.edu

MS12

Shapes and Diffeomorphisms in Medical Image Analysis

Abstract not available at time of publication.

Laurent Younes
Applied Mathematics and Statistics
JHU
laurent.younes@jhu.edu

MS13

A Nonconvex Model for Speckle Noise Removal

This work focuses on the problem of multiplicative noise removal. We draw our inspiration from the modeling of speckle noise. By using a MAP estimator, we can derive a functional whose minimizer corresponds to the denoised image we want to recover. Although the functional is not convex, we prove the existence of a minimizer and we show the capability of our model on some numerical examples. We study the associated evolution problem, for which we derive existence and uniqueness results for the solution. We prove the convergence of an implicit scheme to compute the solution. This joint work with Gilles Aubert, Laboratoire J.A. Dieudonn, Universit de Nice Sophia Antiplis.

Jean-Francois Aujol
CMLA, ENS Cachan, CNRS, UniverSud
aujol@cmla.ens-cachan.fr

Gilles Aubert
Universite de Nice-Sophia-Antipolis
gaubert@math.unice.fr

MS13

Image Restoration Under Various Noises Using L1 Fidelity on Frame Coefficients

We consider the denoising of an image (or a signal) containing edges as well as smooth regions from data contaminated with various noise distributions (including multiplicative noises). classical ways to solve such problems are variational methods and shrinkage of a representation of the data in a basis or a frame. We propose a method which combines the advantages of both approaches and avoids their main drawbacks. Following the wavelets shrinkage of Donoho and Johnstone, we set to zero all frame coefficients with respect to a reasonable suboptimal threshold. Then we minimize a criterion composed of an ℓ^1 data fidelity term in the domain of the coefficients and an edge-preserving (e.g. TV-like) regularization in the domain of the image. In fact, our shrunk frame data involves both large coefficients corresponding to noise (outliers) and some coefficients, erroneously set to zero, leading to Gibbs-like oscillations in the shrinkage-based solution. Our criterion allows all these coefficients to be selectively restored, without modifying the other coefficients which are nearly faithful. We show the well-posedness and several properties of our criterion. We also propose an approximation of this method which is accurate enough and very fast. We present numerical experiments with signals and images corrupted with different noises. The obtained results demonstrate the advantages of our approach over the main alternative methods.

Sylvain Durand
LAMFA
Université de Picardie Jules Verne
sylvain.durand@u-picardie.fr

Mila Nikolova
Centre de Mathématiques et de Leurs Applications (CMLA)
ENS de Cachan, CNRS
nikolova@cmla.ens-cachan.fr

MS13

Nonlinear Inverse Scale Space and Nonconvex Regularization

We are motivated by a recently developed nonlinear inverse scale space method for image denoising, whereby noise can be removed with minimal degradation. The additive noise model has been studied extensively, using the ROF model, an iterative regularization method, and the inverse scale space flow. However, the multiplicative noise model has not been studied thoroughly yet. Earlier total variation models for the multiplicative noise cannot easily be extended to the inverse scale space, due to the lack of global convexity. In this paper, we review existing multiplicative models and present a new total variation framework for the multiplicative noise model, which is globally strictly convex. We extend this convex model to the nonlinear inverse scale space flow, and its corresponding relaxed inverse scale space flow. We demonstrate the convergence of the flow for the multiplicative noise model, as well as its regularization effect and its relation to the Bregman distance. We investigate the properties of the flow, and study the dependency on flow parameters. The numerical results show an excellent denoising effect and significant improvement over earlier multiplicative models.

Stanley J. Osher
University of California
Department of Mathematics
sjo@math.ucla.edu

MS13

Convexity and Lipschitz Optimization for Shape Priors in Variational Image Segmentation

In this work, we introduce a novel implicit representation of shape which is based on assigning to each pixel a probability that this pixel is inside the shape. This probabilistic representation of shape resolves two important drawbacks of alternative implicit shape representations such as the level set method: Firstly, the space of shapes is *convex*. Secondly, we prove that the introduction of shape priors into variational image segmentation leads to functionals which are convex with respect to shape deformations. For a large class of commonly considered (spatially continuous) functionals, we prove that – under mild regularity assumptions – segmentation and tracking with statistical shape priors can be performed in a globally optimal manner. In experiments we demonstrate the advantage of global versus local optimality.

Daniel Cremers, Frank R. Schmidt
Department of Computer Science

University of Bonn
dcremers@cs.uni-bonn.de, schmidtf@cs.uni-bonn.de

MS14
Support Theorems for the Geodesic Ray Transform

Let $(M, \partial M, g)$ be a compact simple Riemannian manifold with boundary. We assume that the metric g is real-analytic. We consider the geodesic ray transform on M and prove support theorems for this transform. Our results generalize the classical support theorem for the Radon transform proved by Helgason to the Riemannian manifold setting. The proof is based on analytic microlocal analysis and a microlocal version of Holmgren's uniqueness theorem, first used in integral geometry by Boman and Quinto.

Venkateswaran Krishnan
Department of Mathematics
Tufts University
venkyp.krishnan@gmail.com

MS14
Combining Image Reconstruction and Image Analysis

The author will describe his new implementation of the combination of reconstruction and analysis to fan beam X-ray CT geometry. The author will consider the combination with phase contrast and a diffusion filter.

Alfred Louis
Institut fuer Angewandte Mathematik
Universitaet des Saarlandes
louis@num.uni-sb.de

MS14
Reflections in Wave Equation Imaging

It belongs to the folklore of seismic imaging that the presence of reflectors strongly improves the quality of seismic reflection imaging. Likewise, the CARI principle in ultrasound mamography makes use of reflectors. We give an analysis of the impact of reflectors in the Born approximation. For the fully nonlinear problem we present numerical examples which suggest that the results of the linear analysis still hold.

Frank Natterer
University of Münster
Department of Mathematics
nattere@math.uni-muenster.de

MS14
L^1 Regularization Applied to Electron Tomography

Electron tomography (ET) is a tomographic problem where the data typically has a very high noise level. We present some new findings on the application of L^1 regularization to ET, and describe methods for designing a regularization functional and choosing the regularization parameters.

Hans Rullgaard
Department of Mathematics
Stockholm University
hansr@math.su.se

MS15
Spectral Curvature Clustering (SCC) and Hybrid Modeling

We propose a fast multi-way spectral clustering algorithm for hybrid linear modeling. We describe some of its supporting theory which also guides our practical choices. We also emphasize some of the techniques that significantly improve its performance over other multi-way clustering methods. We exemplify application of the algorithm to several real-world problems while comparing it with other methods, and also discuss some extensions to both settings of hybrid nonlinear modeling and detection.

Guangliang Chen, Gilad Lerman
Department of Mathematics
University of Minnesota
glchen@math.umn.edu, lerman@umn.edu

MS15
Subspace Segmentation via Lossy Data Compression and its Applications in Computer Vision

In this talk, we introduce a new method for clustering high-dimensional data that are drawn from a mixture of subspaces (or almost degenerate Gaussian). The method is based on minimizing the coding length of the final segmented data. We propose a simple, new agglomerative algorithm for minimizing the coding length. The algorithm is remarkably effective robust to outliers, and has superior performance over existing clustering algorithms based on expectation and maximization. We will present many new successful applications of this method in computer vision and machine learning, including image segmentation, motion segmentation, and manifold learning.

John Wright, Shankar Rao, Yi Ma
Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign
jnwright@uiuc.edu, srrao@uiuc.edu, yima@uiuc.edu

MS15
Translated Poisson Mixture Model for Stratification Learning

A framework for the regularized and robust estimation of non-uniform dimensionality and density in high dimensional noisy data is introduced in this work. This leads to learning stratifications, that is, mixture of manifolds representing different characteristics and complexities in the data set. The basic idea relies on modeling the high dimensional sample points as a process of Translated Poisson mixtures, with regularizing restrictions, leading to a model which includes the presence of noise. Theoretical asymptotic results for the model are presented as well. The presentation of the theoretical framework is complemented with artificial and real examples showing the importance of regularized stratification learning in high dimensional data analysis in general and computer vision and image analysis in particular.

Gloria Haro
UPC
glohao@gmail.com

Guillermo Sapiro
University of Minnesota
Dept Electrical & Computer Engineering
guille@umn.edu

Gregory Randall
Uruguay
randall@fing.edu.uy

MS15

Clustering Linear and Nonlinear Manifolds using Generalized Principal Components Analysis

Over the past two decades, we have seen tremendous advances on the simultaneous segmentation and estimation of a collection of models from sample data points, without knowing which points correspond to which model. Most existing segmentation methods treat this problem as "chicken-and-egg", and iterate between model estimation and data segmentation. In this lecture, we will show that for a wide variety of data segmentation problems (e.g. mixtures of subspaces), the "chicken-and-egg" dilemma can be tackled using an algebraic geometric technique called Generalized Principal Component Analysis (GPCA). We will also present extensions of GPCA for clustering data lying on a union of both linear and nonlinear subspaces. The lecture will also touch upon a few motivating applications of GPCA in computer vision, such as image/video segmentation, 3-D motion segmentation and dynamic texture segmentation.

Rene Vidal
Department of Biomedical Engineering
Johns Hopkins University
rvidal@cis.jhu.edu

Yi Ma
Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign
yima@uiuc.edu

Alvina Goh
Department of Biomedical Engineering
Johns Hopkins University
alvina@cis.jhu.edu

MS16

Euler's Elastica Inpainting by Dual Approach

We propose an image inpainting model using Euler's Elastica (EE) energy and dual approach. Using the co-area formula, it can be seen that EE energy is an efficient model to inpaint piecewise smooth images. However, EE inpainting is hard to implement and standard numerical models are slow and difficult to stabilize. This justifies the development of a faster and robust numerical model based on a dual approach. Results are shown on synthetic and real-world images. Joint work with J. Darbon and T.F. Chan.

Xavier Bresson
UCLA
Department of Mathematics
xbresson@math.ucla.edu

MS16

Inpainting by a Modified Cahn-Hilliard Equation

We propose a modified version of the Cahn-Hilliard equation for inpainting binary images. The resulting model benefits from efficient numerical methods developed for the standard Cahn-Hilliard equation, allowing its fast solution. It can also be extended to gray-scale and color images. Based on joint works with Andrea Bertozzi, Alan Gillette, and Chiu-Yen Kao.

Selim Esedoglu
Department of Mathematics
University of Michigan
esedoglu@umich.edu

MS16

Image Coding based on Segmentation and Inpainting

We discuss an interesting new application of segmentation and inpainting technique to image coding and compression. Image encoding via compression addresses the problem of reducing the amount of data necessary to represent a digital image. The underlying basis of the reduction is removing redundant data. Instead of sampling on frequency information, we direct to sampling on spatial information, for examples, edges, level sets, and geometry of objects. Decoding requires the process of recovery of missing data based on given information. For this purpose, we apply inpainting techniques. We give a mathematical frame to edge-based image coding and demonstrate some numerical results.

YoonMo Jung
Duke University, USA
jung@math.duke.edu

MS16

Image Inpainting Using a TV-Stokes Equation

Based on some geometrical considerations, we propose a two-step method to do digital image inpainting. In the first step, we try to propagate the isophote directions into the inpainting domain. An energy minimization model combined with the zero divergence condition is used to get a nonlinear Stokes equation. Once the isophote directions are constructed, an image is restored to fit the constructed directions. Both steps reduce to the solving of some nonlinear partial differential equations. Details about the discretization and implementation are explained. The algorithms have been intensively tested on synthetic and real images. The advantages of the proposed methods are demonstrated by these experiments. Joint work with Stanley Osher and Randi Holm.

Xue-cheng Tai
University of Bergen
Dept of Applied Mathematics
tai@math.uib.no

MS17

Fourier Sketching: Low Complexity Computation of Sparse DFT

I will present a greedy, randomized algorithm that computes the DFT of length N when only S coefficients are nonzero but have unknown location, in the spirit of recent work by Gilbert, Strauss, and co-workers. The complexity is empirically sublinear and scales like $S(\log N)^2$. While some elements of the algorithm are directly taken from Gilbert et al., some steps such as the coefficient estimation are novel. Applications include fast decoding for compressed sensing, without even formulating an ell-1 problem or expliciting the measurement matrix.

Laurent Demanet

Mathematics, Stanford
demanet@gmail.com

MS17

Greedy Signal Recovery and Uncertainty Principles

We demonstrate a simple greedy algorithm that can reliably recover a vector from incomplete and inaccurate measurements. Our algorithm, Regularized Orthogonal Matching Pursuit (ROMP), seeks to close the gap between two major approaches to sparse recovery. It combines the speed and ease of implementation of the greedy methods with the strong guarantees of the convex programming methods. For any measurement matrix that satisfies a Uniform Uncertainty Principle, ROMP recovers a n-sparse signal from its inaccurate measurements in at most n iterations, where each iteration amounts to solving a Least Squares Problem. The noise level of the recovery is proportional to the norm of the error, up to a logarithmic factor. In particular, if the error term vanishes the reconstruction is exact. This stability result extends naturally to the very accurate recovery of approximately sparse signals.

Deanna Needell
Mathematics, UC Davis
dneedell@math.ucdavis.edu

Roman Vershynin
Mathematics
University of California at Davis
vershynin@math.ucdavis.edu

MS17

One Sketch for All: Fast Algorithms for Compressed Sensing

Compressed Sensing is a new paradigm for acquiring the compressible signals that arise in many applications. These signals can be approximated using an amount of information much smaller than the nominal dimension of the signal. Traditional approaches acquire the entire signal and process it to extract the information. The new approach acquires a small number of nonadaptive linear measurements of the signal and uses sophisticated algorithms to determine its information content. Emerging technologies can compute these general linear measurements of a signal at unit cost per measurement. This paper exhibits a randomized measurement ensemble and a signal reconstruction algorithm that satisfy four requirements: (1) The measurement ensemble succeeds for all signals, with high probability over the random choices in its construction. (2) The number of measurements of the signal is optimal, except for a factor polylogarithmic in the signal length. (3) The running time of the algorithm is polynomial in the amount of information in the signal and polylogarithmic in the signal length. (4) The recovery algorithm offers the strongest possible type of error guarantee. Moreover, it is a fully polynomial approximation scheme with respect to this type of error bound. Emerging applications demand this level of performance. Yet no other algorithm in the literature simultaneously achieves all four of these desiderata. This talk will present and update work that originally appeared in ACM STOC 2007. It is joint work with Anna C. Gilbert, Joel A. Tropp, and Roman Vershynin.

Martin Strauss
Mathematics and EECS
University of Michigan
martinjs@umich.edu

MS17

CoSaMP: Iterative Signal Recovery from Incomplete and Inaccurate Measurements

Compressive Sampling offers a new paradigm for acquiring signals that are compressible with respect to an orthobasis. The major algorithmic challenge is to approximate a compressible signal from noisy samples. Until recently, all provably correct reconstruction techniques have relied on large-scale optimization, which tends to be computationally burdensome. This talk describes a new iterative, greedy recovery algorithm, called CoSaMP that delivers the same guarantees as the best optimization-based approaches. Moreover, this algorithm offers rigorous bounds on computational cost and storage. It is likely to be extremely efficient for practical problems because it requires only matrix–vector multiplies with the sampling matrix. For some cases of interest, the running time is just $O(N * \log^2(N))$, where N is the length of the signal.

Joel Tropp
Applied and Computational Mathematics
Caltech
jtropp@acm.caltech.edu

Deanna Needell
Mathematics, UC Davis
dneedell@math.ucdavis.edu

MS18

Methods and Algorithms for Dimensionality Reduction of High Dimensional Image Data

This presentation is concerned with the problem of dimensionality reduction of hyperspectral image data of complex geospatial geometric structures. The image cubes under consideration are generally large, with over 100 bands and of at least 100,000-pixel resolution. It is well known that linear methods, such as principal component analysis (PCA) and multi-dimensional scaling (MDS), are certainly not effective for the study of this problem, and current nonlinear methods encounter various difficulties, particularly in neighborhood selection and data set tiling. Our approach to this problem is based on diffusion maps and diffusion wavelets. An important advantage of this approach is that the diffusion process can be easily applied to control the neighborhood size. In order to facilitate such diffusion processes, we will discuss certain neighborhood selection rules to address the choice of suitable neighbors and introduce certain landmark technique to significantly reduce the diffusion kernel size for the need of memory saving and computational stability.

Charles Chui
Institute of Computational Harmonic Analysis
University of Missouri
charleskchui@yahoo.com

Jianzhong Wang
Sam Houston State University
mth_jxw@shsu.edu

MS18

Diffusion Geometry As a Toolkit for Image Pro-

cessing

We illustrate the use of multiscale diffusion geometry and Harmonic analysis on graphs, to organize and process vector valued images. In particular denoising, segmentation ,search within an image and matching, will all be discussed in this context. Various applications to medical and hyperspectral imagery will be provided.

Ronald Coifman
Yale University
Department of Computer Science
coifman@math.yale.edu

MS18

Real Time User-assisted Image Analysis

It is critical for many applications in image and video analysis to provide the user or analyst with efficient tools to interact with the data. In this talk we will describe such a tool. In particular, we present a real time framework for user-assisted segmentation. The proposed technique is based on the optimal, linear time, computation of weighted geodesic distances to user-provided scribbles, from which the whole data is automatically segmented. The weights are based on spatial and/or temporal gradients, considering the statistics of the pixels scribbled by the user, without explicit optical flow or any advanced and often computationally expensive feature detectors. These could be naturally added to the proposed framework as well if desired, in the form of weights in the geodesic distances. An automatic localized refinement step follows this fast segmentation in order to further improve the results and accurately compute the corresponding matte function. Additional constraints into the distance definition permit to efficiently handle occlusions such as people or objects crossing each other in a video sequence. The presentation of the framework is complemented with numerous and diverse examples. Joint work with X. Bai, following earlier work with L. Yatziv and A. Protiere.

Guillermo Sapiro
University of Minnesota
Dept Electrical & Computer Engineering
guille@umn.edu

MS18

Organization of Intermediate-level Visual Features

Visual representations are naturally grouped into early representations of information abstracted directly from the image; and high-level characterizations of object and scene properties. Intermediate to those are representations that facilitate matching; that capture perceptual organization over long-distance scales; and that support inferences to complex features such as *airports.* We discuss such intermediate-level feature organization algorithms based on non-linear dimensionality reduction techniques and geometric harmonics.

Steven Zucker
Yale University
Computer Science and Electrical Engineering
steven.zucker@yale.edu

MS19

Distributed Compressive Sensing with the Dirichlet Process

In many applications, one is interested in simultaneously performing inversion of multiple CS measurements. We propose a novel multi-task compressive sensing framework based on a Bayesian formalism, where a sparseness prior is adopted. The key challenge is that not all of the measured data are necessarily appropriate for sharing when performing inversion, and one must therefore infer what sharing of data across the multiple CS measurements is appropriate. Toward this end, a Dirichlet process (DP) prior is employed.

Larry Carin
Electrical & Computer Engineering
Duke University
lcarin@ee.duke.edu

MS19

Difference Imaging from Linear Spatial-Domain Projections

Using compressive optical measurements, we consider direct reconstruction of the difference between two images taken at different time instants. We first show that the linear MMSE reconstruction operator depends on the cross-correlation between the two images. We then consider reconstruction performance when the measurements consist of a finite number of linear spatial projections of the two images. We also quantify performance when a time series of difference images is reconstructed from a series of linear projections. Various projection operators are compared.

Nathan Goodman, Mark Neifeld, Shikhar Shikhar
Department of Electrical and Computer Engineering
University of Arizona
Goodman@ece.arizona.edu, neifeld@ece.arizona.edu, shikhar@ece.arizona.edu

MS19

Compressive Imaging for Increased Field-of-view Exploitation

We consider the application of compressive imaging to the problem of wide-area persistent surveillance. There are cases under study where optical architectures have been developed which require the incorporation of compressive imaging to perform the indicated exploitation. We utilize one such architecture to show a dramatic increase in performance for wide-area persistent surveillance. This architecture is described as a field-of-view multiplexing imager and its relation to compressive imaging is discussed and exploited.

Robert Muise
Lockheed Martin
robert.r.muise@lmco.com

MS19

Manifold-based Image Understanding from Compressive Measurements

The emerging theory of Compressive Sensing (CS) states that an image obeying a sparse model can be reconstructed from a small number of random linear measurements. In this talk we will explore manifold-based models as a generalization of sparse representations, and we will discuss the possible applications of these models not only in single- and multi-image recovery from compressive measurements, but also in scalable inference settings, where a detection, estimation, or classification can be made using far fewer compressive measurements than would be required for recovery.

Michael Wakin
Department of Electrical Engineering and Computer Science
University of Michigan
wakin@umich.edu

MS20

3D-visualization and Analysis of Morpho-topological Features During Cell Migration and Implications to Biomedical Research on Fish Embryos

We apply in vivo spinning disk microscopy in GFP-transgenic fish embryos and 3D feature extraction to study migration of individual cells and aggregates in different morphogenetic contexts. Active surface meshes and invariant moments reveal morpho-topological transitions during migration such as lattice formation and rosette-like supra-cellular arrangements, phenomena that require precise genetic control. Experiments with genetically modified organisms reveal the interaction of migrating cells with embryonic microenvironments in normal and pathological conditions.

Steffen Härtel
ICBM, Faculty of Medicine
University of Chile
shartel@med.uchile.cl

Carmen Lemus, Karina Palma, Luisa Pereiro, German Reig, Alejandra Catenaccio, Leonel Muñoz, Felipe Olmos, Alejandra Garcia, Veronica Eisner, Miguel Concha
University of Chile
clemus@puc.cl, anubis1008@gmail.com, lpereiro@med.uchile.cl, gerreig@yahoo.com.ar, alecatenaccio@yahoo.com.ar, lamunoz@med.uchile.cl, felipe@olmos.cl, al_garcia@med.uchile.cl, veisner@gmail.com, mconcha@med.uchile.cl

MS20

On the Evaluation of Posture Deviations in Sagittal Plane Images of Human Patients

We introduce an effective approach to assess human postural deviations during Global Postural Reeducation (GPR) physiotherapy treatment, using image processing techniques. Sagittal plane images were acquired under orthopedist supervision, during the patient treatment. After segmenting and calculating curvature based measurements from the contour of the human silhouettes, we designed tools so that the specialist can quantify the effectiveness of the physiotherapy treatment. Possible extensions of this application to other medical treatments will be also presented.

Fátima Medeiros
Teleinformatics Engineering Department
Federal University of Ceara
fsombra@ufc.br

MS20

Pattern Recognition on Biomedical Datasets

Biomedical imaging supports the exploitation of the complex relation between biological function and structure at multiple levels of biological systems, using image analysis and understanding. The focus of this minisymposium is to present state-of-art methods to process, analyze and understand multi-modal images and their applications, including discussions about the recent advances in processing large biomedical datasets.

Daniela M. Ushizima
Visualization and Math Groups
Lawrence Berkeley National Laboratory
daniela@hpcrd.lbl.gov

Edward Bethel
Lawrence Berkeley National Laboratory
ewbethel@lbl.gov

MS20

Image Classification through Machine Learning Techniques

Several Biomedical Imaging analyses involve classifying digital images into categories or classes. From datasets of images with known classification, supervised Machine Learning (ML) techniques may be used in the induction of classifiers able to perform the desired discrimination for unseen images from the same domain. This presentation will cover the main classification problems in Biomedical imaging analyses and show how supervised ML techniques can be employed in their solution.

Marcelo Zanchetta
ABC Federal University
marcelo.zanchetta@gmail.com

Ana C. Lorena
Center of Mathematics, Computation and Cognition
ABC Federal University
aclorena@gmail.com

MS21

Counterexamples in Blind Deconvolution

Energy functionals with nonconvex regularization terms often have useful properties in image processing, while exhibiting such serious shortcomings as non uniqueness and false solutions. Likewise, blind deconvolution of blurred imagery is an important subject that is not fully understood. This talk will focus on two recently developed efficient blind deconvolution ideas. One approach can produce infinitely many distinct physically realistic reconstructions. Another well-regularized and highly efficient technique often results in physically impossible optical transfer functions, and necessarily questionable reconstructions. We show how to rehabilitate such otfs in the light of the theorems of Bochner, Schoenberg, Polya and Askey on characteristic functions. Applications to interesting real images will be provided.

Alfred S. Carasso
Nat'l Inst of Standards & Tech
alfred.carasso@nist.gov

MS21

Semi-Group Theory for Non-convex Energy Functionals

A very successful approach to enhance distorted images is to let them evolve some time under the flow of an appropriately chosen evolutionary equation. If we are concerned to preserve the structures in the image, these equations usually contain some sort of backward diffusion to keep sharp edges which makes it difficult to get a rigorous solution theory for those differential equations. We try to overcome this problem by writing the equations in the spirit of semi-group theory as an iterative variational problem which could only be achieved with non-convex energy functionals. Taking the relaxations of these functionals, we will introduce a new solution concept for such evolutionary equations.

Peter Elbau
RICAM
peter.elbau@oeaw.ac.at

MS21

Average Performance of the Sparsest Approximation Using a General Dictionary

We consider the minimization of the number of non-zero coefficients (the ℓ_0 "norm') of the representation of a data set in terms of a dictionary under a fidelity constraint. (Both the dictionary and the norm defining the constraint are arbitrary.) This (nonconvex) optimization problem naturally leads to the sparsest representations, compared with other functionals instead of the ℓ_0 "norm'. Our goal is to measure the sets of data yielding a K-sparse solution—i.e. involving K non-zero components. Data are assumed uniformly distributed on a domain defined by any norm—to be chosen by the user. A precise description of these sets of data is given and relevant bounds on the Lebesgue measure of these sets are derived. They naturally lead to bound the probability of getting a K-sparse solution. We also express the expectation of the number of non-zero components. We further specify these results in the case of the Euclidean norm, the dictionary being arbitrary.

Francois Malgouyres
LAGA
Université Paris 13
malgouy@math.univ-paris13.fr

Mila Nikolova
Centre de Mathématiques et de Leurs Applications (CMLA)
ENS de Cachan, CNRS
nikolova@cmla.ens-cachan.fr

MS21

Image Recovery by Variational Cartoon-texture Decomposition Model

In this work, we aim to recover an unknown image from a degraded version (blurry and possibly noisy). We solve this inverse problem by energy minimization and regularization. We seek a solution of the form $u + v$, where u is a function of bounded variation (cartoon component), while v is an oscillatory component (texture), modeled by a Sobolev function with negative degree of differentiability. Experimental results show that this cartoon + texture model better recovers textured details, by comparison with the more standard models where the unknown is restricted only to the space of functions of bounded variation.

Yunho Kim
Department of Mathematics
UCLA
yuno1123@math.ucla.edu

Luminita A. Vese
University of California, Los Angeles
Department of Mathematics
lvese@math.ucla.edu

MS22

Properties of Extremals in Variational Image Decomposition

We analyze a variational model recently proposed for image decomposition into cartoon and texture. The first term in the energy is the total variation of the unknown u (cartoon component), while the second term is the L^1 norm applied to $k * (f - u)$, where k is a smoothing analytic kernel, and f is the given image data. The texture component is given by f-u.

John Garnett
Department of Mathematics, UCLA
jbg@math.ucla.edu

Triet Le
Department of Mathematics, Yale University
triet.le@yale.edu

Luminita A. Vese
University of California, Los Angeles
Department of Mathematics
lvese@math.ucla.edu

MS22

Two Novel Nonlocal Nonlinear Diffusions for Image Denoising

Two novel nonlinear diffusions will be proposed characterized by their diffusion coefficient nonlocal dependence on the solution itself through a fractional derivative. Mathematical features of the new equations will be highlighted which make the equations an effective tool for image denoising.

Patrick Guidotti
University of California at Irvine
gpatrick@math.uci.edu

MS22

Nonlocal Operators with Applications to Image Processing

We propose the use of nonlocal operators to define new types of flows and functionals for image processing (and elsewhere). A main advantage over classical PDE based algorithms is the ability to handle textures and repetetive structures. This topic can be viewed as an extension of spectral graph theory and the diffusion geometry framework to functional analysis and PDElike evolution equations.

Stanley J. Osher
University of California
Department of Mathematics

sjo@math.ucla.edu

Guy Gilboa
UCLA Mathematics
gilboa@math.ucla.edu

MS22

Multiscale Decomposition of Images: Deblurring, Denoising and Segmentation

We discuss hierarchical multiscale decompositions of images. Viewed as an L^2 function, a given image f is hierarchically decomposed into the sum or product of simpler "atoms" u_k. To this end, the u_k's are obtained as dyadically scaled minimizers of standard functionals arising in image analysis. This leads to the desired hierarchical decomposition, $f \sim \sum T u_k$, where T is a blurring operator. We characterize such minimizers (by duality) and derive precise energy decomposition of f in terms of its "atmos" u_k. Numerical results illustrate applications of the new hierarchical multiscale decomposition for blurry images, images with additive and multiplicative noise and image segmentation.

Eitan Tadmor
University of Maryland
USA
tadmor@cscamm.umd.edu

Suzanne Nezzar
The Richard Stockton College of New Jersey
nezzars@stockton.edu

Luminita A. Vese
University of California, Los Angeles
Department of Mathematics
lvese@math.ucla.edu

MS23

Mathematical Problems of Time-domain Seismic Imaging

Abstract not available at time of publication.

Sergey Fomel
University of Texas at Austin
sergey.fomel@beg.utexas.edu

MS23

Seismic Imaging Meets Compressive Sampling

Compressive sensing has led to fundamental new insights in the recovery of compressible signals from sub-Nyquist samplings. It is shown how jittered subsampling can be used to create favorable recovery conditions. Applications include mitigation of incomplete acquisitions and wavefield computations. While the former is a direct adaptation of compressive sampling, the latter application represents a new way of compressing wavefield extrapolation operators. Operators are not diagonalized but are compressively sampled reducing the computational costs.

Felix J. Herrmann
The University of British Columbia
Department of Earth and Ocean Sciences
fherrmann@eos.ubc.ca

MS23

Seismic Inversion and Multiple Scattering

We deal with a classical inverse problem of reflection seismology in which the acoustic impedance distribution is to be retrieved, the velocity being fixed. The seismic source also appears as an unknown of the problem. If heterogeneity causes important multiple scattering, a linearization can hardly be envisaged. We investigate a solution to this nonlinear inverse problem with special emphasis on the inversion of VSP (Vertical Seismic Profile) data.

Patrick Lailly
Institut Francais du Petrole
Patrick.LAILLY@ifp.fr

Florence Delprat-jannaud
IFP
florence.delprat-jannaud@ifp.fr

Laurence halpern
Université Paris 13
halpern@math.univ-paris13.fr

Ludovic Metivier
IFP
ludovic.metivier@ifp.fr

MS23

'Wave Equation' Seismic Imaging in Large Scale Geometries

We study wave equation seismic imaging with different geometries, e.g. overturned rays or underside reflections. We show that wave equation common image gathers are free of kinematic artifacts, under certain assumptions. We study the assumptions for relevant cases in exploration and global imaging contexts.

Christiaan C. Stolk
University of Twente
c.c.stolk@ewi.utwente.nl

Maarten V. de Hoop
Purdue University
mdehoop@purdue.edu

MS24

FAIR: Flexible Algorithms for Image Registration: Part II

In the second part we present practical algorithms for image registration. Clearly, there is no one-for-all method that works in any situation. For an individual application modalities of images, additional knowledge, modeling issues, and computational time constraints needs to be taken into account. Based on the fundamentals from part I we will outline algorithms addressing these points.

Stefan Heldmann
University of L
"ubeck
Institute of Mathematics
heldmann@math.uni-luebeck.de

MS24

Multi-aperture/Multi-diversity Compact Imaging Systems: Design and Fabrication of a Low-Cost,

Multi-Spectral Imaging System

This presentation reports the design and construction of a low-cost, multi-spectral imaging system using a single, large format CCD and an array of 18 individual lenses coupled to individual spectral filters. The system allows the simultaneous acquisition of 18 sub-images, each with potentially different optical information. The sub-images are combined to create a composite image, highlighting the desired spectral information. Because all the sub-images are acquired simultaneously, the composite image shows no motion artifact. Although the present configuration uses 17 narrow bandpass optical filters to obtain multi-spectral information from a scene, the system is designed to be a general purpose, multi-aperture platform, easily reconfigured for other multi-aperture imaging modes.

Scott Mathews
The Catholic University of America
Washington, DC, USA
mathewss@cua.edu

MS24
FAIR: Flexible Algorithms for Image Registration - Part I

Image registration is one of the most challenging tasks within digital imaging. Given two images R and T, one is looking for a transformation y such that a deformed version $T(y(x))$ of T is similar to R. The problem arises, for example, when images taken from different objects, perspectives, times, or devices need to be compared or fused.This part I talk outlines the mathematical background for the algorithms presented in part II.

Jan Modersitzki
McMaster University
Department of Computing and Software
modersit@cas.mcmaster.ca

MS24
Multi-aperture/Multi-diversity Compact Imaging Systems: Part II

Digital super-resolution refers to computational techniques that exploit the generalized sampling theorem to extend image resolution beyond the pixel spacing of the detector. We investigate the use of pupil phase diversity in a multi-lenslet camera system to enable the recovery of high resolution images when the system is affected by defocus blur. In addition we explore the use of pupil phase as a way to physically precondition and regularize the computational super-resolution problem.

Pau'l Pauca
Wake Forest University
Winston-Salem, NC, USA
paucavp@wfu.edu

Todd Torgersen
Wake Forest University
torgerse@mthcsc.wfu.edu

MS25
Fast Gradient-Based Image Registration Algorithm Incorporating a 3D Model

Precise localization of a camera with respect to known, arbitrary geometry requires a registration algorithm that incorporates the underlying 3D geometry. This work presents such an algorithm that registers a 2D image to an image paired with (or generated from) a 3D model. The algorithms dense optimization approach avoids feature selection/correspondence, and a reformulation of the objective function yields high computational efficiency. We present results from endoscopic surgical guidance and georegistration of aerial video.

Scott A. Merritt
Naval Air Warfare Center
Weapons Division
scott.a.merritt@navy.mil

William Higgins
The Pennsylvania State University
weh2@psu.edu

MS25
3-D Priors for Scene Learning

A framework for scene learning which uses information extracted from pedestrians in a scene, as seen from a single video camera, will be presented. We introduce a 3D prior representing the pedestrian's appearance and learn it using a single standard video camera and the Radon transform. This 3D prior is then used to estimate the agreement between a set of tentative parameters describing the camera transformation and basic characteristics of scene-illumination and actual video observations, taking into account not only the pixels occupied by the pedestrian, but also those occupied by his shadow and/or reflection.

Diego Rother
University Of Minnesota
diroth@gmail.com

Kedar Patwardhan, Iman Aganj
University of Minnesota
kedar@umn.edu, iman@umn.edu

Guillermo Sapiro
University of Minnesota
Dept Electrical & Computer Engineering
guille@umn.edu

MS25
Meaningful Characteristics Algorithm with 3-D Occlusions-Disocclusions Tracking, Applications to 3-D Geo-Mosaics from Video

We present a recently developed method [L. Rudin, P. Monasse, P. Muse, and F. Cao Novel Computational Technique for Super-Dense Digital Terrain Elevation Reconstruction through Method of Epipolar Characteristics Tracking, 2007, Proceedings ASPRS 2007 Annual Conference, Tampa Fl.] for estimating super-dense 3-D geometry of urban scenes and other terrains from an image sequence captured by a calibrated airborne video camera. The flight is assumed to be at constant velocity in a piecewise straight path and the camera is oriented at nadir. Under these conditions, the epipolar lines are stationary. We extract characteristics propagation patterns from the stationary epipolar lines. This is analogous to the method of characteristics for advection partial differential equations. The geometry of the characteristics is directly linked to the distance between the camera and the observed 3-D scene point, to the 3-D occlusion geometry. Intersection of characteristics accurately estimates 3-D and image locations of occlusions and dis-occlusions, first such result in the video analysis literature. This is analogous to the shock tracking in non-linear advection problems. Accumulating and integrating all 3-D estimations over the entire flight sequence permits to build a 3-D mosaic of the scene. This novel algorithm opens up the camera field, making it fully 3-D panoramic. This work is done in collaboration with the National Geospatial Agency (NGA). Results are demonstrated on NGA aerial video data recently collected for this approach.

Leonid Rudin
Cognitech, Inc.
lenny@cognitech.com

Pascal Monasse
CEREMADE
Universite PARIS Dauphine
monasse@cmla.ens-cachan.fr

Jean-Michel Morel
ENS Cachan
morel@cmla.ens-cachan.fr

MS25

N-Tangents Algorithm for 3-D to 3-D Registration of Shapes, Applications to 3-D Mosaic, Shape Search, Shape ID

We present the recently developed method for the non-local 3-D shape registration and analysis [L. Rudin, J.L. Lisani, J.M. Morel, 2006, Invariant 3-D Shape Matching with N-Tangents, US Patent, Pending; L. Rudin, J.L. Lisani, J.M. Morel, Novel Method for 3-D Biometric Face/Head Total and Partial Comparison through Scanner-Invariant Slicing, Proceedings American Academy Forensic Science 60th Annual Metting, AAFS 08, Washington, DC]. The classical techniques to compare 3-D surface-shapes are either exploit numerical, e.g. least-square, matching of surface shapes [A method for registration of 3-D shapes Besl, P.J. McKay, H.D., Pattern Analysis and Machine Intelligence, IEEE Transactions Feb 1992, Volume: 14, Issue: 2, page(s): 239-256.], or the 3-D data is matched through registration of landmarks, which are meaningful loci that can be unambiguously defined and repeatedly located with a high degree of accuracy and precision [Bookstein, F. L. 1991. Morphometric tools for landmark data: geometry and biology. Cambridge Univ. Press, New York.]. These methods may be classified as a "local" 3-D registration techniques, since they are based on point-to-point comparison cumulative metrics. Most recently a new class of "global" 3D shape comparison methods was pioneered in [AM Bronstein, MM Bronstein, R Kimmel, Expression-invariant 3D face recognition, Proc. Audio and Video-based Biometric Person Authentication, 2003 - Springer.], which is based on comparison of coordinate-system invariant geodesic curves that connect pairs of surface points. There is a need for a robust "partial" comparison method that is able to identify matching 3-D shape parts, even if the rest of the shape is missing or distorted by the scanning apparatus. Many 3-D scanning applications require to accurately co-register consecutive 3-D scans with little intersection. None of the above techniques solve this problem. The affine-invariant 3-D surface-shape registration method was proposed by authors in [L. Rudin, J.L. Lisani, J.M. Morel, 2006, Invariant 3-D Shape Matching with N-Tangents, US Patent, Pending; J.L. Lisani L. Rudin, J.M. Morel, 2007, 3-D Shape Matching Affine-Invariant Slicing, (Submitted); L. Rudin, J.L. Lisani, J.M. Morel, Novel Method for 3-D Biometric Face/Head Total and Partial Comparison through Scanner-Invariant Slicing, Proceedings American Academy Forensic Science 60th Annual Metting, AAFS 08, Washington, DC.]. It is based on a fundamental principle that geometric tangency is preserved by affine transformations, e.g. by zooming and skewing. We consider "intrinsic" 3-D shape coordinates systems and scaling, produced by global N-tangents, e.g. tri-tangents and bi-tangents. N-tangent is a surface that is tangential to the 3-D shape in N distinct points. When analyzed wrt. such intrinsic system, "oriented and affine-scaled" 3-D surface patches and 3-D / 2D curve slices can be compared among 3-D shapes. Complexity of the search is reduced dramatically, making it possible to register large collections of complex 3-D shapes such as human faces, cars, etc. The traditional 3-D face matching methods will fail when only partial 3-D scans are present and shapes are to be compared on a non-continuous, and small intersection data. We demonstrate robust "mosaicing" of 3-D shapes with little intersection and "data holes". We initially demonstrate the computational performance and stability of our method on the 3-D scanned database of "doll-heads" with affine variation of scanning parameters. Several comparison examples with human Face/Head 3-D scans are also presented. The method applies to 3-D shapes of any complexity.

Leonid Rudin
Cognitech, Inc.
lenny@cognitech.com

Jose- Luis Lisani
Univ. de les Illes Balears, Palma, Spain
Cognitech, Inc
lisani@uib.es

Jean-Michel Morel
ENS Cachan
morel@cmla.ens-cachan.fr

MS26

Optimal Scaling of Prestack Migration

Reverse time migration is a linear process which can be described as the adjoint of a linearized modeling operator mapping perturbations of Earth mechanical properties about a reference model to perturbations about the corresponding predicted data. The composition of this modeling operator with its adjoint is a pseudodifferential operator which has been studied extensively in the past and is well understood. This talk will describe a simple algorithm to estimate the action of this normal map and effectively turn migration into approximate inversion, and present examples for the variable density acoustics case.

Eric Dussaud
Total
eric.dussaud@total.com

William Symes
Rice University
symes@caam.rice.edu

MS26

Spectral-element and Adjoint Methods in Computational Seismology

We provide an overview of the use of the spectral-element method (SEM) in seismology. We discuss how the equations that govern seismic wave propagation may be solved numerically based upon the SEM to address the forward problem in seismology. Examples of synthetic seismograms calculated based upon the SEM are compared to data recorded by seismographic networks. We also discuss the challenge of using the remaining differences between the data and the synthetic seismograms to constrain better Earth models and source descriptions. This naturally leads to adjoint methods, which provide a practical approach to this formidable computational challenge and enable seismologists to tackle the inverse problem.

Jeroen Tromp
California Institute of Technology
Division of Geological & Planetary
jtromp@caltech.edu

MS26

Seismic Imaging, Partial Reconstruction and Double Beamforming: A Curvelet Transform Perspective

A key challenge in seismic imaging reflectors from surface reflection data is subsurface illumination, given available data coverage on the one hand and complexity of the background model (of wavespeeds) on the other hand. The imaging is, here, described by the generalized Radon transform. To address the illumination challenge we develop a method for partial reconstruction. We make use of the curvelet transform, the associated matrix representation of the generalized Radon transform, which needs to be extended in the presence of caustics, and its structure, and phase-linearization. We pair an image target with partial waveform reflection data, and develop a way to solve the matrix normal equations that connect their curvelet coefficients via diagonal approximation. Moreover, we develop an approximation, reminiscent of Gaussian beams, for the computation of the generalized Radon transform matrix elements only making use of multiplications and convolutions, given the underlying ray geometry. Throughout, we exploit the (wavenumber) multi-scale features of the dyadic parabolic decomposition underlying the curvelet transform and establish approximations that are accurate for sufficiently fine scales. The analysis we develop here has its roots in (double) beamforming and beam-stack imaging, parsimonious pre-stack Kirchhoff migration, pre-stack plane-wave (Kirchhoff) migration, and delayed-shot prestack migration.

Maarten V. de Hoop
Purdue University
mdehoop@purdue.edu

Hart Smith, Guenther Ulhmann
University of Washington
hart@math.washington.edu,
gunther@math.washington.edu

Rob van der Hilst
Massachusetts Institute of Technology
hilst@mit.edu

MS27

Reduced Modelling of Pulse Wave Propagation in the Cardiovascular System

The nonlinear, 1D equations of blood flow in compliant vessels are solved in arterial networks and in the time domain using a discontinuous Galerkin scheme. The model is tested by comparison against a well-defined experimental 1:1 replica of the left heart and the largest 37 systemic arteries in the human. It is applied to assess the 'reservoir-wave hypothesis', which allows a better understanding of the mechanics behind the main features of arterial pulse waveforms.

Jordi Alastruey Arimon
Dept of Aeronautics
Imperial College, UK
jordi.alastruey-arimon@imperial.ac.uk

Kim Parker
Dept of Bioengineering
Imperial College London, UK
k.parker@imperial.ac.uk

Joaquim Peiro
Dept of Aeronautics
Imperial College London, UK
j.peiro@imperial.ac.uk

Spencer Sherwin
Imperial College London
s.sherwin@imperial.ac.uk

MS27

Phyiological Modeling Coupled with Image Processing Techniques

We provide an overview of mathematical modeling methods for understanding wave propagation phenomena in the vasculature. Using modeling as a simulation platform, we demonstrate how to provide insight into disease development and effects of compound intervention. We provide an example that demonstrates the coupling of mathematical models with image processing methods for improving on envelope detection of peak Doppler flow. This improvement translates into more accurate predictions and better biomarkers that may be used for profiling the hemodynamic fingerprint of a compound in development.

Karim Azer
Applied Computer Science and Mathematics Dept.
Merck & Co., Inc.
Karim_Azer@Merck.com

Craig Fancourt, Jing Xu
Merck & Co., Inc.
craig_fancourt@merck.com, jing_xu2@merck.com

Matthew Walker III
Imaging Department
Merck Research Laboratories
matthew_walker3@merck.com

MS27

Sensitivity Analysis Applied to Cardiovascular Models

Classical deterministic sensitivity analysis is performed on the model of cardiovascular dynamics first presented by Olufsen et al (J Appl Phys, 2005). The model predicts cerebral blood flow blood flow acquired by transcranial Doppler and arterial blood pressure collected with a Finapres device. The relative sensitivity solutions of the model state equations are calculated to separate parameters into sensitive and insensitive groups. The groupings were used to successfully reduce the effective parameter space by half and the computation time by two thirds, plus design a simpler, equally valid model with two-thirds of the state equations and half the model parameters.

Laura M. Ellwein
North Carolina State University
lmellwei@ncsu.edu

Hien T. Tran
North Carolina State Univ
Department of Mathematics
tran@math.ncsu.edu

Cheryl Zapata
North Carolina State University
clzapata@ncsu.edu

Vera Novak
Division of Gerontology
Beth Israel Deaconess Medical Center and Harvard Med. School
vnovak@bidmc.harvard.edu

Mette Olufsen
North Carolina State University
Department of Mathematics
msolufse@ncsu.edu

MS27

One-dimensional Generalized Newtonian Models for Flow in Slender Vessels

It remains computationally unfeasible to model the full three-dimensional (3D) equations for flows in complex systems such as the circulatory system. For geometries where the aspect ratio of vessel diameter to length is small, one-dimensional (1D) models can be used. However, the existing models are restricted to fluids of constant viscosity. In this work, 1D models are developed for fluids with non-constant viscosity, with particular emphasis on power-law fluids. The governing equations are developed for flow of generalized Newtonian fluids in flexible walled vessels. Closure constants are selected based on analytical and numerical solutions to the full problem. The predictive capability of the 1D model is evaluated for the clinically relevant benchmark problem of flow through a tapered vessel.

Anne Robertson
University of Pittsburgh
annerob@engr.pitt.edu

MS28

(Pre)Dualisation and Primal-dual Methods in TV-regularization

In this talk, we discuss Fenchel-Legendre (pre)dual formulations of the L2-TV (Rudin-Osher-Fatemi-model) as well as the L1-TV model. Based on the respective predual we then develop an algorithmic framework resulting in a primal-dual active set type solution process in both cases considered. We highlight theoretical issues as well as aspects of an appropriate numerical implementation. Finally, a report on numerical results illustrates the behavior of the solution methods.

Michael Hintermueller
University of Sussex, United Kingdom
Department of Mathematics
michael.hintermueller@uni-graz.at

MS28

Salient Properties of the Solutions for Non-smooth and Possibly Nonconvex Regularization (with Indications for Modern Minimisation Schemes)

We consider the minimizers of energies composed of a convex (e.g. quadratic) data-fidelity term and a nonsmooth regularization term applied on the discrete gradients or the finite differences of any order between neighbouring pixels. We show that the solutions involve large regions where these gradients or differences are zero. In the case of non-convex regularization, we show that the solutions are composed of constant regions separated by edges that are higher than a constant that can be calculated. We show that characteristic functions are nearly exactly restored if the regularization is bounded. We give pertinent bounds on the restored data and on the residuals. All properties are illustrated using numerical examples. We present adapted numerical approaches where the problem is reformulated as the minimization of a smooth function under a set of linear (or affine) constraints. These are efficiently solved using interior point methods.

Mila Nikolova
Centre de Mathématiques et de Leurs Applications (CMLA)
ENS de Cachan, CNRS
nikolova@cmla.ens-cachan.fr

MS28

Four-Color Theorem and Level Set Methods for Watershed Segmentation

A marker-controlled and regularized watershed segmentation is pro- posed for cell segmentation. Only a few previous studies address the task of regularizing the obtained watershed lines from the traditional marker- controlled watershed segmentation. In the present formulation, the topo- graphical distance function is applied in a level set formulation to per- form the segmentation, and the regularization is easily accomplished by regularizing the level set functions. Based on the well-known Four-Color theorem, a mathematical model is developed for the proposed ideas. With this model, it is possible to segment any 2D image with arbitrary number of phases with as few as one or two level set functions. The algorithm has been tested on real 2D fluorescence microscopy images displaying rat cancer cells, and the algorithm has also been compared to a standard wa- tershed segmentation as it is implemented in MATLAB. For a fixed set of markers and a fixed set of challenging images, the comparison of these two methods shows that the present level set formulation performs better than a standard watershed segmentation.

Xue-cheng Tai
University of Bergen
Dept of Applied Mathematics
tai@math.uib.no

MS28

Bregman Iterative Algorithms for l1-Minimization with Applications to Compressed Sensing

We propose simple and extremely efficient methods for solving the Basis Pursuit problem

$$\min\{\|u\|_1 : Au = f, u \in \mathbf{R}^n\},$$

which is used in compressed sensing. Our methods are based on Bregman iterative regularization and they give

a very accurate solution after solving only a very small number of instances of the unconstrained problem

$$\min_{u \in \mathbf{R}^n} \mu \|u\|_1 + \frac{1}{2}\|Au - f^k\|_2^2,$$

for given matrix A and vector f^k. We show analytically that this iterative approach yields exact solutions in a finite number of steps. We were able to solve huge instances of compressed sensing problems quickly on a standard PC. We demonstrate the effectiveness of the algorithm by experiments of compressed MR imaging.

Wotao Yin
Rice University
wotao.yin@rice.edu

Stanley J. Osher
University of California
Department of Mathematics
sjo@math.ucla.edu

Donald Goldfarb
Columbia University
goldfarb@columbia.edu

Jerome Darbon
Mathematics
UCLA
jerome@math.ucla.edu

MS29

A Wavelet-Laplace Variational Technique for Image Deconvolution and Inpainting

We construct a new variational method for blind deconvolution of images and inpainting, motivated by recent PDE-based techniques involving the Ginzburg-Landau functional, but using more localized wavelet-based methods. We present results for both binary and grayscale images. Comparable speeds are achieved with better sharpness of edges in the reconstruction.

Andrea L. Bertozzi, Julia Dobrosotskaya
UCLA Department of Mathematics
bertozzi@math.ucla.edu, juliadobro@yahoo.com

MS29

Level Set Based Nonlocal Surface Restoration

We extend nonlocal denoising techniques related to NL means from images to surfaces, using a level set representation. We test our techniques on real and synthetic surfaces taken from brain imaging and terrain data. This is joint work with Bin Dong, Jian Ye and Ivo Dinov.

Stanley J. Osher
University of California
Department of Mathematics
sjo@math.ucla.edu

MS29

Segmentation under Occlusions Using Selective Shape Prior

In this work, we address the problem of segmenting multiple objects, under possible occlusions, in a level set framework. A variational energy that incorporates a piecewise constant representation of the image in terms of the object regions and the object spatial order is proposed. To resolve occluded boundaries, prior knowledge of shape of objects is also introduced within the segmentation energy. By minimizing the above energy, we solve the segmentation with depth problem, i.e. estimating the object boundaries, the object intensities, and the spatial order. A novelty here is that the spatial order information available in the image model is used to dynamically impose prior shape constraints only to occluded boundaries. We also discuss extensions to handle translucent objects and multiple objects from a shape library.

Sheshadri Thiruvenkadam
University of California, Los Angeles
sheshad@math.ucla.edu

Tony F. Chan
National Science Foundation
tfchan@nsf.gov

Byung Hong
UCLA CSc
hong@cs.ucla.edu

MS29

Image Segmentation Based on Expectation-Maximization Algorithm With Local Adaptivity

We develop an efficient algorithm to combine statistical inference with geometric information for image segmentation. The idea is to couple global statistics extracted from efficient statistic models with local geometric information. In particular, an adaptive local filter based on local statistics and geometric information, such as local orientation and anisotropy, is developed.

Hongkai Zhao
University of California, Irvine
Department of Mathematics
zhao@math.uci.edu

Shingyu Leung
UC irvine
syleung@math.uci.edu

Gang Liang
UC Irvine
liang@uci.edu

Knut Solna
University of California at Irvine
ksolna@math.uci.edu

MS30

High Performance 3-D Image Reconstruction for Molecular Structure Determination

The single particle reconstruction process from cryo-electron microscopy (cryo-EM) consists of taking a collection of 2-D projection images from various angular orientations and recovering a 3-D volume representation. Accurate volume reconstruction can provide important information on complex molecular structures and their assemblies. However, the reconstruction process can be computationally challenging for large-volume structures, due to massive data and memory requirements. In this talk, we describe a sophisticated parallel implementation and a robust iterative algorithm that researchers can use to achieve large-scale molecular structure reconstruction.

Julianne Chung
Emory University
jmchung@emory.edu

Chao Yang
Lawrence Berkeley National Lab
CYang@lbl.gov

Philip Sternberg
Lawrence Berkeley National Laboratory
PSternberg@lbl.gov

MS30

Applications of Blind Deconvolution and Superresolution

Algorithms for compensating image degradations associated with blur, noise, and undersampling to improve image quality especially in niche scientific areas such as medical and astronomical applications. However, a suprisingly large fraction of the published papers make naive assumptions regarding the physical models of the image formation process that serve as the starting point for algorithm development. This paper explores application of both basic non-uniformity correction, contrast enhancement, and sharpening methods and sophisticated methods such as multi-frame blind deconvolution, phase diversity, and superresolution to images collected under a wide range of conditions. This comparison shows the importance and benefit of tailoring the mix of algorithmic elements, and models to best match the nature of the degradations to be compensated for.

David Gerwe
Boeing IDS
Lasers & Electro Optics
David.R.Gerwe@Boeing.com

MS30

Implementation and Optimization of a Multi-Frame Blind Deconvolution Iterative Algorithm

We describe our implementation of a multi-frame blind deconvolution (MFBD) iterative algorithm. Our application for this MFBD algorithm is the removal of atmospheric turbulence blurring in astronomical imagery. Key features include its parallel architecture for increased speed on distributed-memory nodes, its inclusion of multiple ways to parameterize the blurring functions in the imagery, and its ability to incorporate a variety of prior knowledge constraints such as support and positivity

Charles L. Matson
Air Force Research Laboratory
charles.matson@kirtland.af.mil

Kathy Borelli
KJS-Consulting
kathy@ohanasteelbuildings.com

MS30

Cryo-EM Reconstruction of 3D Biological Structures

In the post-genomic era, high-resolution determination of protein structures becomes extremely important for accurate interpretations of biological functions at the molecular level. The 3D reconstruction of macromolecular structures from 2D electron microcopy images of frozen hydrate samples (CryoEM) has many advantages over other imaging techniques. However, in order to perform a successful reconstruction, one has to solve a variety of difficult image processing problems. In this talk, I will give an overview on these problems and the state-of-art algorithms for solving them.

Chao Yang
Lawrence Berkeley National Lab
CYang@lbl.gov

MS31

A Weighted Average of Sparse Several Representations is Better than the Sparsest One Alone

Cleaning of noise from signals is a classical and long-studied problem in signal processing. Algorithms for this task necessarily rely on an a-priori knowledge about the signal characteristics, along with information about the noise properties. For signals that admit sparse representations over a known dictionary, a commonly used denoising technique is to seek the sparsest representation that synthesizes a signal close enough to the corrupted one. As this problem is too complex in general, approximation methods, such as greedy pursuit algorithms, are often employed. In this line of reasoning, we are led to believe that detection of the sparsest representation is key in the success of the denoising goal. Does this means that other competitive and slightly inferior sparse representations are meaningless? Suppose we are served with a group of competing sparse representations, each claiming to explain the signal differently. Can those be fused somehow to lead to a better result? Surprisingly, the answer to this question is positive; merging these representations can form a more accurate, yet dense, estimate of the original signal even when the latter is known to be sparse. In this talk we demonstrate this behavior, propose a practical way to generate such a collection of representations by randomizing the Orthogonal Matching Pursuit (OMP) algorithm, and produce a clear analytical justification for the superiority of the associated Randomized OMP (RandOMP) algorithm. We show that while the Maximum a-posterior Probability (MAP) estimator aims to nd and use the sparsest representation, the Minimum Mean-Squared-Error (MMSE) estimator leads to a fusion of representations to form its result. Thus, working with an appropriate mixture of candidate representations, we are surpassing the MAP and tending towards the MMSE estimate, and thereby getting a far more accurate estimation, especially at medium and low SNR.

Michael Elad, Irad Yavneh
Computer Science Department
Technion
elad@cs.Technion.AC.IL, irad@cs.technion.ac.il

MS31

Divergence-free and Curl-free Wavelets on the Square: Effective Construction and Associated Algorithms

We present tensor-product divergence-free and curl-free wavelets on the square, and associated fast algorithms. We will consider periodic boundary conditions, as well as homogeneous Dirichlet boundary conditions. Then we will explain how to provide the Helmholtz-Hodge decomposition in this wavelet framework. Finally we will show applications for the analysis and simulation of 2D turbulent flows.

Valerie Perrier
Grenoble Institut of Technology, France
Valerie.Perrier@imag.fr

MS31

Sparse Representation on the Sphere for Polarized Data

We present a new multiscale transform on the sphere for polarized data. We show how it can be used for different applications such denoising and components separation.

Jean-Luc Starck
Laboratoire AIM, CEA/DSM-CNRS-Universite Paris Diderot
CEA Saclay, DAPNIA/SEDI-SAP, Service d'Astrophysique
jstarck@cea.fr

MS31

Sparsity-based Source Separation with Scale-discretized Steerable Wavelets

In this talk, we discuss the issue of source separation in a signal on the sphere or on the plane, relying on the sparsity of one signal component in a scale-discretized steerable wavelet basis. The steerability of wavelets allows to probe in detail the local morphology of a signal at each analysis scale. It gives access to local measures of signed-intensity, orientation, elongation, etc. The scale discretization of the wavelets allows the reconstruction of the signal analyzed. In this context, local directional features can be identified at any scale from their sparsity in wavelet space, and reconstructed after their separation from other signal components. In cosmology, this approach reveals to be of great interest for the search of topological defects in the cosmic microwave background signal, such as cosmic strings.

Yves Wiaux
EPFL
yves.wiaux@epfl.ch

Pierre Vandergheynst
Ecole Polytechnique Federale de Lausanne
pierre.vandergheynst@epfl.ch

David Hammond
EPFL
david.hammond@epfl.ch

MS32

Fast BV + Texture Decomposition

In this talk based on a joint work with Triet Le and Luminita Vese we will review former work on the problem of decomposing a digital image into an oscillatory part and a BV part. This problem was posed by Yves Meyer as a variational problem, and is also (partially) adressed by compressive sensing techniques. We shall discuss several implementations and variants, including a fast one, which gives a nonlinear version of the classical low-pass, high-pass decomposition.

Antoni Buadès
MAP5, Universite Paris Descartes
vdmiabc4@uib.es

Jean-Michel Morel
ENS Cachan
morel@cmla.ens-cachan.fr

MS32

Two Novel Nonlocal Nonlinear Diffusions for Image Denoising II

In this talk, we present the implementation and a variety of numerical experiments of the two new nonlocal nonlinear diffusion models for noise reduction proposed in P. Guidotti's talk. The experiments will demonstrate that the new models preserve and enhance the most desirable aspects of the closely-related Perona-Malik equation.

James V. Lambers
Stanford University
Department of Energy Resources Engineering
lambers@stanford.edu

MS32

Inverse Scale Spaces versus Bregman Flow

In this talk we discuss two variants of inverse scale spaces. One is based on the iterative Tikhonov Morozov method and one on the iterative Bregman distance regularization. For the inverse scale space flow equations existence and uniqueness results are discussed. Comparisons with other inverse scale approaches are given as well. Parts of the work are based on joint work with M. Burger, K. Frick, C. Groetsch, S. Osher.

Otmar Scherzer
University Innsbruck
otmar.scherzer@uibk.ac.at

MS33

Hellinger Distance Based Image Matching Model

In this talk we present a novel image matching model which combines the Monge-Kantorovich(MK) mass transport model with the Hellinger distance function in the probability theory. The optimal matching minimizes the Hellinger distance between two images. A primal-dual approach is employed to analyze the existence and uniqueness/non-uniqueness of the optimal matching. A numerical algorithm is also provided to compute the optimal matching.

Pengwen Chen, Changfeng Gui
University of Connecticut
pengwen@math.uconn.edu, gui@math.uconn.edu

MS33

White/Gray/CFS and Partial Volume Segmentation of MRI Brain Images

We propose a multi-phase image segmentation model, that is based on regional statistics of the image and Modica-Mortola phase transition theory, and formulated in level set formulation. The proposed model is implemented using convex-concave procedure (CCCP). The selection of the initial partition to avoid unwanted local minimum, and the approximations of the indicate functions of each subregion are discussed. This algorithm has been applied to white/grey/CFS segmentation as well as partial volume analysis of MRI brain images.

Fuhua Chen
Department of Mathematics
University of Florida
fuhua@math.ufl.edu

Yunmei Chen
University of Florida
yun@math.ufl.edu

Hemant Tagare
Yale University
hemant.tagare@yale.edu

MS33

A Geometric Approach to Non-rigid Registration

Finding a non-rigid registration (or warping) between images and a non-rigid correspondence between boundaries of organs in an image is a fundamental problem in biomedical image processing. In this talk, I will present a theory in which registration and correspondence problems can be put in a unifying geometric framework. A key aspect of the theory is to treat the registration or the correspondence itself as geometric object (a manifold). This point of view shows very clearly how properties of registration and correspondence algorithms are related to differential forms on the manifold and certain natural projection operators. The theory gives registration and correspondence algorithms with guaranteed properties.

Hemant Tagare
Yale University
hemant.tagare@yale.edu

MS33

MRI Tissue Segmentation Using a Variational Multilayer Approach

We propose piecewise-constant models for segmenting three dimensional MRI brain data into white matter, gray matter and cerebro-spinal fluid. Our method is based on a multilayer or nested implicit curve evolution in variational form, well adapted for this problem, and it is solved using the Euler-Lagrange equations. Several experimental results and comparisons with manual segmentation and with automated segmentation are presented, together with quantitative assessment.

Ginmo Chung
Department of Mathematics
UCLA
senninha@math.ucla.edu

Luminita A. Vese
University of California, Los Angeles
Department of Mathematics
lvese@math.ucla.edu

Ivo D. Dinov
UCLA
Center for Computational Biology
ivo.dinov@loni.ucla.edu

Arthur Toga
UCLA
Laboratory of Neuro Imaging
toga@loni.ucla.edu

MS34

Primal-Dual EM-TV and Segmentation in Context of Inverse Problems

In this talk we discuss primal-dual EM-TV techniques for cartoon reconstruction and segmentation of images in inverse problems. We simultaneously combine EM algorithms and total variation regularization to obtain cartoon reconstructions of image data with Poisson noise. Extensions to iterative TV by using Bregman iteration and inverse scale-space methods are studied. We manage ROF-functionals efficiently by nonlinear primal-dual methods. Numerical results for deconvolution problems in optical nanoscopy and PET in medical imaging illustrate our proposed methods.

Christoph Brune
Institut fuer Numerische und Angewandte Mathematik
Westfaelische Wilhelms-Universitaet Muenster
christoph.brune@uni-muenster.de

MS34

An Adaptive Selection Rule for a Spatially Dependent Regularisation Parameter in the Rudin-Osher-Fatemi Model

In this talk, we will discuss how to choose the regularization parameter in the the Rudin-Osher-Fatemi image restoration model. Since the regularization parameter controls the trade-off between the image smoothness and the preservation of details, we consider a spatially dependent choice and propose an iterative method to determine a set of (local) regularization parameters corresponding to the image regions pertinent to different scales. The sizes of these regions can be adjusted adaptively based on local features. Numerical results which are based on a primal-dual active set solver show that this method can provide better performance of suppressing noise as well as preserving details in the image.

Yiqiu Dong
Institute of Mathematics and Scientific Computing
University of Graz
yiqiu.dong@gmail.com

MS34

A Primal-dual Hybrid Gradient Descent Method for Total Variation Minimization

We propose a simple yet efficient algorithm for total variation minimization with applications in the image processing realm. This descent-type algorithm alternates between the primal and dual formulations and exploit the information from both the primal and dual variables. Therefore, it is able to converge faster than either pure primal or dual gradient descent methods as empirically demonstrated in our paper. Finally, we show that this idea also works for other optimization problems involving the non-smooth absolute value function.

Mingqiang Zhu
UCLA Mathematics Department
mqzhu@ucla.edu

MS35

Sampling Methods for Low-frequency Electromagnetic Imaging

We study the detection of hidden objects by electromagnetic imaging using fast non-iterative methods known as sampling or factorization methods. We give an overview of the different low-frequency approximations that evolve from the time-harmonic Maxwell's equations and the applicability of the factorization method to the corresponding imaging problems. We also present some results about the detection of inclusions that are not sharply separated from the background medium for real conductivity EIT, and a new variant for complex conductivity EIT that works without reference measurements.

Bastian Gebauer
Institut für Mathematik
Joh. Gutenberg-Universität Mainz, Germany
gebauer@math.uni-mainz.de

Martin Hanke
Joh. Gutenberg-Universität
Mainz, Germany
hanke@math.uni-mainz.de

Christoph Schneider
Institut für Mathematik
Joh. Gutenberg-Universität Mainz, Germany
cs@math.uni-mainz.de

MS35

Inverse Electromagnetic Scattering for Small Inclusions in Layered Media

We consider an inverse scattering problem for time–harmonic Maxwell's equations in a two–layered background medium. Assuming that the size of the scatterers is much smaller than the wavelength of the incident field, we justify a noniterative reconstruction method that determines the number and the positions of the unknown scatterers. This method is based on an asymptotic expansion of the near zone scattered field as the size of the scatterers tends to zero.

Roland Griesmaier
Institut fuer Mathematik
Johannes Gutenberg-Universitaet Mainz
griesmaier@mathematik.uni-mainz.de

MS35

Convex Source Support and Its Application to Electric Impedance Tomography

The aim in electric impedance tomography is to recover the conductivity inside a body from boundary measurements of current and voltage. Often, the object has known background conductivity but is contaminated by inhomogeneities. We try to extract all possible information about the support of such inclusions from only one measurement pair of impedance tomography. Our noniterative method is based on the concept of convex source support, which stems from earlier works of Kusiak and Sylvester.

Nuutti Hyvönen
Helsinki University of Technology
Institute of Mathematics
nuutti.hyvonen@hut.fi

Martin Hanke
Johannes Gutenberg-Universität, Mainz
hanke@mathematik.uni-mainz.de

Stefanie Reusswig
Johannes Gutenberg-Universität, Mainz, Germany
reusswig@mathematik.uni-mainz.de

MS35

Inverse Rough and Periodic Surface Scattering Problems

We consider inverse scattering problems for one-dimensional rough and periodic surfaces. In principle, there are two different inverse problems one can investigate: First, detection of a local contamination of a known rough surface using near field measurements on a finite measurement line above the surface. Second, detection of the entire rough surface by near field measurements. For the special case of a periodic surface, one usually wants to detect the surface from measurements of the so-called Rayleigh coefficients. In this talk, we show how the Factorization method, introduced by Andreas Kirsch, can be applied to such problems for various boundary conditions and illustrate our results by numerical examples. Applications include for instance non-destructive testing of photonic crystals and radar imaging.

Armin Lechleiter
University of Karlsruhe, Karlsruhe, Germany
lechleiter@math.uka.de

MS36

Image Analysis Through Unknown Random Compressed Sensing Using Diffusion Geometry

We indicate that diffusion geometric analysis can be used to intrinsically process images which have been acquired as randomly encoded patches. In particular we show that for hyperspectral imagery the results are intrinsic and independent of the choice of randomized spectra. Diffusion Geometry considers the data base of all measurements, and proceeds to organize them enabling compressed sensing through local randomizers.

Ronald Coifman
Yale University
Department of Computer Science
coifman@math.yale.edu

MS36

Resolution and Noise

Abstract not available at time of publication.

Jean-Michel Morel
ENS Cachan
morel@cmla.ens-cachan.fr

MS36

Learning Multiscale Dictionaries for Image and Video Enhancement

In this talk we describe novel approaches for learning multiscale sparse image representations leading to state-of-the-art denoising, inpainting, and demosaicing. Joint work

with J. Mairal and M. Elad.

Guillermo Sapiro
University of Minnesota
Dept Electrical & Computer Engineering
guille@umn.edu

MS36
Correlation Based Imaging

We discuss imaging in the context of cluttered media. In such a situation spectral information in the measurements may be used for imaging purposes. We discuss this problem and how wave propagation modeling can provide a tool for imaging and efficient computational methods.

Knut Solna
University of California at Irvine
ksolna@math.uci.edu

Josselin Garnier
Universite Paris 7
garnier@math.jussieu.fr

Maarten V. de Hoop
Purdue University
mdehoop@purdue.edu

MS37
Deformation Compensation in Dynamic Tomography Through the Attenuated Radon Transform

Time dependent deformations preserving the acquisition geometry, more precisely transforming the set of projection lines into an other set of lines, can be, under some assumptions, analytically compensated in dynamic tomography. In a previous work the deformation along each line was restricted to be linear. In this work we consider deformations along each line yielding, after a change of variable in the equation, the attenuated Radon transform, whose analytic inverse is known in 2D.

Laurent Desbat
TIMC-IMAG, In3S, Faculté de Médecine, UJF
38706 La Tronche, FRANCE
laurent.desbat@imag.fr

MS37
Numerical and Theoretical Explorations in Helical and Fan-beam Tomography

Katsevich's inversion formula for helical tomography is explored in the limit of vanishing pitch, yielding a general reconstruction formula for fan-beam tomography. Several numerical implementations of this and a related fan-beam formula are proposed, implemented, and compared. This gives insight into some numerical questions also encountered in the three-dimensional case, including a theoretical explanation of the usefulness of a shift in the convolution kernel for removal of ringing artifacts.

Adel Faridani, Ryan Hass
Oregon State University
faridani@math.oregonstate.edu,
hassr@math.oregonstate.edu

MS37
Sampling Functions with Symmetries Applications to 2-D and 3-D Tomography

Classical sampling refers to data acquisition on a single uniform set of points. If the measured function possesses a symmetry, however, data may be assumed on an additional set. The union of the two sampling sets is generally nonuniform. We characterize the sampling sets that arise from employing the symmetry property and discuss conditions under which symmetry may be used to overcome the effects of undersampling. Applications to fan-beam and helical CT are presented.

Larry Gratton
Berea College
Mathematics and Computer Science
Larry_Gratton@berea.edu

MS37
A Newton Solver for Electrical Impedance Tomography

We present a variant of Newton's method for solving the inverse problem of 2D electrical impedance tomography under the complete electrode model. The most delicate part in any Newton-like regularization is the stable computation of the correction step from the locally linearized system. Therefore, we adapt dynamically the level of regularization for computing the correction to the local degree of ill-posedness. Besides presenting numerical experiments we also discuss convergence of the algorithm.

Andreas Rieder, Armin Lechleiter
University of Karlsruhe, Germany
andreas.rieder@math.uni-karlsruhe.de,
lechleiter@math.uni-karlsruhe.de

MS38
Monotone Operator Splitting and Fast Solutions to Inverse Problems with Sparse Representations

This work focuses on several constrained optimization problems involved in sparse solutions of linear inverse problems. We formalize all these problems within the same framework of convex optimization theory, and invoke tools from convex analysis (proximity operators) and maximal monotone operator splitting. We characterize all these optimization problems, and to solve them, we propose fast iterative splitting algorithms, namely forward-backward and Peaceman/Douglas-Rachford splitting iterations. This framework includes some previously proposed algorithms as a special case. With non-differentiable sparsity-promoting penalties, the proposed algorithms are essentially based on iterative shrinkage. Furthermore, the computational burden of all our algorithms is one application of fast analysis and synthesis operators at each iteration. This makes them very competitive for large-scale problems. Applications to several inverse problems such as denoising, super-resolution and compressed sensing are also reported to demonstrate the wide range of applicability of our approach.

Jalal Fadili
CNRS, Univ. of Caen, France
Jalal.Fadili@greyc.ensicaen.fr

MS38

Radon Needlets, a Sparse Representation for Tomography

In inverse problem, the representation of the signal should be adapted to both the signal and the operator: the signal has to be sparse in the representation while the spectral behavior of the basis elements has to be controled. Through the example of fan beam tomography, we present here a new way to build such a representation: the needlet construction. We will introduce the mathematical construction of the needlets and illustrate their efficiency with some numerical examples. An emphasis will be made on the benefits, in inverse problem, of adding redundancy to sparse representation.

Erwan Lepennec
Université Paris 7
lepennec@math.jussieu.fr

MS38

Bregman Iterative Algorithms for Compressed Sensing

Bregman iterative regularization (1967) was introduced by Osher, Burger, Goldfarb, Xu and Yin as a device for improving TV based image restoration (2004) and was used by Xu and Osher in (2006) to analyze and improve wavelet shrinkage. In recent work by Yin, Osher, Goldfarb and Darbon we devised simple and extremely efficient methods for solving the basis pursuit problem which is used in compressed sensing. A linearized version of Bregman iteration was also done by Osher, Dong, Mao and Yin. This requires two lines of MATLAB code and is remarkably efficient. This means we rapidly and easily solve the problem: minimize the L1 norm of u so that $Au = f$ for a given k by n matrix A, with $k << n$ and f in R^k By some beautiful results of Candes, Tao, Donoho and collaborators, this L1 minimization gives the sparsest solution u, under reasonable assumptions.

Stanley J. Osher
University of California
Department of Mathematics
sjo@math.ucla.edu

MS38

A Grouplets Tour of Texture Processing

In this talk I will present a new grouplet transform to process locally parallel textures. This transform extends the original construction of Mallat and is adapted to the modeling of natural textures. Unlike previous transforms routinely used for texture analysis, grouplets provide a sparse representation of directional textures. Indeed, transforms like wavelets or Gabor fail to compress geometric patterns present in natural textures. The grouplet transform is implemented with a fast adaptive algorithm that extracts a geometric flow and filters recursively the texture along this flow. The resulting transformed coefficients correspond to the decomposition of the image on a multiscale tight frame adapted to the image content. The grouplet coefficients of a geometric texture are both sparse and nearly independent, which makes this representation suitable for various texture processing tasks. I will show applications to texture inpainting and texture synthesis, which both require the joint optimization of the geometric flow and the grouplet coefficients.

Gabriel Peyre
CEREMADE
gabriel.peyre@ceremade.dauphine.fr

MS39

Variational Models for Image Colorization via Chromaticity and Brightness Decomposition

Colorization refers to an image processing task which recovers color of gray scale images when only small regions with color are given. We propose a couple of variational models using chromaticity color component to colorize black and white images. We first consider Total Variation minimizing (TV) colorization, and further modify our model to weighted harmonic maps for colorization.

Sung Ha Kang
University of Kentucky
Mathematics Department
skang@ms.uky.edu

Riccardo March
Istituto per le Applicazioni del Calcolo, CNR
march@iac.rm.cnr.it

MS39

Conformal Parameterization and Variational Problems on Surfaces

Parameterization is an important process that maps a complicated surface to a simple domain. After the surface is parameterized, we can analyze and solve problems defined on the surface on the simpler domain. Conformal parameterization is often used. A conformal parameterization is a special kind of harmonic map that preserves the local geometry. It induces a simple Riemannian metric on the surface which results in a lot of advantages. In this talk, I am going to describe how we can parameterize a surface conformally onto different parameter domains, such as the sphere, 2D rectangles, punctual disks, etc. In the second part of my talk, I will describe how we can solve variational problems/PDEs easily on the surface using the conformal parameterization. Applications to image processing on the surface, human brain mapping research will also be described.

Lok Ming Lui
UCLA
malmlui@math.ucla.edu

MS39

A Texture Synthesis Approach to Euler's Elastica Variational Inpainting

We present an inpainting algorithm for both textured and non-textured images. Euler's elastica inpainting by Chan et al. repairs smooth areas while maintaining edge detail, but is slow due to a stiff 4th-order PDE. Efros and Leung used texture synthesis for inpainting that works well for repeating patterns. We combined these techniques to accelerate and constrain the PDE solution and turned a stiff minimization into a combinatorial optimization problem, quicker to solve and more stable.

Kangyu Ni
UCLA
Department of Mathematics

kangyu.ni@gmail.com

Doug Roble
Digital Domain
doug@d2.com

Tony F. Chan
UCLA
chan@math.ucla.edu

MS39

A Curvilinear Search Method for p-Harmonic Flows

The problem of finding p-harmonic flows arises in a wide range of applications including micromagnetics, liquid crystal theory, directional diffusion, and chromaticity denoising. In this paper, we propose an innovative curvilinear search method for minimizing p-harmonic energies over spheres. Starting from a flow (map) on the unit sphere, our method searches along a curve that lies on the sphere in a manner similar to a standard inexact line search descent method. We show that our method is globally convergent if the step length satisfies the Armijo-Wolfe conditions. Computational tests are presented to demonstrate the efficiency of the proposed method and a variant of it that uses Barzilai-Borwein steps.

Donald Goldfarb, Zaiwen Wen
Columbia University
goldfarb@columbia.edu, zw2109@columbia.edu

Wotao Yin
Rice University
wotao.yin@rice.edu

MS40

The Chimera of Optimality in Signal and Image Processing

Alfred M. Bruckstein
Computer Science Department
Technion IIT, Haifa, Israel
freddy@cs.technion.ac.il

MS40

Generalizing the Non-Local-Means to Super-Resolution-Reconstruction of Image Sequences

Super-resolution reconstruction proposes a fusion of several low quality images into one higher quality result with better optical resolution. Classic super resolution techniques strongly rely on the availability of accurate motion estimation for this fusion task. When the motion is estimated inaccurately, as often happens for non-global motion fields, annoying artifacts appear in the super-resolved outcome. Encouraged by recent developments on the video denoising problem, where state-of-the-art algorithms are formed with no explicit motion estimation, we seek a super-resolution algorithm of similar nature that will allow processing sequences with general motion patterns. In this talk we base our solution on the Non-Local-Means (NLM) algorithm. We show how this denoising method is generalized to become a relatively simple super-resolution algorithm with no explicit motion estimation. Results on several test movies show that the proposed method is very successful in providing super-resolution on general sequences.

Michael Elad
Computer Science Department
Technion
elad@cs.Technion.AC.IL

Matan Protter
The CS depoartment
The Technion, Israel
matanpr@cs.technion.ac.il

Hiro Takeda, Peyman Milanfar
EE Department, UCSC, Ca.
htakeda@soe.ucsc.edu, milanfar@soe.ucsc.edu

MS40

Adaptive Non-local Transforms for Image/video Denoising, Restoration, and Enhancement, and for Compressive Sensing Image Reconstruction

The talk is devoted to a powerful and effective extension of the non-local filtering paradigm. We replace the conventional non-parametric image modeling based on the sample mean or weighted mean by a transform-domain representation where multiple patches from different spatial locations are collectively represented in higher-dimensional data structures. This corresponds to a non-local image transform which is adaptive with respect to the image content. We illustrate this approach and give an overview of its successful application to several image processing problems. The common point is enforcing sparsity within this overcomplete non-local representation. In most of the presented examples, the BM3D (Block-Matching and 3D filtering) denoising algorithm [Dabov et al., IEEE TIP 16(9) 2007] is used as a pragmatical way to generate the adaptive representation and to then enforce sparsity via shrinkage. Besides the basic image and video denoising problem, we will address image restoration (deblurring), image enhancement (sharpening), and compressive sensing image reconstruction (inverse tomography, image upsampling/zooming, and image interpolation). The presented methods are expression of the state-of-the-art, in terms of both objective and subjective visual quality. This quality is achieved at a competitive computational cost. We conclude the talk highlighting few open problems. The material of the talk is joint work with Kostadin Dabov, Aram Danielyan, Vladimir Katkovnik, and Karen Egiazarian.

Alessandro Foi
Tampere University of Technology
Tempere, Finland
Alessandro.Foi@tut.fi

MS40

Fast Super-Resolution of Video Sequences using Sparse Directional Transforms

Innovations in display technology are fueling the growth of display resolution in all electronic devices ranging from portable handheld devices to television sets. However, the programming aimed at these devices has not always caught up with this increase in resolution due to various reasons such as limited bandwidth, backward compatibility to older devices and costs involving infrastructure upgrade. For example, in Japan, most video services are limited to either QCIF or QVGA resolution; however, new mobile phones are now capable of displaying VGA resolution. Furthermore, portable devices are no longer limited by form factor (and hence resolution) with innovations such as foldable displays and eyewear. Simple linear interpolation methods are typically used to bridge this gap in resolution. However, the images/videos obtained using these methods are usually blurred and do not lead to a good viewing experience. In this talk, we describe non-linear methods that exploit the sparseness of image/video signals to produce super-resolution reconstructions which are very sharp and are of good quality. However, these non-linear methods involve many iterations of a basic algorithm and are very slow. Using our state-of-the-art algorithm (SWAT), we can achieve similar quality or better in just two iterations. We will also describe the details of SWAT and the features that enable the algorithm to be fast.

Onur Guleryuz
DoCoMo Communications Laboratories USA
guleryuz@docomolabs-usa.com

Sandeep Kanumuri
DoCoMo USA Labs
skanumuri@docomolabs-usa.com

MS40

Bayesian Non-local Means, Image Redundancy and Adaptive Estimation for Image Representation and Applications

To develop better image analysis algorithms, new models able to capture the spatial and temporal regularities and geometries seen in images and videos are needed. In contrast to the usual pixel-wise methods, a line of work consists now in modeling semi-local interactions from image patches. In this talk, we propose statistical patch-based formulations inspired from the Non-local means filter (Buades, Coll, Morel 2005) for image analysis and detection of unusual spatio-temporal patterns in the scene.

Charles Kervrann
IRISA - INRIA Rennes / MIA - INRA
Rennes, France
ckervran@irisa.fr

Patrick Perez
IRISA - INRIA Rennes
perez@irisa.fr

Jerome Boulanger
Institut Curie
jerome.boulanger@curie.fr

MS41

Ultrasonic Detection and Characterization in Diffusive Media Using a Coherent Array of Transducers.

We present a new imaging technique dedicated to the detection of a target embedded in a strongly scattering medium. Our technique separates the single-scattered echoes from the multiple scattering background. Once this operation is performed, the detection of the target is achieved by applying the DORT method. The quality of detection is assessed theoretically with Random Matrix Theory and shown to be better than what is obtained with echography and the classical DORT method.

Alexandre Aubry
Laboratoire Ondes et Acoustique
ESPCI
alexandre.aubry@espci.fr

Arnaud Derode
Laboratoire Ondes et Acoustique
Université Paris 7
arnaud.derode@espci.fr

MS41

Stability of Kinetic Models for Imaging in Random Media

Kinetic models offer an accurate description of the propagation of high frequency waves in heterogeneous media when the so-called mean free path is comparable to or small compared to the overall distance of propagation. In order to use the kinetic models to solve imaging or inverse problems, we also need to ensure that the measurements are statistically stable, i.e., independent of the realization of the random medium. The statistical instability may be characterized by the so-called scintillation function. In the simplified Ito-Schroedinger regime of wave propagation, we obtain explicit bounds and limiting expressions for the scintillation function as the wavelength of the propagating waves tends to zero. This is joint work with Olivier Pinaud.

Guillaume Bal
Department of Applied Physics & Applied Mathematics
Columbia University
gb2030@columbia.edu

MS41

Layer Anihilator and Smooth Velocity Estimation in Finely Layered Media

This talk is concerned with acoustic wave imaging of localized scatterers in finely layered media. We introduce a novel data filter, called a layer anihilator which is designed to enhance the echoes coming from the scatterers that we wish to image. The success of the filter depends on our knowledge of the smooth part of the background velocity and, in fact it provides an efficient tool for estimating it. We shall discuss some theory and show numerical results.

Liliana Borcea, Fernando González del Cueto
Rice University
Dept Computational & Appl Math
borcea@caam.rice.edu, fcueto@caam.rice.edu

George C. Papanicolaou
Stanford University
Department of Mathematics
papanico@math.stanford.edu

Chrysoula Tsogka
University of Crete and FORTH-IACM
University of Crete
tsogka@tem.uoc.gr

MS41

Background Velocity Estimation Using Cross Correlations of Incoherent Waves

We will analyze the incoherent waves reflected by a random medium in the case in which the medium has three-dimensional rapid random fluctuations and one-dimensional slow variations. We will show that the second-order statistics of the reflected wave is determined by the slow spatial variations of the background velocity via a system of transport equations. By observing the reflected wave, it is possible to invert this system and to reconstruct the background velocity.

Josselin Garnier
Universite Paris 7
garnier@math.jussieu.fr

Knut Solna
University of California at Irvine
ksolna@math.uci.edu

MS41

Coherent Interferometric Imaging for Synthetic Aperture Radar in the Presence of Noise

We discuss the coherent interferometric imaging strategy in the context of synthetic aperture radar, in which a single antenna is used as an emitter and as a receiver at successive positions along a trajectory.

Knut Solna
University of California at Irvine
ksolna@math.uci.edu

Josselin Garnier
Universite Paris 7
garnier@math.jussieu.fr

MS42

Phase Estimation from Intensity-Only Field Measurements

Two recursive methods are presented, and compared, for estimating the amplitude and phase of a wave field from intensity-only measurements on two or more planes. The problem is framed as a nonlinear optimization, and the two techniques are specified by similar formulas, despite fundamental differences in the optimization criterion used for each. Results will be presented from both simulated and experimental data. Relevant applications would include, e.g., near-field antenna measurements, holography, tomography, and inverse SAR imaging.

Ross W. Deming
consultant, General Dynamics IT
ross.deming@hanscom.af.mil

Robert Linnehan
AFRL/RYHE
robert.linnehan2@hasncom.af.mil

MS42

Ultra Narrowband RF Tomography and Autofocusing

Ultra narrowband RF tomography uses a constellation of distributed sensors to form images with limited bandwidth. Experimental images have been formed using a single tone. The talk will present current experimental work at AFRL in this research area. In addition, a crucial step in coherent change detection from SAR images is accurate GPS/INS sensor location measurements. To improve upon these noisy estimates, we propose a scheme based on near-field geometric invariants and persistent sensing.

Jason T. Parker
AFRL/RYRT
jason.parker@wpafb.af.mil

Matthew Ferrara
AFRL/RYAT
matthew.ferrara@wpafb.af.mil

MS42

Compressive Sensing for Multi-Static Radar Imaging: Theory and Numerical Experiments

The compressive-sensing framework assumes the scene is relatively sparse in some (unknown) basis and the measurements are made in another basis with the appropriate properties. We address (i) the discrete sampling approximation of the image space, (ii) the satisfaction of the "restricted isometry property" as a function of waveform design and collection geometry, and (iii) robustness to clutter/noise. Finally, we present some illustrative numerical experiments related to this theory.

Mark Stuff, Brian Thelen, Nikola Subotic, Kyle Cooper, William Buller
MTRI
mark.stuff@mtu.edu, brian.thelen@mtu.edu, nikola.subotic@mtu.edu, kyle.cooper@mtu.edu, william.buller@mtu.edu

Jason T. Parker, James Browning
AFRL/RYRT
jason.parker@wpafb.af.mil, james.browning@wpafb.af.mil

MS42

Wide-band Pulse-echo Imaging with Distributed Apertures in Multi-path Environments

We derive a new image reconstruction method for distributed apertures operating in complex environments. The aperture elements can be distributed spatially in an arbitrary fashion, can be several hundred wavelengths apart, and can involve transmission from multiple elements simultaneously. Moreover, the object to be imaged can be either in the near-field or far-field of the array. Our method is capable of exploiting information about multipath scattering in the environment, statistics of the objects to be imaged, and statistics of the additive (possibly non-stationary) noise. We formulate the image reconstruction problem as an inversion of a bilinear mapping that maps object reflectivity to an operator which in turn acts on the transmitted waveforms. We use transmitted waveforms to reveal the action of this bilinear mapping. We develop a minimum-norm inversion which takes the form of a family of linear operators (a filter bank) applied to the pulse-echo measurements. This processing is implemented by means of inner products between the measurements and pre-computed quantities, separately for each receiving element. Our approach is therefore well suited for parallel implementation, and can be performed in a distributed manner.

Birsen Yazici
Department of Electrical, Computer and Systems Engineering
Rensselaer Polytechnic Institute
yazici@ecse.rpi.edu

MS43
Spectral Surface Quadrangulation

I will discuss our work on remeshing triangulated surfaces with meshes composed entirely of well-shaped quadrilaterals and with very few extraordinary points. The basis for this method is our Morse-theoretic analysis of the eigenfunctions of the Laplace-Beltrami operator on piecewise-linear manifolds, which induces a decomposition of the surface into quadrangular patches. The meshes we produce faithfully preserve the structure of the original shape, and are quite well-suited for use in constructing Catmull-Clark subdivision surfaces.

Michael Garland
NVIDIA
mgarland@nvidia.com

Timo Bremer
LLNL
ptbremer@llnl.gov

MS43
Shape Recognition Schemes Based on the Spectrum of the Laplacian

Spectral methods based on the eigenvalues of the Laplacian are emerging as a very robust tool in computer vision applications such as shape recognition and image retrieval. Features that arise naturally in the theoretical study of eigenvalue estimates–based on combinations of eigenvalues, or on dimensionless combinations of these physical attributes with various geometric quantities–are invariant and can be used to uniquely characterize objects. In this presentation, we will demonstrate these notions through various applications.

Lotfi Hermi
University of Arizona
Department of Mathematics
hermi@math.arizona.edu

MS43
Quadrature Formulas on Manifolds

Let X be a smooth manifold, $\mathcal{C}$ be a finite set of points on X, λ_k, ϕ_k be the eigenvalues and eigenfunctions of the Laplace Beltrami operator on X, μ be the volume element of X. For $\lambda \geq 0$, we denote the span of $\{\phi_k \ : \ \lambda_k \leq \lambda\}$ by V_λ. For λ to be determined by the mesh norm of $\mathcal{C}$, we prove the existence of nonnegative numbers w_ξ, $\xi \in \mathcal{C}$, such that

$$\sum_{\xi \in \mathcal{C}} w_\xi P(\xi) = \int_X P d\mu, \qquad P \in V_\lambda.$$

This is joint work with F. Filbir at GSF, Munich.

Hrushikesh Mhaskar
California State University, Los Angeles
Dept. of Mathematics
hmhaska@calstatela.edu

MS43
Can We Hear the Shape of Neurons?

Neuroscientists are interested in understanding functionality of neurons using morphology of their dendrite patterns. Extracting morphological/geometric information of such complicated patterns, however, is a formidable task. We propose a method to classify such dendrite patterns using the eigenvalues of the Laplacian defined on them. These Laplacian eigenvalues are known to contain geometric information of the domain, such as volume, surface area, etc. Hence, we can use them as features for classification of the dendrite patterns.

Naoki Saito
Department of Mathematics
University of California, Davis
saito@math.ucdavis.edu

MS44
Motion Compensation in Gated Emission Tomography

We present a method for reconstructing cardiac image frames and motion using only gated cardiac emission data. Numerical results which demonstrate the superiority of the propose algorithm over standard approaches will be presented.

Bernard A. Mair
University of Florida
Department of Mathematics
bam@math.ufl.edu

MS44
Unsupervised Feature Balancing Multi-Phase Segmentation

The feature balancing method solves an instability issue associated with choosing the number of phases needed to segment the image appropriately. We propose a new variational functional for an unsupervised multiphase segmentation, by adding scale information of each phase. Unsupervised means this method doesnt require any training set nor knowing how many number of phases are needed for a segmentation. We develop a functional that automatically chooses the reasonable number of phases to be detected as well as identify each phase. Using the inverse scale term of each phase, we balance the scale of the features of the images among the phases, while the segmentation is driven by the intensity fitting term. For the numerical method, we explore a fast pixel-wise decision process for the proposed functional. We present number of experiments showing the robustness of this method.

Berta Sandberg
University of California Los Angeles
Department of Mathematics
bsand@math.ucla.edu

Sung Ha Kang
University of Kentucky
Mathematics Department
skang@ms.uky.edu

Tony Chan
University of California Los Angeles
tonyc@college.ucla.edu

MS45

Title Not Available at Time of Publication

Abstract not available at time of publication.

Selim Esedoglu
Department of Mathematics
University of Michigan
esedoglu@umich.edu

MS45

Title Not Available at Time of Publication

Abstract not available at time of publication.

Eldad Haber
Emory University
Dept of Math and CS
haber@mathcs.emory.edu

MS45

Region-Scalable Active Contour Model for Image Segmentation

Intensity inhomogeneities often occur in real-world images and may cause considerable difficulties in image segmentation. We present a new active contour model that draws upon intensity information in local regions at a controllable scale. A region-scalable fitting energy is defined in terms of a contour and two fitting functions that locally approximate the image intensities. This energy is then incorporated into a variational level set formulation with a level set regularization. Due to the scalability, the proposed model is able to segment images with intensity inhomogeneity. Experimental results for synthetic and real images show desirable performances and promising applications.

Chiu Yen Kao
Department of Mathematics
The Ohio State University
kao@math.ohio-state.edu

MS45

Inpainting by Flexible Haar-Wavelet Shrinkage

The task of inpainting is to recover missing regions in an image from the observed (sometimes noisy) incomplete data. We combine ideas from anisotropic regularization and diffusion with Haar-wavelet shrinkage to create a new iterative inpainting algorithm. Each iteration consists of a denoising step which is solved by adaptive Haar-wavelet shrinkage and a second step which corrects the denoised image where the data is known. Due to the anisotropic nature of our denoising step, the algorithm can better handle degraded pixels at edges. Our inpainting algorithm can be interpreted as a forward-backward splitting method to minimize a certain functional. We prove convergence of the algorithm, in particular the existence of a minimizer of the corresponding functional. Numerical examples illustrate the good performance of our inpainting method. This is joint work with R. H. Chan (The Chinese University of Hong Kong) and G. Steidl (University of Mannheim).

Simon Setzer
University of Mannheim
ssetzer@kiwi.math.uni-mannheim.de

MS46

Title Not Available at Time of Publication

Abstract not available at time of publication.

Richard G. Baraniuk
Rice University
Electrical and Computer Engineering Department
richb@rice.edu

MS46

A Taste of Compressed Sensing

Compressed sensing seeks to capture a signal/image with as few measurements as possible. We shall give a brief discussion of this fascinating field with the emphasis on the accuracy of representation in the compressed sensing setting.

Ronald DeVore
Department of Mathematics
University of South Carolina
devore@math.sc.edu

MS46

A Unified Approach to Signal and Image Recovery

I will discuss recent advances in the unification of combinatorial and geometric descriptions of linear measurements for signal and image recovery.

Anna Gilbert
Department of Mathematics
University of Michigan
annacg@umich.edu

MS46

New Results in Sparse Representation

Sparse image representation benefits tremendously from L-1 based methodology. Recently, new modification (that utilizes reweighting) was proposed in both statistics and compressive sensing communities. We report theoretical and experimental results in this line of research.

Xiaoming Huo
Georgia Institute of Technology
xiaoming@isye.gatech.edu

MS47

High-resolution Reservoir Imaging and Monitoring by Regularized Inversion

Imaging methods based on a regularized linearized inversion of seismic data improve the image when complex overburden distorts the propagating wavefield. Iterative inversion is computationally expensive, but for "target-oriented" imaging the computational cost can be dramatically reduced by the explicit computation of the Hessian of the linearized inverse problem. The "target-oriented" methodology is also very effective when applied to the reservoir monitoring problem when we estimate the baseline image jointly with the variations in reflectivity.

Biondo L. Biondi
Stanford University
Geophysics Department
biondo@stanford.edu

Alejandro Valenciano, Gboyega Ayeni
Stanford University
Stanford Exploration Project
valencia@sep.stanford.edu, gboyega.ayeni@yahoo.com

MS47

Seismic Demigration/migration with Curvelets

Seismic migration consists of retrieving the Earth properties (reflectivity) from surface seismic measurements. The result depends on the background velocity model that controls the wave propagation through the Earth. Starting from a reference migrated section, we show how curvelets can efficiently predict a series of other migrated images for perturbed velocity models. The result is obtained by analyzing the distortion of curvelets through the combined demigration/migration operator associated to two different velocity models.

Herve Chauris
Ecole des Mines de Paris
Centre de Geosciences/Geophysique
herve.chauris@ensmp.fr

Truong Nguyen
Ecole des Mines de Paris
truong.nguyen@ensmp.fr

MS47

Cubic Scaling for Caustics and Tangential Reflections

Wavefronts propagating in non-homogeneous media will generically develop caustics in finite time. While curvelets can be used to decompose the image, there is significant overlap near the caustic point. In this talk we discuss a disjoint decomposition of the wavefront, which involves a dyadic-cubic decomposition in the frequency domain. This cubic scaling also arises in the appropriate decomposition of reflected wavefronts near points of tangential contact with convex obstacles.

Hart Smith
University of Washington
hart@math.washington.edu

MS47

Discrete Symbol Calculus and Applications to Seismic Imaging

The complexity of solving the time-dependent wave equation via traditional methods scales faster than linearly in the complexity of the initial data. This behavior is mostly due to the necessity of timestepping at the CFL level, and is hampering the resolution of large-scale inverse scattering problems such as reflection seismology. We report on some algorithmic progress toward time upscaling of the wave equation using discrete symbol calculus for pseudodifferential and Fourier integral operators.

Lexing Ying
University of Texas
Dept. of Mathematics
lexing@math.utexas.edu

Laurent Demanet
Mathematics, Stanford
demanet@gmail.com

MS48

Image Reconstruction from Sparse Data in Photoacoustic Tomography

Photoacoustic tomography (PAT) is a hybrid imaging modality that combines the advantages of optical and ultrasound imaging methods. In current implementations of PAT severely incomplete data sets are typically acquired. In this work, we investigate recent advancements in sparse data image reconstruction within the context of PAT and demonstrate their implications for 3D PAT imaging.

Mark A. Anastasio
Dept. of Biomedical Engineering
Illinois Institute of Technology
anastasio@iit.edu

Emil Sidky
Department of Radiology
The University of Chicago
sidky@uchicago.edu

Kun Wang
Dept. of Biomedical Engineering
Illinois Institute of Technology
kwang16@iit.edu

Xiaochuan Pan
The University of Chicago
Department of Radiology
xpan@uchicago.edu

MS48

Nonconvex Compressive Sensing: Random vs. Structured Sampling

Among the many applications of compressive sensing is the ability to reconstruct images from very few measurements, such as X-ray images or MRI samples. Nonconvex variants have been shown to require even fewer measurements. We examine these methods in the context of reconstructing images (in two or three dimensions) having a sparse gradient, and compare performance and robustness to noise under various sampling procedures.

Rick Chartrand
Los Alamos National Laboratory
rickc@lanl.gov

MS48

Challenges and Methods in PET Image Reconstruction

We present a dual-plate positron emission tomography (PET) scanner for small-animal imaging that can achieve a sensitiivity that is about an order of magnitude better than most existing small-animal PET systems. However, this scanner employs a compact and stationary scanner geometry, and present substantial challenges in image reconstruction. We describe these challenges and discuss methods to address them. We also present a new mathematical formulation for time-of-flight (TOF) PET imaging that can enable reconstructions that are adaptive to local data statistics. Specifically, this new formaulation will enable the use of truncated TOF-PET data function to provide region-of-interest (ROI) imaging.

Chien-Min Kao
Dept . of Radiology

The University of Chicago
c-kao@uchicago.edu

MS48

Image Reconstruction from Incomplete Data in x-ray Projection-based Tomographic Imaging

In the field of compressive sensing there has been much recent progress in sparse image recovery from sparse Fourier transform data, using L1-norm or total variation (TV) minimization of the estimated image. These theoretical advances have implications for tomographic image reconstruction such as Computed Tomography (CT). We have recently been investigating the possibility of image reconstruction from sparse or incomplete x-ray projection data. We will report on recent results for image reconstruction in CT and tomosynthesis.

Emil Sidky
Department of Radiology
The University of Chicago
sidky@uchicago.edu

Xiaochuan Pan
The University of Chicago
Department of Radiology
xpan@uchicago.edu

MS49

Regularization Methods for Ill-Posed Poisson Imaging, Part 1, Computation

In image processing, data is typically collected by a CCD camera, in which case the noise is primarily of Poisson type. When this is taken into account, the negative-log of the Poisson likelihood function, which is non-quadratic but convex, results. A regularization function is added standard Tikhonov, total variation, and differential regularization and the resulting nonnegatively constrained minimization problem is solved using the method that is the focus of this talk.

Johnathan M. Bardsley
University of Montana
bardsleyj@mso.umt.edu

MS49

Regularization Methods for Ill-Posed Poisson Imaging, Part 2, Analysis

The discrete problems considered in the first talk can be viewed as discretizations of variational problems over appropriate function spaces. In this talk, we focus on an analysis of these variational problems. Because we want to use our method for image deblurring as well as for denoising, it is necessary to allow for the underlying model to be ill-posed, in which case it must be shown that the regularized problems are well-posed and convergent.

Dara Laobeul
University of Montana
lndara@hotmail.com

MS49

A Fixed-Point Formulation for Mumford-Shah Segmentation with Data-dependent Regularization

It has been shown that reinitialization of the level set function, though theoretically essential, is often in practice unnecessary for traditional Mumford-Shah segmentation and more recent variations. In this work, we give an explanation for this phenomenon in terms of a fixed-point formulation for solving the Euler-Lagrange equations associated with an adaptation of the Mumford-Shah segmentation algorithm with an edge-based, data-dependent regularization.

Aaron Luttman
Clarkson University
aluttman@clarkson.edu

MS49

L1TV computes the Flat Norm: Some Theory and Applications

In recent work with Simon Morgan, we have shown that the Chan-Esedoglu L1TV functional from image analysis actually computes the flat norm from geometric measure theory. The practical ramifications of this observation are very promising. In the talk I will explain the result and give examples of applications.

Kevin Vixie
Los Alamos National Lab
vixie@speakeasy.net

MS50

TV Regularization Techniques in Photonic Imaging

In this talk we discuss TV regularization techniques for cartoon reconstruction and segmentation of images in inverse problems. We simultaneously combine EM algorithms and total variation regularization to obtain reconstructions of image data with Poisson noise. Extensions to iterative regularization by using Bregman iterations and inverse scale-space methods are studied. We investigate anisotropy concepts incorporating a-priori knowledge about the object geometry. Numerical results for deconvolution problems in optical nanoscopy and molecular imaging based on PET illustrate our proposed methods.

Christoph Brune
University of Muenster, Germany
christoph.brune@uni-muenster.de

MS50

Nanoimaging of Cellular Structures

A serious problem for the nanoimaging of cellular macromolecular complexes is the conventional light optical resolution restricted to about 200 nm laterally and 600 nm axially. Various recently introduced laseroptical nanoscopy approaches such as 4Pi- and STED/RESOLFT Microscopy allowed to overcome this problem and to extend the spatial analysis far beyond these limits. Here we report on two alternative approaches, SMI (Spatially Modulated Illumination) microscopy and SALM (Spectrally Assigned Localization Microscopy). (SMI) far field light microscopy uses structured illumination to improve spatial analysis. SALM is based on labelling of point like objects with different spectral signatures (colours), spectrally selective registration and high precision localization monitoring. In this report, the focus will be on SMI and SPDM (a particular SALM procedure) nanoimaging approaches. Using SPDM, under appropriate conditions we presently achieve an effective optical lateral resolution of cellular nanostructures in the 10 nm range (ca. 1/50 of the exciting wavelength).

In combination with appropriate laseroptical tools, SPDM and other SALM techniques are expected to eventually allow to achieve an effective far field lightoptical resolution in 3D down to the molecular scale (few nm, or 1/50 to 1/100 of the exciting wavelength).

Christoph Cremer
University of Heidelberg
cremer@kip.uni-heidelberg.de

MS50

Statistical Multiresolution Criteria for Deconvolution Problems in Microscopy

In recent years, there has been a growing interest within statistics to study multiresolution criteria which allow to distinguish white noise from data containing some structure at some, non-specified resolution. Applying these criteria to the residuals of an image denoising procedure allows one to judge the quality of the image restoration as the residuals constitute estimates of the noise. The usefulness of this approach has recently been demonstrated for stopping the EM-algorithm in positron emission tomography. We will present further applications for deconvolution problems in 4Pi-microscopy.

Thomas Hotz
Universität of Göttingen
hotz@math.uni-goettingen.de

MS50

Cells, Images...and Numbers: A Numerical Look at Biological Imaging

This talk will address the development of new algorithms for the quantitative analysis of images and to their use in biological projects, such as the detection and tracking of virus in cells, the study of the dynamics of genes in cell nuclei or the movement of quantum dots in cells. It will therefore be at the interface between signal/image processing and cell biology.

Jean-Christophe Olivo-Marin
Institut Pasteur, Quantitative Image Analysis Unit,
CNRS
jcolivo@pasteur.fr

PP0

Multi-Resolution Analysis of Images Via Discrete Pulse Transform

The Discrete Pulse Transform (DPT) is a well-known design method for multi-resolution analysis of sequences. Following a recent generalization of the LULU operators to multidimensional arrays we define DPT of images. The set of discrete pulses in the decomposition of an image are grouped according to certain criterion (e.g. size) to form different resolution layers. The total variation preservation property of DPT implies that the information in the original image is split between the resolution layers without distortion.

Roumen Anguelov
University of Pretoria
roumen.anguelov@up.ac.za

PP0

New Combination Methods to Form Saliency Map for Visual Attention

Some new strategies of combining feature maps to form a saliency map are addressed in this paper. Traditional methods of making saliency map in visual attention are to linearly combine early visual feature maps in a bottom-up manner. In this approach, effect of each feature map would be superimposed to another to finally form saliency map. Here, we have proposed some nonlinear combination methods which can maximally mimic the human visual attention system in order to detect conspicuous objects in a scene.

Hamed Bahmani
Science and Research University
Biomedical Engineering Department
hbahmani@gmail.com

Ali Motie Nasrabadi
Shahed University
Biomedical Engineering Department
nasrabadi@shahed.ac.ir

Mohammad Reza Hashemi Gholpayeghani
Amirkabir University of Technology
Biomedical Engineering Department
hashemi_g@morva.net

PP0

A Flexible Variational Approach to Generalized Gradients in Image Processing

Traditionally geometric energy minimization approaches to image segmentation have almost exclusively been based on the L^2 gradient descent, despite its disadvantages in some applications. So recently generalized gradients, in particular H^1 type gradients, have been proposed as a remedy. In this work, we introduce a novel Lagrangian numerical method to compute generalized gradients. The method is valid in any number of dimensions and allows design and computation of novel geometrically-weighted gradients. We demonstrate the advantages of our approach on Geodesic Active Contour and Mumford-Shah models.

Gunay Dogan
School of Engineering and Applied Science
University of Pennsylvania
gdogan@seas.upenn.edu

Pedro Morin
Departamento de Matemática
Universidad Nacional del Litoral, Argentian
pmorin@math.unl.edu.ar

Ricardo Nochetto
Department of Mathematics
University of Maryland, College Park
rhn@math.umd.edu

PP0

Image Manifolds for Image Processing

A common assumption is that appropriately defined sets of images (e.g. "natural images") form a manifold. We consider projection into such a manifold as a mechanism for image restoration, including denoising as well as more general problems such as deconvolution. In particular, we will focus on practical methods for estimating, given an image or image block to be restored, the appropriate neighborhood on this manifold.

David W. Dreisigmeyer
LANL
dreisigm@lanl.gov

Brendt Wohlberg
Los Alamos National Lab
brendt@lanl.gov

PP0

Fourier Transform of Generalized Gaussian Distribution and Atmospheric Parameters Estimation

The generalized Gaussian distribution GGD is a probability law that is largely used in the field of computer vision and image processing. Until now, the Fourier Transform of the GGD (FTGGD) has not been calculated yet. In this paper we introduce an analytical expression for the FTGGD. Based on this result, we introduce a new computer vision approach : knowing that the atmospheric veil on images is modelled by a GGD based kernel, we use the FTGGD in the estimate of the atmospheric parameters, namely, the optical thickness and the forward scattering parameter.

Franois F. Dubeau, Samir El Mashoubi
Université de Sherbrooke
francois.dubeau@usherbrooke.ca,
samir.el.mashoubi@usherbrooke.ca

Samy Metari
Université de Sherbroole
samy.metari@usherbrooke.ca

Franois Deschnes
Université du Québec en Outaouais
francois.deschenes@usherbrooke.ca

PP0

Non-Local Approaches to Image and Video Resolution Enhancement

We introduce novel "super-resolution" schemes for single images and multi-frame image sequences. Our methods are closely associated with the recently developed "non-local-means denoising filter". The single-frame algorithm relies on the regularity properties of natural images at different scales. In the multi-frame algorithm, no explicit motion estimation is performed, unlike in many other methods. Our results are comparable, if not superior, to many existing approaches, especially in the case of low signal-to noise ratio.

Mehran Ebrahimi
Dept. of Applied Mathematics
University of Waterloo
m2ebrahi@math.uwaterloo.ca

Edward R. Vrscay
Department of Applied Mathematics
University of Waterloo
ervrscay@uwaterloo.ca

PP0

Image Filtering Based on the Prolate Spheroidal Wave Functions

In this talk we discuss the design of windowing techniques based on the Prolate Spheroidal Wave functions, and its application in image filtering. Prolate Spheroidal Wave functions are a band-limited basis that have optimal concentration in the spatial domain. We study the effect of such windows on the original image in both spatial and frequency domains. Design principles and examples in image denoising will be presented.

Maria C. Gonzalez
University of California, Davis
margonza@ucdavis.edu

Hong Xiao
University of California at Davis
hxiao@ucdavis.edu

PP0

On the Improvement of Total Variation Regularization and Its Application on Partially Parallel Imaging

Title: On the improvement of Total Variation regularization and its application on partially parallel imaging Abstract: Difficulty in choosing appropriate parameter limits application of Totoal Variaion (TV) as a regularization tool. We use local mutual information to simplify the parameter decision. The framework is demonstrated through application on Partially Parallel Imaging, for which there is a regulating image with high Signal to Noise Ratio (SNR) but lower spatial resolution, in addtion to the to-be-smoothed low SNR high resolution image. Local mutual information between them is utilized to detect noise/artifac distribution and edges, with which spatially adaptive regularization parameter and type are determined. Iterative regularization is incorporated to pick up signal from residuals. An automatic termination criterion is also provided. Potentially, the proposed method can be applied to general noisy images that do not have regulating images. One possible scheme is to apply a low pass filter on the noisy images to creat regulating images.

Weihong Guo
Department of Mathematics, University of Alabama
wguo@as.ua.edu

Feng Huang
Invivo Corporation
fhuang@invivocorp.com

PP0

Title Histogram Modal Analysis Using the Helmholtz Principle

An algorithm for two dimensional histogram modal analysis that is devoid of any a priori assumptions about the underlying density or the number of modes is presented. A major challenge in two dimensional histogram analysis is to provide an accurate location and description of the extended modal shape. Our approach combines the Fast Level Set Transform of the histogram, the Helmholtz principle along with some new bounds for the tail sum of the multinomial distribution to produce a parameterless method to find the location and shape of the modes. With no a priori knowledge about the color image assumed, the two dimensional modal analysis is applied to color image

histogram segmentation of the CIELAB color space.

Gary Hewer
NAWC Weapons Division
Gary.Hewer@navy.mil

PP0

Critical Regions in Multidimensional Lattice Height Data

We propose a new method, inspired by the Conley index theory and by the framework of discrete multivalued dynamical systems, for detection of critical regions and connections between them in arbitrary dimensions. In contrast to previously known approaches, topological information is extracted from the original data without forcing them to satisfy the isolation and non-degeneracy assumptions of the Morse theory. This is the first step towards contributions to construction of isosurfaces and isovolumes.

Tomasz Kaczynski
Universite de Sherbrooke
Sherbrooke, Canada
tomasz.kaczynski@usherbrooke.ca

Madjid Allili
Bishop's University
Sherbrooke, Canada
mallili@ubishops.ca

David Corriveau, Sara Derivière
Universite de Sherbrooke
david.corriveau@usherbrooke.ca,
sara.deriviere@usherbrooke.ca

PP0

Relevant Transitions of the Gaussian Scale Space Hierarchy

The Gaussian scale space image is the solution of $\partial_t L = \Delta L$,$L_{t=0} = L(x)$. A hierarchical structure in $L(\mathbf{x}, t)$ is derived by combining the critical curves ($\nabla_{\mathbf{x}} L(\mathbf{x}, t) = 0$) containing catastrophe points ($\nabla_{\mathbf{x}} \nabla_{\mathbf{x}} L(\mathbf{x}, t) = 0$) and scale space saddles ($\Delta L = 0$), with iso-intensity manifolds through the scale space saddles. In this work we describe relevant possible transitions for the hierarchical structure when the structure is changed under the influence of one control parameter.

Arjan Kuijper
Radon Institute for Computational & Applied Mathematics
Austria
arjan.kuijper@oeaw.ac.at

PP0

On the Construction of Topology-Preserving Transformations

Considering two images called template and reference, registration consists in finding an optimal diffeomorphic transformation such that the deformed template matches the reference. The question of maintaining a diffeomorphism through the process motivates the proposed work. In this purpose, a functional minimization problem on a convex subset of an Hilbert space is studied from a theoretical and numerical viewpoint. We then see how it can be embedded in a more general algorithm to keep the determinant of the transformation positive.

Carole Le Guyader
IRMAR
INSA de Rennes, France
carole.le-guyader@insa-rennes.fr

Christian Gout
Université de Valenciennes
et du Hainaut-Cambrésis
christian.gout@univ-valenciennes.fr

Dominique Apprato
Universite de Pau
Dept Mathematique Recherche
dominique.apprato@univ-pau.fr

PP0

Non-Rigid Image Registration by Regional Mle Approach

In non-rigid image registration techniques, some developments have been made to improve the classical SSD(the Sum of Squared intensity Difference)model by using MLE approaches. In this presentation, we consider new technique that partitions the image domain into several regions of different statistics, and then, uses a regional MLE based approach to find the optimal deformation field.

Jinseop Lee
Department of Mathematics
Universtiy of Florida
lee@math.ufl.edu

Yunmei Chen
University of Florida
yun@math.ufl.edu

PP0

Wavelet-Based PCA for Face Recognition under Varying Illumination

An efficient wavelet subband representation method is proposed for face identification under varying illumination. In our presented method, prior to the traditional principal component analysis (PCA), we use wavelet transform to decompose the image into different frequency subbands, and a low-frequency subband with three secondary high-frequency subbands are used for PCA representations. Our aim is to compensate for the traditional wavelet-based methods only selecting the most discriminating subband and neglecting the scattered characteristic of discriminating features.

Mong-Shu Lee
Department of Computer Science and Engineering,
National Taiwan Ocean University
mslee@mail.ntou.edu.tw

PP0

Estimating Tumor Bounds in Bioluminescence Tomography

Bioluminescence tomography is an emerging small animal imaging modality that has many important applications in biomedical research, from drug development to studies of tumor metastasis. The prototypical model for this inverse source problem is based on the time-independent diffusion equation. While a general inversion algorithm is not feasible, the task of estimating a tumor volume can be approached using principles of compressive sensing and Ikehatas enclosure method.

Matthew A. Lewis
UT Southwestern Medical Center at Dallas
matthew.lewis@utsouthwestern.edu

PP0

Tomographic Reconstruction Through a Least-Squares-B-Splines Fitting

The reconstruction of the density function representing a section of a Fluid Catalytic Cracking process inside an opaque cylinder (riser) is proposed here. This is computed through the information of the attenuation suffered by a set of gamma rays that cross the riser. We propose a least squares fitting of a B-splines surface, assuming some smoothness conditions of the original function. The results seem satisfactory for a low number of projections and near radial functions.

Silvio Melo
Centro de Informática
Universidade Federal de Pernambuco
sbm@cin.ufpe.br

Carlos Dantas
Departamento de Energia Nuclear
Universidade Federal de Pernambuco
ccd@ufpe.br

Eric Oliveira, Francisco Simões
Centro de Informática
Universidade Federal de Pernambuco
ericfisica@yahoo.com.br, chicofpms@hotmail.com

Maria Santos
Centro de Cincias Exatas e da Natureza
Universidade Federal de Pernambuco
batgal60@yahoo.com.br

PP0

A Level Set Method Inspired Stereo Matching Technique

According to the level set method, shocks and expansion waves form at local extrema of the level set function. Away from local extrema, the speed function can be assumed to be smoothly varying. In vision problems, occlusions and disocclusions correspond to shocks and expansion waves respectively. This paper introduces the idea of feature fronts (as opposed to the traditional feature points) which are defined using the local extrema of a sufficiently (Gaussian-) smoothed image. By matching feature fronts between the left and right images, a simple dense stereo matching method is introduced. This method can be interpreted as a location-dependent adaptive windowing technique with the added twist that the window on the left image need not be of the same size as the window on the right image for corresponding pixels. By its construction, the method can handle illumination changes well. Mismatches introduced by sensor noise, specular reflection, occlusion, and disocclusion are explicitly detected and treated. Other distinguishing features of this geometry-based method are that it neither invokes the Markovian assumption nor uses robust distance metrics. This method is applicable to general scenes and is not restricted to scenes dominated by fronto-parallel surfaces.

Beddhu Murali
Essential Knowledge Systems, LLC
University of Southern Mississippi
embed@bellsouth.net

PP0

A convex projection algorithm for the Magnetoencephalography inverse problem

This poster presents a novel algorithm for the bioelectromagnetic inverse problem in which the parameters of equivalent current dipoles (ECDs) representing the brain neural activities are estimated from magnetoencephalography (MEG) data. The ECD positions projected on the xy-plane has been well localized algebraically by the direct method proposed by us. In this poseter, we propose a convex projection algorithm to estimate the unmeasured magnetic field on the lower hemisphere of the head so that the z-components of the ECD positions are also well reconstructed.

Takaaki Nara
The University of Electro-Communications
nara@mce.uec.ac.jp

Shigeru Ando
The University of Tokyo
ando@alab.t.u-tokyo.ac.jp

PP0

Nmda Receptors Are Involved in Ginkgo Extract-Induced Facilitation on Memory Retention of Passive Avoidance Learning in Rats

The current study intended to investigate the effect of Ginkgo intake on amnesia while NMDA (N-methyl d-aspartic acid) receptors blocked by the administration of MK-801. The study used passive avoidance (PA) task to investigate the effect of chronic administration of Ginkgo extract (40 and 90 mg/kg; oral) on the memory span in male Wistar rats, suffering from MK-801-induced forgetfulness (0.06 and 0.1 mg/kg; i.p.). The results indicate that Ginkgo was able to remove MK-801-induced forgetfulness, indicating that Ginkgo can affect memory retention but not effect on passive avoidance acquisition, using pathways other than glutamatergic system as well.The results might indicate that Ginkgo extract can be effective in removing forgetfulness caused by inhibiting NMDA receptors from performing their activities.

Elaheh Nooshinfar
Shaheed Beheshti Medical University
e_nooshinfar@yahoo.com

PP0

Extracting Phase from X-Ray Images for Motion Modeling

To design an efficient radiation treatment for lung or liver cancer patients, knowledge of respiratory motion is important. To model this motion, we take a series of x-ray images in a treatment position and develop an algorithm to reconstruct a respiration phase in every image by assessing deformation between images. We also present error analysis based on experiments with moving phantoms.

Olesya Peshko

McMaster University
peshkoo@mcmaster.ca

Douglas Moseley, Andrew Hope
Princess Margaret Hospital
douglas.moseley@rmp.uhn.on.ca,
andrew.hope@rmp.uhn.on.ca

Tamas Terlaky
Dept. of Computing and Software
McMaster University
terlaky@mcmaster.ca

PP0
A Novel Numerical Technique for Fluorescence-Enhanced Optical Tomography

Fluorescence-enhanced near infrared (NIR) optical imaging is a developing diagnostic and prognostic tool for cancer screening. Optical imaging problem was formulated as a nonlinear least-squares-type simple bounds constrained optimization problem. A novel image reconstruction algorithm was developed based upon the Penalty modified barrier function and the gradient based truncated Newton with trust region method for large scale problems. Three dimensional images of fluorescence absorption coefficients and lifetimes were reconstructed from experimentally measured data.

Ranadhir Roy
University of Texas-Pan American
rroy@utpa.edu

PP0
Large Blind Deconvolution in 4Pi Microscopy

The size and position of the main peak and the side lobes of the 4Pi convolution kernel depend on a phase parameter, which has been assumed to be space-invariant so far. This assumption is violated e.g. for inhomogeneous refractive indices, which is one of the main problems in 4Pi microscopy. The joint recovery of the three-dimensional density of fluorescent markers and the slowly varying phase function is considered as a nonlinear inverse problem, which is tackled by a special iterative regularization method.

Robert Stück, Thorsten Hohage
Georg-August-Universität Göttingen
stueck@math.uni-goettingen.de,
hohage@math.uni-goettingen.de

PP0
Incorporating Shape Boundary Information into Disconnected Skeleton Framework

Disconnected Skeleton was proposed as a novel shape representation. Based on a special distance surface estimated using iterative diffusion, it captures the very stable properties of shapes. However, this representation lacks the inclusion of information about shape boundary. To overcome this limitation, we propose to extract radii of the maximal disks along the extracted branches from a related distance surface proposed by Tari, Shah and Pien and to incorporate this information into disconnected skeleton framework.

Aykut Erdem
M.E.T.U.
Dept. of Computer Engineering
aykut@ceng.metu.edu.tr

Sibel Tari
Middle East Technical University
stari@metu.edu.tr

PP0
Resolution Analysis of Ionospheric Tomography

Ionospheric tomography is an inverse problem characterized by sparse data sets. We use simulated data to examine the ideal grid size given the spacing of ground receivers and the effects of over-refining the grid, and look at strategies for dealing with the highly uneven data coverage typical in this method.

Jenna R. Tong, Paul Spencer, Cathryn Mitchell
Department of Electronic and Electrical Engineering
University of Bath
jrt24@bath.ac.uk, p.spencer@bath.ac.uk,
c.n.mitchell@bath.ac.uk

PP0
Simulations for Methodological Comparisons among Multivariate Neuroimaging Techniques

Functional neuroimaging faces a dilemma. While moving toward more appropriate multivariate analyses of data, the early development of several distinct multivariate techniques (Partial Least Squares and Independent Component Analysis among others), without much research into how the methods compare with each other, has fractured the field. We develop a systematic collection of simulations for comparing the current methods, and for use as a basis of comparison as new methods are developed.

Matthew D. Turner
University of California, Irvine
Dept. of Cognitive Sciences
mturner@uci.edu

Jessica Turner
University of California, Irvine
Dept. of Psychiatry
turnerj@uci.edu

PP0
On Discrete Convolutions in a Quarter-Plane

For discrete convolution operator in a quarter-plane one consuders its Fourier image and shows the invertibility of such operator is equivalent to unique solvability of certain periodic linear conjugation problem for functions of two complex variables. Vasil'ev V.B., Wave factorization of elliptic symbols: theory and applications, Dordrecht-Boston-London, Kluwer Academic Publishers, 2000.

Vladimir B. Vasilyev
Department of Mathematics and Information Technologies
Bryansk State University
vbv57@inbox.ru

PP0
Orthant-Wise Gradient Projection Method for

Compressive Sampling

The compressive sampling problem can be formulated as l_1-regularized least square problem. The objective function can be reformulated as a quadratic approximation orthant-wise. We efficiently apply orthant-wise gradient projection method to solve this optimization problem, and prove its convergence to the global optimal solution. Computational experiments demonstrate that the proposed method outperforms other methods in previous literatures.

Qiu Wu
Electrical and Computer Engineering
The University of Texas at Austin
qwu@mail.utexas.edu

PP0

Improvement of Accuracy in Deformable Registration in Radiation Therapy

In deformable registration, the finer objects of low contrasts cannot be matched accurately while using the global Gaussian model. We now present a model that partitions the domain of the images into several regions such that the residue between the deformed and study images on each region is Gaussian distributed with zero mean and variance to be optimized. By taking different variances on different regions, the deformation can be more efficient and accurate.

Xiaojing Ye
Mathematics Department, University of Florida
358 Little Hall, Gainesville, FL32611-8105
xiaojing@math.ufl.edu

Yunmei Chen
University of Florida
yun@math.ufl.edu