CP1

Adaptive Finite Element Methods for Inverse Imaging Problems

In many realistic 3d imaging problems, such as biomedical tumor diagnostics or underground imaging, the resolution requested by practitioners is unachiavable using globally refined meshes. However, while now the leading paradigm in PDE solvers, adaptivity has not been widely used for inverse problems. We will present a mathematical framework for imaging applications using automatically adapted meshes, and present results obtained in optical tomography for tumor detection and sound wave imaging applications.

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CP1

A New Approach to Inverse Problem Solving Using Radon-Based Representations

We carry out image deconvolution by transforming the data into a new general discrete Radon domain that can handle any assumed boundary condition for the associated matrix inversion problem. For each associated angular segment, one can apply deconvolution routines to smaller (and possibly better) conditioned matrix inversion problems than the matrix inversion problem for the entire image. We then devise methods for doing this scheme locally to provide estimates based on a multi-scaled representation.

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CP1

Multiscale Formation Imaging Using Array Resistivity Logging Data

Existing log interpretation methods use a single model. Such an approach does not allow fully extracting information from the recorded logs. Our imaging method uses a set of log-resolution-dependent models designed for array tools possessing different vertical resolution and depth of investigation. We generate an image using coarse models, inverting the logs with the lowest resolution. We then perform iterative image refining using multiscale models. The method reconstructs the borehole's surrounding features clearly and quantitatively.

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CP1

Detecting Interfaces in a Parabolic-Elliptic Problem from Surface Measurements

Assuming that the heat capacity of a body is negligible outside certain inclusions the heat equation degenerates to a parabolic-elliptic interface problem. For the case that the heat conductivity is higher inside the inclusions we show by an adaptation of the so-called Factorization Method that the locations of the interfaces are uniquely determined by thermal measurements on the surface of the body. We also present some numerical results for this inverse problem.

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CP1

A Threshold-Based Method for Inverse Solutions to Reconstruct Complex Obstacles, with Application to the Inverse Problem of Electrocardiography

Inspired by the inverse problem of electrocardiography, we introduce a method to reconstruct a two-level image or image sequence with multiple objects and complex transition regions. We construct a first, two-level estimate of the solution (here, heart potentials) using an adaptive threshold-based boundary, which becomes a constraint for a second, Tikhonov regularized, estimate. We iterate (recursively or in time) between the two estimates. Simulation results using measured canine data show considerable improvement over standard Tikhonov solutions.

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CP1

Electron Microscope Tomography: Calculating and Inverting the Generalized Ray Transform

In order to ensure high quality three dimensional reconstructions from large images, electron microscope (EM) tomography requires compensation for the curvilinear trajectories of electrons through the sample. We report on generalizations of bundle adjustment, filtration and backprojection algorithms which are intended to achieve this purpose. These techniques have been realized in a new software system for EM tomography. Error estimates may be obtained via the theory of Fourier integral operators derived from the generalized ray transform.

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CP1

A New Level Set Technique for the Simultaneous Imaging of Shapes and Material Properties from Two-Phase Flow Data

In many imaging applications arising in the field of inverse problems the goal is to reconstruct regions in which the material properties assume two different values. In our talk we will present a novel level set strategy for finding simultaneously interfaces and properties of these regions. As an example, we will apply our novel technique to the situation of reservoir characterization from two-phase flow data. Numerical examples for realistic situations in 2D are shown as well.

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CP2

A Novel Image Registration Scheme Based on Watershed Transform and Curve Matching

We propose a novel and robust image registration scheme. First, a novel modified watershed segmentation followed by a region merging process is performed for the image pair to be registered. This algorithm preserves salient regions as well as closed region boundaries. Then a scale-space curve matching algorithm is used to select pairs of matching regions. Mutual information registration is performed on matched regions subsequently. The curve matching algorithm will provide initial values for the registration parameters. Our results will show automatic, high-quality registration.

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CP2

Proper Image Line Interpolation

Probability densities for the interpolation of lines of image pixels using Gaussian radial basis functions are considered, where the basis function variance is determined such that the interpolation extrapolates properly. Here proper extrapolation by definition asymptotically approaches the well-known linear mean and quadratic variance functions of the Gaussian probability density of the least squares line. A derivation of proper image line interpolation and examples of its application to real images are provided.

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CP2

A Variational Approach to Blending Based on Warping for Non-Overlapped Images

We present a new model for image blending based on warping. With partial differential equations the model gives a sequence of images, which has the properties of both blending of image intensities and warping of image shapes. We modified the energy functional in the paper by Liao et. al in order to adapt the idea of the shape warping to the image blending. We cover not only overlapped images but also non-overlapped ones.

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CP2

Mumford-Shah Super-Resolution

We introduce a new method for contructing a high-resolution image from a sequence of low-resolution images using the Mumford-Shah functional. Minimizing the Mumford-Shah energy also results in denoising, deblurring, and segmentation of the images. We discuss the problem of registration of the image sequence, a crucial first step in constructing an enhanced high-resolution image. Results will be presented discussing the capabilities and limits of image super-resolution.

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CP2

Nonrigid Image Registration Using Physically

Based Models

Though fluid model offers a good approach to nonrigid registration with large deformations, it suffers from the smearing artifacts introduced by the viscosity term. To overcome this drawback, we present an inviscid model expressed in a particle framework, and derive the corresponding nonlinear PDEs for computing the coordinate transformation. Our idea is to simulate the template image as a set of particles moving toward the target positions. The proposed model can accommodate small/large deformations, with sharper edges and less computational cost. We demonstrate the performance and efficiency of the proposed model on a variety of images including synthetic and real data.

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CP3
Minimal Sampling Requirements for Region-of-Interest Fourier Imaging

We consider the problem of reconstructing a specified subregion of a spatially limited function from samples of the Fourier transform of the function. For such a problem sampling at Nyquist rate is not necessary in general. We derive necessary and sufficient sampling conditions for uniform, and for periodically non-uniform sampling patterns; and obtain bounds on the sampling density for general non-uniform sampling. The results are extended to Papoulis generalized sampling scheme and applied to single-channel and parallel MR imaging.

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CP3
Fractal Image Coding: Beyond Compression?

Historically, most research in fractal image coding (FIC) focused on its compression capabilities. As such, much of the development was driven by bitrate considerations. What can be done when this constraint is removed? By recourse to a series of computer experiments, we show that a number of domain subblocks will, using affine greyscale maps, generally approximate a given range subblock almost as well as the optimal subblock (we also examine the distribution of domain-range approximation errors as a function of noise variance). Therefore, there is much potential for FIC to perform a variety of image processing tasks, e.g., noise reduction, edge detection, noise estimation. We report on a series of experiments that support this claim.

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CP3
Homeomorphisms Between Fractal Tops and Applications in Digital Imaging

New results relating to "overlapping" IFSs and their application to digital imaging and computer graphics will be presented.

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CP3
Generalized Fractal Image Coding Using Projections onto Convex Sets

We show how fractal image coding can be viewed and generalized in terms of the method of projections onto convex sets (POCS). Our work picks up on the Ph.D. thesis of T. Puh (1996) and his work with P. Combettes (1996) on operator theoretic image coding, showing explicitly how self-similarity properties of an image can be translated into POCS-type inequality constraints. We also show how POCS allows additional constraints to be applied along with fractal decoding. This formulation also permits a breaking away from the traditional idea of fractal coding as domain-to-range mapping. We outline the mathematical foundation of this approach along with some interesting applications including: (1) the elimination of post-processing in fractal decoding, (2) solving the problem of image reconstruction given an incomplete fractal code and (3) image denoising.

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CP3
Improving the Sampling Efficiency of Fast Tomographic Backprojection Algorithms

We introduce a new $O(N^2 log P)$ algorithm that backprojects an $N \times N$ pixel image from P projections. It expresses backprojection as the hierarchical shearing and addition of intermediate images with a distinctive "bow-tie"-shaped spectral support. Previous fast algorithms have not fully exploited this support. By maintaining the intermediate images in one frequency-variable and one space-variable, different frequency components can be sampled with different sampling periods, enabling a more efficient sampling scheme and reduced computation.

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CP3

Adaptive Sampling Based on the Frequency Distribution of Function Values

We show that a function space can be incrementally sampled based on the histogram of the function values in the already collected sample set. We present an adaptive sampling scheme based on active walkers whose step size adapts with the state of the histogram. Our approach is particularly suited for applications in which obtaining samples is expensive, making algorithms based on gradient or rejection sampling inefficient. We demonstrate the performance with various image processing examples.

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CP3

The Discrete Fourier Transform on Regular Hexagonal Structures and a fast algorithm

For various application in digital image processing, the use of hexagonal grid structures has proven advantageous over the commonly used square grid. Recent developments in the uses of hexagonal grids have led to several promising applications in Soil Moisture and Ocean Salinity space mission, and Equal Area Analysis of whole world imaging. In this talk we give an overview of hexagonally sampled image processing, and present the DFT on regular hexagonal structures and a fast algorithm. We also discuss several advantages of those new structures over other more well-known structures.

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CP4

Image Representation and Analysis in RNA Folding Predictions

Since the late 70's, energy minimization methods by dynamic programming have been devised to predict the RNA secondary structure given its primary sequence. The secondary structure of an RNA molecule is a representation of the pattern complementary base pairing that are formed between nucleic acids. The output of secondary structure prediction methods, in the form of energy dot plots, can be represented as images. By filtering and analyzing these images, information can be gained about RNA secondary structure motifs that are functionally important. Furthermore, by measuring distances between images, it is possible to predict which point mutations will cause conformational rearrangements by destroying or creating biologically relevant motifs.

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CP4

Application of a Search Model to the Assessment of Radiologist Performance

During image interpretation a radiologist searches an image for possible lesions and marks and rates suspect regions. A statistical model of this process and an estimation procedure for determining its parameters have been developed. The model accounts for the intrinsically unpredictable number of responses generated in such "free-response" studies. Location and confidence level data collected during mammographic image interpretations were analyzed to yield estimates of three parameters. These quantify the radiologist's ability to find lesions, the radiologist's ability to avoid non-lesion locations and the lesion's perceived signal-to-noise ratio. The first two of these are search parameters that have no counterpart in the widely used binormal model used to analyze ROC data. Knowledge of the parameters can be used to determine what type of radiologist training might be most helpful. Other potential applications of the method, including optimizing algorithmic observers, are indicated. Since search is a fundamental aspect of many activities in both human and machine vision, the ability to estimate the efficiency of an observer's search mechanism may have considerable significance.

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CP4

Ultrawideband Microwave Breast Cancer Detection: a Glrt for 3-D Mri-Derived Numerical Phantoms

Active microwave imaging is a promising modality for breast cancer detection that exploits the dielectric-properties contrast between malignant and normal breast tissue. We consider an ultrawideband radar technique using a generalized likelihood ratio test (GLRT) to detect tumors based on multichannel backscatter data obtained from 3-D MRI-derived numerical breast phantoms. Enforcing a low false discovery rate, we show that small tumors in heterogeneous breast tissue are consistently detected and localized.

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CP4

Solution X-Ray Scattering from Virus Particles Labeled with a Strong Scatterer and 3-D Reconstructions

Scattering of x-rays from a solution of identical virus particles measures the spherical average of the magnitude-squared of the electron number density in the particle. From this 1-D data set it is possible to infer 3-D structure at low spatial resolution. Analogous to isomorphous replacement in x-ray crystallography, a method is described for improving the 3-D structure by combining information from native and from labeled particles where the label is a strong x-ray scatterer. These problems involve non convex optimization problems which are solved by stochastic search.

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CP4

An Ideal-Observer Model for Optimizing an Energy and Depth-Dependent X-Ray Imaging System.

The Bayesian ideal observer sets an absolute upper bound for observer performance in a detection task, so it should be used for system optimization whenever possible. We formulate analytic expressions of probability density functions to estimate the likelihood ratios of an ideal-observer for an energy- and depth-dependent x-ray system model. This formulation uses the analytic characteristic function of the system and object representation in the x-ray spectrum. This likelihood ratio can be calculated numerically with a dimensionality-reduction method.

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CP4

An Iterative Approach to 3D Electron Density Imaging Using Scattered X-Rays

We have developed an analytical Compton scatter technique to image 3D electron density distributions with a single projection. This is the first step towards implementing quantitative 3D mammography aimed at improving the ability to detect and specify breast calcifications and tumors with no increase in dose. Using Monte Carlo simulation, this technique is able to localize single 0.5 mm diameter calcifications with a $1 \times 2.5 \times 2.5mm^3$ imaging resolution. An ROC analysis indicates 80% sensitivity and 95% specificity.

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CP4

Using Multiple Tensor Deflection to Reconstruct White Matter Fiber Traces With Branching

The relationship between brain structure and complex behavior is governed by large-scale neurocognitive networks. Diffusion weighted imaging is a noninvasive technique that can visualize the neuronal projections connecting the functional centers. In this paper, we assume there are up to two diffusion channels at each voxel. A variational framework for 3D simultaneous smoothing and recovering of multi-diffusion tensor field as well as a novel multi-tensor deflection(MTEND) algorithm for extracting white matter fiber traces based on it are provided. By applying the proposed model to synthetic data and human brain high angular resolution diffusion magnetic resonance imaging data of several subjects, we show the effectiveness of the model in recovering branching fiber traces. Superiority of the proposed model over existing models are also demonstrated.

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CP5

Complex-Sinusoidally Modulated Imaging for Optical Flow Detection

In this paper, we show a gradient-based method of optical flow determination for a novel solid-state imaging device, three-phase correlation image sensor, 3PCIS (IEEE Trans. ED-50, 10, 2059-2066, 2003). It is featured as: 1) Single frame is sufficient to obtain optical flow. No temporal differentiation is needed. 2) It is free from inherent velocity limit of the conventional optical flow equation-based method. 3) The aperture problem and the singularity (e.g. occlusion boundary) problem can be significantly reduced. The result is based on the newly derived optical flow equation

$$(v_x\partial_x + v_y\partial_y)(g(x,y) - g_0(x,y)) = j\omega g(x,y),$$

where

$$g_0(x,y) = \int_{-T/2}^{T/2} f(x,y,t)dt$$

$$g(x,y) = \int_{-T/2}^{T/2} f(x,y,t)e^{j\omega t}dt$$

are the intensity image output and the correlation image output of 3PCIS, T is the frame interval, and ω is the modulation frequency.

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CP5

A Study of the Discrete Maximum Principle for the Beltrami Color Flow

We analyze the discrete maximum principle for the Beltrami color flow. The Beltrami flow can display linear as well as nonlinear behavior according to the values of a parameter β, which represents the ratio between spatial and color distances. The standard schemes fail, in general, to satisfy the discrete maximum principle. In this work we show that a nonnegative second order difference scheme can be built for this flow only for small β, i.e. linear diffusion. Since this limitation is too severe, we construct a novel finite difference scheme, which is not nonnegative and satisfies the discrete maximum principle for all values of β. Numerical results support the analysis.

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CP5

p-norm PDEs

Minimizing the integral $\int_\Omega \|\nabla u\|^p d\Omega$ for an image u under suitable boundary conditions gives PDEs with well-known results for $p = 1, 2$, namely Total Variation and Laplacian diffusion, respectively. Without fixing p, one obtains a framework related to the p-Laplace equation. In this work we derive this general framework, discuss its properties, show relations with gauge coordinate (directional derivative) descriptions of the PDEs, and give examples of its use in filtering.

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CP5

A Multiscale Image Representation Using Hierarchical (bv, l^2) Decompositions

We will discuss a new multiscale image representation model using hierarchical (BV, L^2) decompositions. First, we decompose an image $f \in L^2(\Omega)$ into $u + v$, where $u \in BV(\Omega)$ minimizes the Rudin-Osher-Fatemi functional and $v \in L^2(\Omega)$ is the residual. This decomposition depends on a parameter λ. We iterate this process for different monotone values of λ, applying the decomposition to the residual of the previous step to obtain a multiscale representation of f. We will discuss some theoretical properties of this method as well as show numerical results. Finally, we will show that this decomposition can also be applied to other variational models.

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CP5

Sobolev Gradients for Imaging Applications

The use of Sobolev gradients has proved very useful for the numerical solution of a wide class of partial differential equations, including transonic flow, minimal surface, and the Ginzburg-Landau equations of superconductivity. In this talk we summarize results of applying this methodology to a problem in imaging, namely, the f=u+v+w decomposition of an image for edge detection and texture discrimination.

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CP5

Image Analysis on a General Domain Using Laplacian Eigenfunctions

We present a method to analyze images recorded on a domain of general shape by expanding them into the eigenfunctions of the Laplacian defined there. To compute these eigenfunctions, we diagonalize the integral operator commuting with the Laplacian using a fast algorithm based on multiwavelets of Alpert, instead of directly solving the Helmholtz equation on the domain (which can be quite complicated and costly). We also present its application to image approximation and statistical image analysis.

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CP6

A Modified Mumford-Shah Model Based Simultaneous Segmentation and Registration

A new variational region based model for simultaneous image segmentation and registration using a modified Mumford-Shah technique is proposed. The segmentation is obtained by minimizing a modified Mumford-Shah model. A global rigid registration is assisted by the segmentation information and region intensity values. The experimental results with an application to synthetic and simulated human brain MRI images show the effectiveness of the presented model to segment and register novel images simultaneously.

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CP6

Using the Shape Gradient for Active Contour Segmentation: From the Continuous to the Discrete Formulation

Segmentation can be formulated as a domain energy minimization. The shape gradient represents an infinitesimal change in the energy when deforming the domain. Following a gradient descent strategy, the deformation must ensure the shape gradient negativity. We show that this negativity is not preserved when discretizing the "natural" continuous deformation. Instead, we propose to choose the deformation as a linear combination of pre-defined deformations, also allowing to introduce some knowledge on the optimal domain.

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CP6

Variational Shape Optimization for Image Segmentation

We consider the geodesic active contour/surface model in a shape optimization framework. This allows us to choose faster and smoother descent directions. We introduce a novel finite element discretization for the optimization in 2D and 3D with the following features: 1) No parametrization, 2) Time step adaptivity to achieve best descent at each step, 3) Space adaptivity to resolve the data efficiently, 4) Topological changes in 2D. (joint with P.Morin, R.H.Nochetto)

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CP6

Active Contours Without Edges for Botanical Video Segmentation

Leaves absorb CO_2 through pores in their surface. The opening of these pores results in water loss through evaporation, so a leaf is faced with the global optimization problem of maximizing CO_2 uptake while minimizing H_2O loss. After injecting a dye into a leaf which fluoresces when the pores close, one can analyze the fluorescence patterns in an experimental video to determine how a leaf locally solves the optimization problem. We propose to segment the videos into a multiply-connected region of active fluorescence and its complement using a method based on *active contours without edges* which is solved in a level-set framework using a three-dimensional semi-implicit numerical scheme.

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CP6

Background Extraction Using Statistical Without-Edge Method

We identify the object from an image and extract the others by segmenting an image at least into two regions and determining which regions are in the object or in the background. We take the adaptive active-segmentation framework suggested by M. Rousson and R. Deriche. We compute the Gaussian parameters of the regions and use the level set method. In the case of vector-valued image, we use the HSV color model with multi-level sets.

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CP6

Symmetry Based Segmentation with Level Sets

Shape symmetry is an important cue for image understanding. In the absence of more detailed prior shape information, segmentation can be significantly facilitated by symmetry. However, when symmetry is distorted by perspectivity, the detection of symmetry becomes non-trivial, thus complicating symmetry-aided segmentation. We present an original approach for segmentation of symmetrical objects accommodating perspective distortion. The key idea is the use of the replicative form induced by the symmetry for challenging segmentation tasks. This is accomplished by dynamic extraction of the object boundaries, based on the image gradients, gray levels or colors, concurrently with registration of the image symmetrical counterpart (e.g. reflection) to itself. The symmetrical counterpart of the evolving object contour supports the segmentation by resolving possible ambiguities due to noise, clutter, distortion, shadows, occlusions and assimilation with the background. The symmetry constraint is integrated in a comprehensive level-set functional for segmentation that determines the evolution of the delineating contour. The proposed framework is exemplified on various images and its superiority over state of the art variational segmentation techniques is demonstrated.

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CP7

Fast and Exact Discrete Image Restoration Based on Total Variation and on Its Extensions to Levelable Potentials

We investigate the decomposition property of posterior restoration energies on level sets in a discrete Markov Random Field framework. This leads us to the concept of 'levelable' potentials (which TV was shown to be the paradigm of). We prove that convex levelable posterior energies can be minimized exactly with level-independant binary graph cuts. We extend this scheme to the case of non-convex levelable energies, and present convincing restoration results for images degraded by impulsive noise.

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CP7

A Majorization-Minimization Algorithm for Total Variation Image Deconvolution

In recent work on image deconvolution, a certain class of iterative algorithms for non-quadratic convex (very high dimensional) optimization problems has been proposed. These algorithms can be used for image restoration under total variation (TV) regularization and also for wavelet-based approaches. Monotonicity and convergence properties for this class of algorithms are well established. In this talk, we describe recently introduced second-order (also known as two-step) versions of these algorithms, which exhibit dramatic speedups relatively to the original versions.

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CP7

A General Framework for Variational Optical Flow and Image Registration Problems Based on a Robust Multigrid Solver

Optical flow and the related non-rigid image registration both lead to a variational minimization problem that requires robust and efficient numerical solvers due to the often non-smooth input data and the large number of unknowns in real applications. We present a flexible framework that can handle the usual data terms, various regularizers and one can also include landmark or feature based information. The standard multigrid solver can be enhanced by using Galerkin coarsening, block- or linewise smoothers or iterant recombination. It is also possible to specify matrix dependent transfer operators. These techniques lead to good convergence rates even in the case of non-smooth input data. Our results consist of the optical flow for 2D image sequences and the image registration of 3D medical data sets.

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CP7

Efficient Solution of Optimization-Based Image Denoising Problems

The purpose of this talk is to study different optimization formulations for image denoising problem. Different combinations of fitting and regularization parts are considered and solution methods are compared for solving the arising nonsmooth optimization problems. Especially, we study the applicability of the Limited Memory Bundle Method (LMBM) for solving image processing problems. LMBM (M. Haarala et al., Optimization Methods and Software, Vol. 19, 2004) has especially been developed for large-scale nonsmooth optimization.

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CP7

Optimization Involving L^∞-Norm for Image Restoration

Energies involving a L^∞ norm appear in some recent applications of image processing. Examples include the denoising of uniform noise or the decomposition of an image into an oscillating and a geometric component. Such a norm is difficult to minimize because it is non differentiable. In this talk, we will present a way to construct simple algorithms - based on constrained optimization - to solve such problems.

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CP7

Total Variation Minimization and Graph Cuts for Moving Objects Segmentation

Based on the recent works of Chambolle and Darbon and Sigelle, we solve a Rudin-Osher-Fatemi problem with Chambolle projection algorithm and threshold the result at the level α to solve the shape optimization problem

$$\frac{1}{2}\sum_{i,j} g_{i,j}\left(|u_{i+1,j}-u_{i,j}|+|u_{i+1,j}-u_{i,j}|\right.$$
$$\left.+\frac{1}{\sqrt{2}}\left(|u_{i+1,j+1}-u_{i,j}|+|u_{i-1,j+1}-u_{i,j}|\right)\right)$$
$$+\sum_i(\alpha-f_i)\theta_i$$

Typically, f is an optical flow magnitude and g a classical edge function.
The main advantage over existing methods (level sets...) is to avoid a recomputation for each value of α. We also investigate fast techniques like graph cuts.

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CP7

Total Variation Image Denoising Via Basis Pursuit: Initial Results

While there is a direct equivalence, for 1-D signals, between Total Variation denoising (TVDN) and Basis Pursuit denoising (BPDN) with a Heaviside dictionary, it is not easily extended to 2-D without introducing anisotropy into the gradient in the TVDN regularisation term. We propose an isotropy-preserving approach, based on BPDN with a parameterised dictionary, and comment on performance and computational issues.

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CP8

Optical Snow Analysis Using the 3D-Xray Transform

There are many methods to analyze motion in computer vision. Most of classical methods use optical flow, layered motion or segmentation analysis in order to measure motion. In this work we detect optical snow motion in video by using the discrete 3D-Xray transform. Optical snow is used as an instance for a framework that analyzes many motion types such as snowfall, tree movements, cars traffic, people walking or monitoring an object in a natural scene. The discrete 3D-Xray transform is situated as a core algorithm in medical imaging where 3D reconstructions from projections is needed. The 3D-Xray transform partitions the 3D space into specific planes. The detection of optical snow motion and object tracking are achieved through analysis of the energy distributions on these 3D-Xray planes.

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CP8

Axial Representation of Shapes Based on Principal Curves

Generalized cylinders model uses hierarchies of cylinder-like modeling primitives to describe shapes. We propose a new definition of axis for cylindrical shapes based on principal curves. In a 2D case, medial axis can be generated from the new axis, and vice versa. In a 3D case, the new axis gives the natural (intuitive) curve skeleton of the shape instead of complicated surfaces as medial axis. This is illustrated by numerical experiments on 3D laser scan data.

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CP8

Comparing Two Area Frames Using Two Sample Non-Parametric Statistical Tests

For the June Surveys, data at the National Agricultural Statistics Service (NASS) is gathered within land-use strata on segments. With-in strata, five crops are of interest to the Area Frame Survey — corn, cotton, and the three seasons of wheat. Creating new sample frames is labor intensive, and ideally, new frames should outperform the old frames. We wish to determine if the data collected under the 'old' frame for a particular year is the same under the 'new' frame for the successive year. It is desired to compare the dispersion of the two frames. This paper discusses some non-parametric statistical tests for dispersion and provides some results of the comparisons.

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CP8

Cumulus Cloud Segmentation Based on Subdivision

As part of CuPIDO (http://geography.asu.edu/zehnder/cupido/), an observational program designed to examine cumulous cloud develop associated with the Southern American Monsoon, we have developed a method to segment cumulous clouds from digital images. An image is recorded from a fixed camera every 10 seconds during the active periods of the monsoon. The foundation of our segmentation method is an adaptive triangulation refinement scheme. This scheme is paired with a hue-saturation histogram and a background registration model to differentiate cumulous clouds from the sky and cirrus clouds. We address the special challenges present in cloud segmentation.

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CP8

Multi-Scale Shape Analysis Using Symmetry Sets

The Symmetry Set (SS) and its subset the Medial Axis with the annotated version the Shock Graph - are shape descriptors that are used to compare shapes. These methods are only considered at the scale of the given shape. We embed the SS in a mean curvature flow (the shape suited version of the Laplacian diffusion) driven multi-scale context. Properties of this flow for shapes and the SS and consequences for shape comparison are given.

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CP8

2D Shape Model Selection Via Efficiency Measures

This talk proposes efficiency of representation as a criterion for evaluating shape models, then applies this criterion to compare two popular shape models: the boundary curve and the medial axis. We will present two adaptive encodings for non-compact classes of shapes, one using the boundary curve and the other using the medial axis, and determine precise conditions for when the medial axis is more efficient. If time allows, we will briefly mention our construction of explicit near-optimal boundary-based approximations for compact classes of shapes and their relation to the non-compact formulation. Finally, we will present some empirical results from the application of our efficiency criterion to three shape databases.

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CP9

Detection and Continuation of Filaments in 3D Images

In this work, we are interested in the detection of filaments (1D curves) in 3D images. We propose to search for curves of minimal total curvature on a subset of the image domain, defined from the image Hessian matrix eigenvalues.As some filaments are interrupted due to imperfect segmentation on noisy data, we propose a continuation method based on Ginzburg-Landau energy where the filaments are the zeros a complex valued function.

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CP9

Quantitative Analysis Improvement in Optical Coherence Tomography (OCT)

OCT is a rapidly emerging imaging technology that enables micron-resolution visualization of the cross sectional structure of the retina and anterior eye with higher resolutions than any other non-invasive imaging modality. We present specific improvements in the quantitative analysis of the current commercial OCT system. With such quantification, it is possible to obtain earlier detection of pathology as well as improved monitoring of disease progression and response to therapy.

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CP9

Economizing Mach Filters for Automatic Target Recognition

A mathematical formulation for reducing the number of

MACH filters necessary for target recognition is developed. A prototype method based on interpolation is used to obtain a continuous model. Choice of basis functions based on cubic Splines, Gaussian and Sinc functions are considered. A method of economizing the number of filters is successfully implemented.

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CP9
Task-Specific Compressed Sensing for Hyperspectral Automatic Target Detection

We demonstrate task-specific compressed sensing utilizing near Infrared (NIR) hyperspectral Hadamard multiplexed imaging. The sensor incorporates a digital mirror array to realize Hadamard codes, sensing inner products of the underlying scene rather than the scene itself. An Automatic Target Recognition (ATR) metric drives the sensor to collect only relevant information, resulting in a multiple resolution hyperspectral data cube with full resolution where targets are present and low resolution elsewhere. Essentially, this is compressed sensing.

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CP9
A Parametric, Two-Dimensional Random Field with the General Markov Autocorrelation

This paper presents a parametric, two-dimensional random field that is useful for statistically modeling ensembles of images and for generating pseudo-random images with desired stochastic properties. The random field generalizes the autocorrelation function of a Markov random field with parameters controlling five important characteristics: vertical mean-spatial-detail, horizontal mean-spatial-detail, rotation angle, intensity variance, and spatial structure. These five parameters provide a high-degree of statistical control over the random field. Experimental results show that the parametric autocorrelation function of the random field provides an accurate model for ensembles of real world images. This paper also presents a computationally efficient method to construct pseudo-random images, by drawing random lines (consistent with the desired axial mean-spatial-details and rotation angle), assigning random intensity values to the resulting polygons (consistent with the desired intensity variance), and randomizing phase (consistent with the desired spatial structure). The resulting pseudo-random images are useful as inputs for assessing performance of simulated imaging systems and image processing algorithms across a range of images with controlled stochastic properties.

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CP9
Image Denoising by Inhomogeneous Diffusion

The standard kernel estimator using the Gaussian kernel may be written in integral form as

$$f(x,h) = \frac{1}{\sqrt{2\pi}h}\int_{-\infty}^{\infty} y(u)\exp\left(-\frac{(x-u)^2}{2h^2}\right)du$$

On putting $t = h^2/2$ and writing $f(x,t)$ for $f(x,h)$ it may be easily checked that f satisfies the heat equation

$$\frac{\partial f}{\partial t} = \frac{\partial^2 f}{\partial x^2}.$$

Kernel estimators with global bandwidths are not appropriate for data sets which exhibit large local differences in smoothness. Meise (2004) gives a procedure for choosing local bandwidths based on the multiresolution criterion of Davies and Kovac (2001). In this talk we show how this strategy can be applied to the heat equation by locally altering the conductivity of the medium. There are two advantages over kernel estimators: The computing time can be decreased by using the finite element methods to solve the differential equation and the results can be improved by detecting the edges of the image. Transferring the procedure to two-dimensional data, we additionally need segmentations of the image, on which we have to check the multiresolution criteria and adapt the local conductivity. It is intended to combine our inhomogeneous cooling algorithm with the fast segmentation algorithm of Friedrich (2005). First results using a segmentation into dyadic squares will be shown.

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CP10
An Orientation-Adaptive Gaussian Scale Mixture Model for Image Denoising

We develop a model for patches of image wavelet coefficients that is explicitly adapted to local orientation. Image patches are described as samples of a Gaussian process that is rotated and scaled by hidden random variables representing the local image orientation and contrast, respectively. A Bayesian denoising method, based on conditioning on and integrating over the hidden variables, yields visually superior results when compared to previous scale mixture models that do not explicitly model orientation.

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CP10

3D Dyadic Wavelet Transform for Image Volume Denoising

Reducing noise in images is a preliminary step in many image processing applications. In this work a method for edge-preserving denoising of three dimensional image data is presented. It is based on the 3D generalization of the dyadic wavelet transform and overcomes the problems presented by the extension to higher dimensions of the classical orthogonal wavelet transfor ms. In fact, a straightforward extension of these separable transforms to multidimensional data gives very poor results, due to the lack of translation invariance that produces undesired artifacts. On the contrary, dyadic wavelets are truly multidimensional translation invariant bases, and the coefficients of the dyadic expansion of an image f at different scales contain informations of the gradient of f smoothed according to the scale. By integrating these geometric informations in the smoothing process we obtain a 3D denoising algorithm capable to preserve as much as possible of the signal features while reducing the noise to a sufficiently low level.

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CP10

The Texas Two-Step: An Optimal Multi-Input Single-Output Deconvolution Framework

Multi-input single-output deconvolution (MISO-D), a common problem in areas such as medical imaging, astronomy, and seismic imaging, aims to extract a crisp deblurred estimate of the target signal from several noisy, blurred observations. Texas Two-step (TX2) is a new, powerful two-step framework to solve the MISO-D problem. First, TX2 reduces the MISO-D problem to a dual single-input single-output deconvolution (SISO-D) problem using sufficient statistics (SSs). Second, TX2 invokes an appropriate SISO-D technique to solve the simpler dual problem. Remarkably, if the SISO-D used by the TX2 is optimal, then the cumulative TX2 MISO-D algorithm is also optimal. Based on these insights, we discover classes of MISO-D problems for which wavelet-based and curvelet-based approaches are asymptotically optimal.

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CP10

A Fourth Order Dual Method for Staircase Reduction in Texture Extraction and Image Restoration Problems

We propose a fourth order dual method for the minimization of the non-smooth semi-norm $\|\Delta \cdot\|_1$ when in amalgamation with new staircase reducing texture decomposition and restoration models of image processing. We claim that the dual method is faster and more stable than the current gradient descent time marching algorithms often used to minimize such energies. Moreover, proofs of convergence of the proposed method, in conjunction with the new imaging models, will be provided.

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CP10

Empirical Bayes Least Squares Estimation Without An Explicit Prior

Bayesian estimation often requires prior probability models, which can be difficult to infer from noisy measurements. We show that for additive noise, Bayesian least-squares estimators can be derived from noisy data distributions. For Gaussian noise, the estimator is based on the logarithmic derivative of this distribution. We develop a local adaptive approximation of the logarithmic derivative , and simulate its behavior on various distributions. Despite its generality, the estimator performs well in denoising photographic images.

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CP10

Fractal Image Coding As a Nonlocal PDE-Based Imaging Method

Let T be a contraction mapping on an appropriate Banach space $\mathcal{B}$. Then the evolution equation $y_t = Ty - y$ produces a continuous evolution $y(\mathbf{x}, t)$ from an arbitrary initial condition to the fixed point $\bar{y} \in \mathcal{B}$ of T. One application of this result (J. Bona and ERV, Fractals in Engineering Conference, 2005) has been where T is a contractive *fractal transform* that replaces "range" subblocks of an image I with spatially contracted and greyscale modified "domain" subblocks of I. In conventional fractal image coding, T is applied discretely. But with the evolution equation approach, it can be applied continuously in the form of a nonlocal differential equation. In this paper, we report on more recent experiments where diffusion terms have been added, e.g., $\frac{\partial y}{\partial t} = \epsilon \triangle y + Ty - y$, for both positive and negative diffusion. Applications to fractal image denoising methods are examined. As well, we look at an evolution equation in the wavelet domain that performs a continuous fractal-wavelet transform.

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MS1

Sampling Signals from a Union of Subspaces

One of the fundamental assumptions of traditional sampling propositions is that the signals to be sampled come from a single vector space. However, in many cases, the signals of interest live in a union of subspaces. Examples include piecewise polynomials, sparse approximations, nonuniform splines, signals with unknown spectral support, overlapping echoes with unknown delay and amplitude, and so on. For these signals, traditional sampling schemes are either inapplicable or highly inefficient. In this talk, we present a new sampling scenario where the signals come from a known union of subspaces and the sampling operator is linear. Geometrically, the sampling operator can be viewed as projecting the signals into a low dimensional space, while still preserves all the information. We show the necessary and sufficient conditions for such sampling operators to exist and show that these conditions are satisfied for large classes of signals. Furthermore, we explicitly find the minimum sampling requirement for several cases, which indicates the power of this framework.

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MS1

Shrinkage for Redundant Representations

Shrinkage is a well known and appealing denoising technique, introduced originally by Donoho and Johnstone in 1994. The use of shrinkage for denoising is known to be optimal for Gaussian white noise, provided that the sparsity on the signal's representation is enforced using a unitary transform. Still, shrinkage is also practiced with non-unitary, and even redundant representations, typically leading to satisfactory results. In this talk we shed some light on this behavior. First, we show that such simple shrinkage could be interpreted as the first iteration of an algorithm that solves the basis pursuit denoising BPDN) problem. Several other recently proposed iterated shrinkage algorithms are also discussed, describing their interrelations, and discussing their convergence properties. Finally, we demonstrate how such algorithms are applicable for an effective denoising of images.

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MS1

Rate-Distortion Performance of Sparse-Signal Coding with Random Measurements

One recently proposed technique for sparse-signal compression is to encode with scalar quantized versions of a large number of random measurements (linear functionals) of the signal. Through a convex optimization, the decoder simultaneously infers the sparsity and estimates the source signal from the quantized measurements. This work quantifies the performance penalty incurred from using random measurements and optimizes the rate-distortion performance of this scheme as a function of the overall quantization rate and dictionary size.

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MS1

Recovering Structured Representations

In many recent results on sparse approximation with dictionaries it is assumed that all atoms from the dictionary are mutually quasi-orthogonal in order to get a decent exact recovery condition. In this talk we show how to replace this global quasi-orthogonal hypothesis by a relaxed "local" quasi-orthogonal condition. This allows us to obtain exact recovery conditions for dictionaries that have clusters of very coherent atoms. We study one example in detail: a dictionary made up of the union of a wavelet basis and a Gabor system (in infinite dimension) for which exact recovery through Basis Pursuit/FOCUSS is theoretically possible.

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MS3

Diffusion MRI: Modeling and Applications

We present the diffusion MRI signal, its applications, and describe three major processing tasks: First, we show how to perform the estimation and statistical segmentation of Diffusion Tensor images by exploiting the information geometry of the space of normal distributions. Next, we formulate the cerebral connectivity mapping problem as computing geodesics on a manifold whose metric derives from the diffusion tensors. Finally, recent techniques extending the diffusion tensor model to higher orders are introduced.

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MS3
3D Curve Inference and Diffusion MRI Analysis

We develop a differential geometric framework for regularizing diffusion MRI data. White matter fibers are modeled as 3D space curves and a notion of *co-helicity* is used to indicate the compatibility between fibre orientation estimates at each voxel with those in a local neighborhood. We validate the approach quantitatively on a biological phantom and on synthetic data, and qualitatively on data acquired *in vivo* from a human brain. We also discuss the use of this technique to improve on fiber tracking results using geometric flow based algorithms.

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MS3
Uncertainty in White Matter Fiber Tractography

Conventional white matter tractography methods estimate fibers by tracing the direction of maximum water diffusivity. A main limitation of this traditional approach is that it gives an impression of being very precise. However, in practice there are several factors that introduce uncertainty in the tracking procedure. Noise, crossing fibers, and image artifacts are all examples of factors that cause variability. A stochastic tractography method that handles noise in a theoretically justified way is described.

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MS4
Overview of Higher Order PDEs in Image Processing

Many problems in image processing require analysis and manipulation of curvature and related information regarding edges. This naturally leads to higher order PDEs for applications ranging from denoising of piecewise linear signals to image inpainting. This talk will review some of the recent work in this area along with some new methods for inpainting of binary images and segmentation of objects with sharp corners. Part of this work is joint with Marc Droske, Selim Esedoglu, and Alan Gillette.

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MS4
Higher Order Corner-preserving Regularization of Active Contours

Recently Tumblin and Turk have devised a fourth order image restoration technique, that includes a coefficient which depends on second derivatives of the the image and successfully applied it to real images for contrast enhancement. For image segmentation with active contours, we introduce a curvature dependent, geometrically intrinsic regularization scheme, which depends on the curvature of moving contour, designed in such a way that corners are not prohibited, which would be the case for classical regularization schemes.

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MS4
A Curvature Depending Functional for Image Segmentation with Occlusions and Transparencies

We consider a functional for image segmentation which takes into account the occlusions and/or the transparencies (or shadowing) between different shapes. The functional includes a Mumford-Shah type energy and a term involving the curvature of the contours. The functional also depends on a function which represents an ordering relation. The order is spatially local so that interwoven shapes are allowed. The qualitative properties of the functional are studied by using the relaxation method of the Calculus of Variations. The relation with the Nitzberg-Mumford-Shiota variational model is also discussed.

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MS4
Simultaneous Non-Smooth Convex Flow Estima-

tion and Decomposition

For the analysis of non-rigid motions variational approaches that are well-posed through regularization but do not penalize relevant flow structures are of interest. Extending Meyer's structure/texture decomposition model to vector fields we focus on the simultaneous optical flow estimation and decomposition using higher-order regularizers. Applying the mimetic finite difference method we discretize the relevant differential operators while preserving the integral identities. Numerical experiments based on convex second-order conic programming demonstrate the feasibility of our approach.

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MS5

A Computational Method for the Restoration of Images With an Unknown, Spatially-Varying Blur

In many image restoration problems, the point spread function (PSF) is both unknown and spatially-varying. In this talk, we present a computational method for use on such problems. The method sections the image of interest into sub-regions on which an accurate spatially-invariant approximation of the PSF can be obtained using *phase diversity*. The image is then restored globally using a method for the restoration of images with a known, spatially-varying blur. Test results on star cluster data will be presented.

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MS5

Numerical Methods for Strongly Coupled Super Resolution Problems

The process of combining, via mathematical software tools, a set of low resolution images into a single high resolution image is often referred to as super-resolution. Algorithms for super-resolution involve two key steps: registration and reconstruction. Most approaches proposed in the literature decouple these steps, solving each independently. This can be effective if there are very simple, linear displacements between the low resolution images. However, for more complex, nonlinear, nonuniform transformations, estimating the displacements can be very difficult, leading to severe inaccuracies in the reconstructed high resolution image. This paper presents a mathematical framework and optimization algorithms that can be used to jointly estimate these quantities. Efficient implementation details are considered, and numerical experiments are provided to illustrate the effectiveness of our approach.

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MS5

A Multilevel Approach to Image Processing

We consider image reconstruction and restoration problems modeled by a linear forward model resulting from the discretization of an integral equation. Our goal is to design fast, preconditioned iterative regularization algorithms for these problems that make use of implicit regularization at coarser grid levels. In particular, unlike many successful preconditioners for discrete ill-posed problems, these multilevel preconditioners have the benefit of being independent of matrix structure. Numerical examples illustrate the promise of this approach.

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MS5

Some Computational Issues in Spectral Imaging

Numerical unmixing algorithms for the characterization of non-resolved objects from spectral image data measurements from pixels are discussed. Spectral unmixing is a challenging problem that entails the determination of constituent distinct spectra (endmembers) as well as their relative fractional abundances from spectral images of an object. We pay especial attention to methods based approximate nonnegative matrix factorizations (ANMF) techniques. We show using numerical experiments that ANMF combined with sensible penalty terms and initializations can improve the quality of endmember determination and subsequent inverse computation of fractional abundances.

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MS6

Image Denoising via Sparse and Redundant Representations over Learned Dictionaries

We address the image denoising problem, where zero-mean white and homogeneous Gaussian additive noise is to be removed from a given image. The approach taken is based on sparse and redundant representations over trained dictionaries. Using the K-SVD algorithm, we obtain a dictionary that describes the image content effectively. Two training options are considered: using the corrupted image itself, or training on a corpus of high-quality image database. Since the K-SVD is limited in handling small image patches, we extend its deployment to arbitrary image sizes by defining a global image prior that forces sparsity over patches in every location in the image. We show how such Bayesian treatment leads to a simple and effective denoising algorithm. This leads to state-of-the-art denoising performance, equivalent and sometimes surpassing recently published leading alternative denoising methods.

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MS6

Sparse Representations and Univariate and Multivariate Bayesian Restoration

This work is concerned with Bayesian denoising within the context of sparse representations. A general univariate bayesian prior model on the representation coefficients is introduced and its properties are established. We prove that such a prior is well adapted to capture sparsity of the representations (leptokurticity and heavy tailness). We also shed the light on the relationship between the hyperparameters of this prior and those of the Besov space within which realizations of such a prior are likely to fall. Several Bayesian estimators (conditional posterior mean and maximum a posteriori) are also given. All these results are extended to the multivariate case where dependency between neighbouring coefficients is imposed. Some special cases of the general prior are finally considered and their computational issues are solved.

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MS6

Exploiting Sparsity-Based Modeling in Hyperspectral Data Processing

Hyperspectral data processing has numerous applications in agriculture, forestry, prospecting, hazardous material identification and material mapping. A modern data set contains data across a few hundred spectral bands, with each individual band image consisting of more than a half million pixel values (where each pixel has a spatial resolution of at least a few square meters). A typical goal is to exploit the high density of spectral sampling to identify surface composition with subpixel accuracy. We discuss the use of sparsity-based modeling and modifications of sparse approximation techniques in denoising hyperspectral data sets and estimating surface composition.

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MS6

Sparse Solutions of Underdetermined Linear Equations by Linear Programming

Consider an underdetermined system of linear equations $y = Ax$ with known y and $d \times n$, matrix A with $d = \delta n$ for $\delta \in (0, 1)$. We seek the sparsest solution, i.e., the x with fewest nonzeros satisfying $y = Ax$. In general this problem is NP-hard. However, for many matrices A there is a threshold phenomenon: if the sparsest solution is sufficiently sparse, it can be found by linear programming. Quantitative values for a strong and weak threshold will be presented. The strong threshold guarantees the recovery of the sparsest solution x_o, whereas a weaker sparsity constraint ensures the recovery of the sparsest solution for most x_o. These thresholds are surprisingly large, indicating the utility of l^1 convex relaxation in recovering the sparsest solution. For instance, with aspect ratio $n/d = 2$ the strong and weak thresholds are approximately $.13d$ and $.55d$ respectively as $n \to \infty$. Interesting properties used in the proof of these results include the neighborliness of polytopes in high dimensions.

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MS7

Diffusion Coarse-Graining with Applications to Texture Analysis

As mentioned in the previous talk, one can — using a Markov random walk point of view — define a system of coordinates with a metric that reflects the connectivity of a data set. Here we describe how to coarse-grain the original random walk while at the same time preserving most of its spectral properties. This construction offers a systematic way of simultaneous parameterization, dimension reduction and clustering of arbitrary data sets in high dimension using intrinsic geometries. Applications to texture classification and analysis are presented.

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MS7

Non-normalized Kernels for Extrinsic Geometry Embedding

Popular dimensionality reduction schemes based on the graph Laplacian only capture the intrinsic geometry of data sets. Yet, for a particular class of applications relying on the notion of shape, the extrinsic geometry is central and must be preserved. In this talk, we move beyond the diffusion framework by presenting a new data embedding scheme based on non-normalized kernels. The representation that we obtain is density-invariant, hence responding to the concern of dealing with different samplings of the same object. We demonstrate the effectiveness of our approach by applying it to curve retrieval.

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MS7

Data Organization and Multisensor Integration Using Diffusion Techniques

In this talk, we present a unified framework for dimensionality reduction based on the computation of diffusion spectral coordinates. The diffusion embedding gives rise to efficient data organization schemes that can be used for improving clustering, classification and regression algorithms. We also address the fundamental questions of density-invariant representations of data, the out-of-sample extension of the embeddings, and the integration of multiple streams of information into a unified representation. Examples related to imaging and audio and visual pattern recognition are presented.

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MS8

The Beltrami Framework in MR-DWI

The Magnetic Resonance Diffusion Weighted Imaging (MR-DWI) is studied from the differential geometry point of view. The imaging process as well as the regularization and analysis are formulated via the Beltrami framework. This study treats fiber tracking in the white matter in the brain and is emploied in various segmentation and phenomena separation tasks.

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MS8

von-Mises Mixtures for Representation of HARD-MRI and its Segmentation

High angular resolution diffusion imaging (HARDI) permits the computation of water molecule displacement probabilities over a sphere of possible displacement directions. This probability is often referred to as the orientation distribution function (ODF). In this paper we present a novel model for the diffusion ODF namely, a mixture of von Mises-Fisher (vMF) distributions. Our model is compact in that it requires very few variables to model complicated ODF patterns which occur specifically in the presence of heterogeneous nerve fiber orientation. We also present a Riemanian geometric framework for computing intrinsic distances, in closed-form, and performing interpolation between ODFs represented by the vMF mixtures. As an example, we apply the intrinsic distance within a fast active contour implementation of the Mumford-Shah segmentation scheme. We present results of this segmentation for HARDI images of rat spinal cords – which show distinct regions within both the white and grey matter. It should be noted that such a fine level of parcellation of the gray and white matter can not be obtained either from contrast MRI scans or Diffusion Tensor MRI scans. We validate the segmentation algorithm by applying it to synthetic data sets where we know the ground truth.

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MS8

Estimation of ADC Profiles from High Angular Resolution Diffusion MRI

We will discuss the problem of the estimation of ADC profiles from High Angular Resolution Diffusion Images (HARDI) as well as the characterization of the diffusion anisotropy using an information theoretic approach. We show how to perform the simultaneous estimation and smoothing of ADC profiles using spherical harmonic series. We also present a simplified model of approximation for the ADC profiles in up to two fibers diffusion cases. We finally propose a method to characterize the local diffusion anisotropy using the cumulative residual entropy.

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MS9

Image Inpainting using the Cahn-Hilliard Equation

The Cahn-Hilliard equation models the behavior of metal alloys under heating. We use a modified version of the Cahn-Hilliard equation to achieve digital inpainting of binary (two-state) images. Due to the varied numerical schemes available for the Cahn-Hilliard equation, this technique for image inpainting is quite fast. Super-resolution using this method will also be discussed.

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MS9

Higher Order Flows on Surfaces

We will examine recent methods for solving PDEs defined on codimension-one surfaces in R^N. By using geometric tools from level set methods (see Sethian, 2000, or Osher and Fedkiw, 2003), we compute PDEs on these curved domains using only finite difference schemes and standard Cartesian grids in the embedding space. In addition to being easy to implement, the methods are readily adaptable to problems where the surface evolves by some external velocity field. These methods suffer the disadvantage of being defined on a larger domain – a small band around the curve or surface. In addition, well-behaved PDEs like the heat equation become degenerate diffusions when computed in the ambient space. We will discuss current work in this area, including an application of this method to fourth order equations on surfaces. The Cahn-Hilliard equation and a model for a thin film of fluid driven down a sphere by gravity are among the examples discussed. We also present a newer formulation of these level set methods that avoids the degeneracy problems mentioned above.

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MS9

Saddle Point Formulation for a Texture-noise Decomposition

We consider the decomposition of an image into a cartoon and texture part introduced by Y. Meyer. The cartoon part is found by minimizing the G-norm of the error with an bounded variation regularization. We rephrase the problem as a saddle point formulation, which can be used for numerical computation.

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MS9

Feature Preserving level-set Surface Smoothing via Anisotropic Diffusion of Normal Vectors

I will discuss a nonlinear energy for feature preserving smoothing of surface normal vectors and how it can be used in a level-set surface processing framework. A gradient descent on the proposed energy preserves sharp discontinuities in the normals while removing noise, and it is a natural generalization of edge-preserving methods in image processing. This is combined with the minimization of a second energy that measures differences between the level-set surface normals and the denoised surface normals from the first energy. Our approach results in a system of two second-order partial differential equations that provide a computationally cheaper approach to higher-order energy minimization.

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MS10

Graph Cut Energy Minimization Methods for Computer Vision and Medical Imaging

See minitutorial abstract.

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MS11

An Adaptive Computational Strategy for Optimal Sparse Signal Approximation

Sparse approximation using redundant signal dictionaries has the reputation of being a computationally intensive, almost intractable task. Yet, algorithms as simple as thresholding sometimes provide solutions that are surprisingly close to those obtained with more time hungry techniques such as Matching Pursuit, Basis Pursuit or FOCUSS. We propose an adaptive computational strategy to compute, with as simple techniques as possible, nearly as good sparse approximations as with substantially more complex ones. The strategy is based on a low cost a priori prediction of the behaviour of complex algorithms which serves as an a posteriori test of the "success" of simple algorithms. We will discuss the tradeoff between the accuracy and the computational cost of the test with numerical examples, and provide simple tests for the thresholding, Matching Pursuit and Basis Pursuit algorithms. Preliminary proposals for FOCUSS type algorithms will also be discussed. The proposed tests – which rely on combined properties of the signal dictionary and the computed sparse approximation – are more accurate and only slightly more complex than known tests based on the (cumulative) coherence of the dictionary and the number of terms of the sparse approximation. To our knowledge, our results tests also provide, for the first time, practical tools that are applicable in real settings, for many standard dictionaries that are not necessarily "quasi-incoherent" such as the union of Gabor and wavelet systems.

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MS11

Super-Gaussian Latent Variable Models for SBL

and ICA

We present a unifying theoretical framework of the model y=Ax+e with strongly super-gaussian mixture source densities having multiple peaked modes or heavy tails. The framework allows the development of provably convergent generalized expectation maximization (GEM)-like estimation algorithms for a large class of parametric statistical signal models arising in problems of sparse Bayesian Learning (SBL) and independent component analysis (ICA).

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MS11

Robust Signal Recovery from Incomplete Observations

Recently, a series of exciting results have shown that it is possible to reconstruct a sparse signal exactly from a very limited number of linear measurements. If our underlying signal f can be written as a superposition of M elements from a known basis, it is possible to recover f from a projection onto a generic subspace of dimension about M log N. We will show that the recovery is robust. That is, if the measurements are perturbed, the reconstruction is still stable. We will discuss the implications of this results for applications such as signal compression and tomographic imaging.

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MS11

On the Lebesgue Type Inequalities for Greedy Approximation

We study the efficiency of greedy algorithms with regard to redundant dictionaries in Hilbert spaces. We obtain upper estimates for the errors of the Pure Greedy Algorithm and the Orthogonal Greedy Algorithm in terms of the best m-term approximations. We call such estimates the Lebesgue type inequalities. We prove the Lebesgue type inequalities for dictionaries with special structure. We assume that the dictionary has a property of mutual incoherence (the coherence parameter of the dictionary is small). We develop a new technique that, in particular, allowed us to get rid of an extra factor $m^{1/2}$ in the Lebesgue type inequality for the Orthogonal Greedy Algorithm.

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MS12

Surfacelets: Exploring Higher Dimensions with Fewer Tears

With the growing capabilities of modern computers and imaging devices, high-resolution 3-D and even higher dimensional volumetric data are increasingly available in a wide gamut of applications, including biomedical imaging, extragalactic astronomy, computer vision, and video processing and compression. To efficiently analyze and make sense of such huge amount of data, we need to create and employ new tools from various fields of engineering, including signal processing. In this talk, we will introduce a new signal representation, called surfacelets, that can be used to capture and represent signal singularities lying on smooth manifolds of co-dimension 1 (e.g. surfaces in R^3). Such singularities are often observed in 3-D medical signals and image sequences (video), where the signals are mostly smooth except on some boundary surfaces. The proposed surfacelets constitute a tight frame, and can be efficiently implemented by a tree-structured filter bank with low redundancy. In the talk, we will also show a few potential applications of the surfacelets, including denoising on 3-D medical data and video sequences.

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MS12

Multiscale Geometry for Images and Textures

The geometry of images is multiscale, because edges of natural images are often blurry, and textures contain a broad range of geometric structures. We handle this geometry using a multiscale geometric association field over the wavelet domain. This scheme is discrete, can be orthogonal or redundant, and leads a description of the geometric content of an image in a multiscale fashion. We apply these new tools to image compression, and to the statistic modelling of turbulent textures.

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MS12

Source Separation by Morphological Diversity

We describe two extensions of the recent Morphological Component Analysis (MCA) method to multichannel data. MCA takes advantage of the sparse representation of structured data in large overcomplete dictionaries to separate features in the data based on their morphology. It was shown to be an efficient technique in such problems as separating an image into texture and piecewise smooth parts or for inpainting applications. A first extension, MMCA, achieves a similar source separation objective based on morphological diversity. A second extension, GMCA, takes advantage of the highly sparse representations of the sources that can be built using MCA. Indeed, parsity is now generally recognized as a valuable property for blind source separation. The efficiency of MMCA and GMCA is confirmed in numerical experiments.

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MS12
Random Projections of Signal Manifolds

Random projections have recently found a surprising niche in signal processing. The key revelation is that the relevant *structure* in a signal can be preserved when that signal is projected onto a small number of random basis functions. Recent work has exploited this fact under the rubric of Compressed Sensing (CS): signals that are sparse in some basis can be recovered from small numbers of random linear projections. In many cases, however, we may have a more specific low-dimensional model for signals in which the signal class forms a nonlinear *manifold* in R^N. This paper provides preliminary theoretical and experimental evidence that manifold-based signal structure can be preserved using small numbers of random projections. The key theoretical motivation comes from Whitney's Embedding Theorem, which states that a K-dimensional manifold can be embedded in R^{2K+1}. We examine the potential applications of this fact. In particular, we consider the task of recovering a manifold-modeled signal from a small number of random projections. Thanks to our (more specific) model, the ability to recover the signal can be far superior to existing techniques in CS.

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MS12
The Wave Atom Basis and its Numerical Implementation

We introduce the orthonormal basis of wave atoms. Being a close relative to the curvelet frame, the wave atom basis obeys a similar parabolic scaling, namely the wavelength of a wave atom is roughly equal to the square of its side length. As a result, each wave atom can be viewed as a stack of curvelets at the same scale and this new orthonormal basis enjoys many useful properties of the curvelet frame. Our construction is a non-standard 2D extension of the recent work of L. Villemoes on wave packets with uniform time-frequency localization. Our numerical implementation, which uses a 'wrapping' technique to compute the decimated coefficients, is highly efficient and preserves orthonormality up to machine accuracy. We will briefly discuss the application of the wave atom basis in numerical computation. This is a joint work with L. Demanet and E. Candes.

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MS13
Limited Data x-ray Tomography Using Nonlinear Evolution Equations

A novel approach to the X-ray tomography problem with sparse projection data is proposed. Non-negativity of the X-ray attenuation coefficient is enforced by modelling it as $\max\{\Phi(x), 0\}$ where Φ is a smooth function. The function Φ is computed as the equilibrium solution of a nonlinear evolution equation analogous to the equations used in level set methods. The reconstruction algorithm is applied to (a) simulated full angle projection data of the Shepp-Logan phantom with sparse angular sampling and (b) measured limited angle projection data of in vitro dental specimens. The results are significantly better than those given by traditional backprojection-based approaches.

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MS13
Thermoacoustic Tomography - Reconstruction of Data Measured under Clinical Constraints

Thermoacoustic tomography (TCT) is a hybrid imaging technique proposed as an alternative to xray mammography. Ideally, electromagnetic energy is deposited into the breast tissue uniformly in space, but impulsively in time, heating tissue and causing thermal expansion. Cancerous masses absorb more energy than healthy tissue, creating a pressure wave, which is detected by standard ultrasound transducers. Idealized TCT data represents integrals of the tissue's EM absorptivity over spheres centered about the receivers.

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MS13

Wavelet-based Reconstruction for Limited-angle X-ray Tomography

The aim of X-ray tomography is to reconstruct an unknown physical body from a collection of projection images. When the projection images are only available from a limited angle of view, the reconstruction problem is a severely ill-posed inverse problem. Statistical inversion allows stable solution of the limited-angle tomography problem by complementing the measurement data by a priori information. In this work, the unknown attenuation distribution inside the body is represented as a wavelet expansion, and a Besov space prior distribution together with positivity constraint is used. The wavelet expansion is thresholded before reconstruction to reduce the dimension of the computational problem. Feasibility of the method is demonstrated by numerical examples using in vitro data from dental radiology.

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MS13

D-bar Reconstruction Method for Electrical Impedance Tomography

In electrical impedance tomography (EIT) one applies a set of electric voltage distributions at the boundary of an unknown physical body, measures the resulting currents through the boundary and reconstructs electric conductivity inside the body. A regularized reconstruction method for two-dimensional EIT is presented and applied to measured data. The method is based on the dbar method first introduced for 2D EIT by A. Nachman.

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MS14

The Geometry of Higher-order Flows in Imaging

In this talk we discuss the formulation of higher-order flows in imaging as gradient flows in metric spaces and similar structures. This allows to gain new insight into the dissipation and convergence properties of the flow, as well as their multiscale nature. For flows that can be set up in Banach spaces, one can also derive a dual flow, which allows to reveal hidden structures of the flow such as segmentation properties (since the dual variables are often edge detectors).

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MS14

Threshold Dynamics for Shape Reconstruction and Disocclusion

Not available at time of publication.

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MS14

On the Use of Ginzburg Landau Models in Image Processing and Computer Vision

Models based on the superconduction theory of Ginzburg and Landau have recently arisen some interest in the image processing and computer vision community. On its basis algorithms haven been invented for inpainting, denoising, segmentation, image sharpening and singularity detection, with this list being all but complete. Further, we have successfully used a Ginzburg-Landau energy for the regularization of ill-posed inverse problems. We will give a short introduction to the Ginzburg-Landau model and highlights some of its applications. We will also comment on numerical aspects of the implementation of Ginzburg-Landau based algorithms.

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MS14

Anisotropic Geometric Gradient Flows in Image Processing

For denoising, inpainting or restoration of images, we have exploited numerical methods relying on morphological image paradigms. This requires a two step procedure. First we locally classify the level sets and their singular surface structures (corners and egdes) via a local description of surface shapes by Wulff shapes. Then we drive an anisotropic level set evolution to process the image morphology. We proposed a novel concept of shape prior for the segmentation and fairing of 3D MRA data.
Furthermore, we apply anisotropic mean curvature motion and anisotropic Willmore flow for a truly co-dimension 2 edge enhancing image denoising and restoration.

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MS15

A New Algorithm Approximating the Differential Equations of Dilation and Erosion

We consider a new algorithm for the approximation of the differential equations of morphological dilation / erosion. The proposed method is a compressive flux corrected transport method. The transport mechanism of dilation / erosion is realised numerically by a diffusive basis scheme, and afterwards the numerical diffusion is annihilated by a discrete stabilised reverse diffusion process. The method not only yields a very sharp resolution of edges, it is also mathematically validated in terms of a multidimensional discrete minimum-maximum-principle.

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MS15

Image Registration on OcTrees

n this talk we concentrate on efficient methods for image registration that work on an OcTree structure. We will show that the complexity of the problem can be significantly reduced and that efficient algorithms can be developed using such structures.

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MS15

A Combined Variational Approach to Homogenization and Registration

In addition to the correction of distortion, some registration problems also require a compensation of grayscale variations. A typical example is the registration of a histological serial sectioning. We propose a registration approach which allows for an automatic correction of grayscale inhomogeneities. This variational based approach is attractive for grayscale compensation in a variety of applications, including histological serial sectioning (staining), optical flow (illumination), ans digital radiography (attenuation).

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MS15

De-speckling of Medical Ultrasound Images

Speckle noise is an inherent property of medical ultrasound imaging, and it generally tends to reduce the image resolution and contrast, thereby reducing the diagnostic value of this imaging modality. As a result, speckle reduction an important prerequisite, whenever ultrasound is employed for tissue characterization. Among the many methods which have been proposed to perform this task, there exists a class of approaches that utilize a multiplicative model of speckled image formation and take advantage of the logarithmical transformation in order to convert multiplicative speckle noise into additive noise. The present study shows conceptually and experimentally that assuming the latter to be a white Gaussian noise as it is done in a dominant number of cases is an oversimplified and unnatural assumption which may lead to inadequate performance of the filtering methods used to suppress the noise. The study introduces a simple preprocessing procedure, which modifies the acquired radio-frequency images (without altering the anatomical information they bear), so that the noise in the domain of the logarithmic transformation becomes very close in its behavior to white Gaussian noise. It allows filtering methods based on assuming the noise to be white and Gaussian, to perform in nearly optimal conditions. The study evaluates performances of three different non-linear filters wavelet de-noising, total variation filtering, and anisotropic diffusion and demonstrates that in all these cases, the modified processing results in a dramatic improvement in the quality of resultant images. Our numerical tests include a series of computer-simulated and in vivo experiments.

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MS16

Compressive Imaging: A New Framework for Computational Image Processing

Imaging sensors, hardware, and algorithms are under increasing pressure to accommodate ever larger and higher-dimensional data sets; ever faster capture, sampling, and processing rates; ever lower power consumption; communication over ever more difficult channels; and radically new sensing modalities. Fortunately, over the past few decades, there has been an enormous increase in computational power and data storage capacity, which provides a new angle to tackle these challenges. We could be on the verge of moving from a "digital signal processing" (DSP) paradigm, where analog signals (including light fields) are sampled periodically to create their digital counterparts for processing, to a "computational signal processing" (CSP) paradigm, where analog signals are converted directly to any of a number of intermediate, "condensed" representations for processing using optimization techniques. At the foundation of CSP lie new uncertainty principles that generalize Heisenberg's between the time and frequency domains and the concept of compressibility. As an example of CSP, we overview "Compressive Imaging", an emerging field based on the revelation that a small number of linear projections of a compressible image contain enough information for image reconstruction and processing. The implications of compressive imaging are promising for many applications and enable the design of new kinds of imaging systems and cameras.

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MS16

Highly Efficient Algorithms for Signal Recovery

I will provide an overview of several recent highly efficient algorithms for signal reconstruction and information recovery.

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MS16

Large-scale Convex Optimization and Sparse Recovery

L1 minimization has proven to be an extremely effective way to recover sparse signals from undersampled measurements. We will discuss some of the computational challenges in solving these programs for large signals (e.g. images with millions of pixels).

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MS16

Recent Algorithmic Advances in Sparse Signal Recovery

We discuss recent algorithmic advances in sparse signal recovery.

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MS17

Methodololgy of Partial Inverse Problems in the Context of Biomedical Imaging

So-called non-stationary inverse problems arise in several biomedical imaging applications, including impedance tomography, perfusion imaging, and inverse electrocardiography. These are actually elementary instances of partial inverse problems, which are characterized by a source function to be determined that is subject to component operators that individually do not address all of the source variables. A recently derived theoretically favored approach for regularization of such problems will be described and contrasted with traditional ad hoc methodologies.

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MS17

Electrical Source Imaging of Neural and Cardiac Activation

Bioelectrical activity is distributed in the three physical dimensions and evolves in time. It is of importance to image bioelectrical activity with high resolution in both the space and time domain. In this presentation, we will discuss electrical source imaging as applied to estimate dynamic electrical sources associated with brain and cardiac activation from noninvasive EEG/ECG. We will review the state of art of electrical source imaging, and our recent development and validation studies in electrophysiological neuroimaging and cardiac imaging.

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MS17

Accurate Image Reconstruction from Highly Sparse Data

In various imaging applications, because of practical constraints, one may encounter issues reconstructing accurate images of limited data. In this work, we will consider limited-data problems that occur in tomographic imaging by presenting a new, total-variation (TV)-based algorithm for image reconstruction from limited divergent-beam projection data. We also compare the result of our TV-based algorithm with those obtained with the widely used EM and ART algorithms.

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MS17

Local Basis Function Expansions for the MEG/EEG Inverse Problem

The magneto/electro-encephalography (MEG/EEG) inverse problem is reformulated using a local basis function expansion by segmenting the cortical surface into a set of overlapping patches and describing each using a small number of basis functions. The basis functions for each patch are designed to minimize the average representation error. The local basis function expansion approach improves computational tractability and performance by significantly reducing the number of free parameters and parsimoniously modeling realistic cortical activity patterns.

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MS18

Multimodal Image Registration Based on Generalized Morphology

Multimodal image registration significantly benefits from previous denoising and structure segmentation and vice versa. A variational approach is presented, which combines the detection of corresponding edges, an edge preserving denoising and the morphological registration via a non-rigid deformation for a pair of images with structural correspondence. The morphology of an image function is split into a singular part consisting of the edge set and a regular part represented by the field of normals on the ensemble of level sets while the deformation itself is regularized by nonlinear elasticity techniques. Numerical experiments underline the robustness of the presented approach and show applications on medical images.

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MS18

Enforcing Local Shape Priors for Brain Segmentation

This paper presents a segmentation algorithm incorporating local shape priors. A shape representation based on integral kernels is introduced and "meaningful" correspondences are established in a variational framework by the construction of diffeomorphisms. The diffeomorphisms lead to build shape priors that allows enforcing local shape information of region boundaries in the segmentation. The shape descriptor is robust to noise and forms a scale-space in which an appropriate scale can be chosen depending on the size of features of interest. The segmentation algorithm is presented in a variational framework incorporating shape energy preserving local shapes in the procedure of the matching.

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MS18

Simultaneous Surface and Volume Registration Using 2D and 3D Mappings

Harmonic and linear elastic maps between two Riemannian manifolds, and their p-harmonic generalizations, are powerful tools for the analysis of biomedical images. Their low computational complexity and their tendency to be bijective in practical applications makes these maps particularly attractive for the registration of both surface and volumetric images. In this talk we review the underlying theoretical and practical aspects of these mappings and present a new method which combines volumetric registration with surface registration to ensure that volumes are registered subject to the constraint that surface features are also aligned. We demonstrate this approach in application to coregistration of brain volumes such that the sulcal features on the cortical surface are also aligned.

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MS18

Brain Matching via Minimizing Lipschitz Extensions

Based on the notion Minimizing Lipschitz Extensions and its connection with the infinity Laplacian, a computational framework for surface warping and in particular brain warping (the nonlinear registration of brain imaging data) is presented in this paper. The basic concept is to compute a map between surfaces that minimizes a distortion measure based on geodesic distances while respecting the boundary conditions provided. In particular, the global Lipschitz constant of the map is minimized. This framework allows generic boundary conditions to be applied and allows direct surface-to-surface warping. It avoids the need for intermediate maps that flatten the surface onto the plane or sphere, as is commonly done in the literature on surface-based non-rigid brain image registration. The presentation of the framework is complemented with examples on synthetic geometric phantoms and cortical surfaces extracted from human brain MRI scans.

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MS19

Lenslet and Photoreceptor Array Acquired Image Superresolution

The objective is to contribute towards the design of end-to-end optimized optical-digital high-resolution (HR), large field-of-view (FOV), miniaturized cameras that is a topic of intense current research interest because of surveillance needs and for development of future generations of mobile phones and computers. Digital HR algorithms recently developed will be summarized and preliminary results on the lenslet-photoreceptor array plexus for attaining large FOV will be discussed.

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MS19

Image Registration

Image registration refers to finding a mapping between two images based on intensity differences. This ill-posed problem is often regularized by an elastic strain energy. We present an optimal control formulation of the problem in which the $L2$ misfit between images is constrained by elasticity equations, and the control variable is the body force. This permits anisotropic, heterogeneous regularization of the control, thereby better addressing the null space of the misfit functional. Applications to cardiac MRI images are presented.

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MS19

Gabor Methods in Seismic Imaging

The Gabor transform, a sampled version of the short time Fourier transform, forms the basis of our nonstationary deconvolution technique for seismic signals. A recording of seismic waves co-mingles reflectivity data of geological structures in the earth with spectral data of the seismic source (typically, a dynamite blast). Deconvolution removes the source signiture blurring, leaving a sharper image of the migrated reflectivity data. Operating in the Gabor domain allows us to correctly model the physics of time-variant source signature changes. Our Gabor deconvolution is a nonstationary extension of Wiener deconvolution, which has proven to be competitive with industry standard TVSW decon.

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MS19

Regularization and Prior Error Distributions in Ill-posed Problems

In this work we given an alternative, stochastic view of Tikhonov regularization. Tikhonov regularization is a common approach to finding parameter estimates for image restoration that minimizes data errors in a weighted least squares sense when the problem is ill-conditioned. A regularization term is added to the minimization problem but rather than view it as regularization, we view the process as minimizing weighted errors in initial parameter estimates. Thus when we regularize we are actually minimizing initial parameter estimate errors in addition to data errors. If parameters and data are thought of as random variables, then a priori information about their errors can be used as weights in the minimization. We will assume that a priori information about data errors are known and give a condition through which a priori information about initial parameter estimates can be inferred. This allows us to improve parameter estimates and give estimates of their uncertainty.

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MS19

Image Restoration and Feature Extraction: Significance and Overview

Stable extraction of information from Positron Emission Tomographic brain images is required for improved understanding and comparison of brain decline during aging, mild cognitive impairment and Alzheimer's Disease. We illustrate how sophisticated total variation deblurring of PET images improves image registration in longitudinal PET studies, and wavelet decomposition provides detail of functional change. Combination of novel approaches thus serves to enhance capabilities for sensitive drug studies.

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MS20

Some New Results and Examples about TV Mini-

mizers

Suppose f is a minimizer for a functional of the type introduced by Rudin, Osher and Fatemi or Chan and Esedoglu. Such f may be thought of a denoisings of some source image s, although they have other interesting interpretations as well. We will show that the sets $\{f \geq y\}$, $-\infty < y < \infty$, satisfy an auxiliary variational problem depending on y. We will also give some new and interesting examples of minimizers.

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MS20

SOCP Methods for Solving Hard Total Variation Regularization Models

Not available at time of publication.

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MS20

Bregman Iteration and Inverse Scale Space for Wavelet Soft Thresholding

We generalize the iterated refinement and nonlinear inverse scale space ideas to wavelet shrinkage and denoising. We obtain the surprising result that soft thresholding iterates to hard thresholding and this iterative procedure improves the results in the sense of Bregman distance.

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MS21

A Single Pixel Camera Based on Compressed Sensing

Digital micromirror devices have proven to be a commercially viable MEMs technology for the video/projector display market. Inspired by the success of this technology, we have combined a microcontrolled mirror with a single optical sensor so that it additionally acquire images, rather than merely adapt current camera technology to serve as an optical sensor. In this project, we have developed a practical image/video camera based on this concept and realized it through the use of compressed sensing. Our design has additional desirable properties including scalable output bit stream, variable image resolutions and video frame rates. We will also discuss the generalization of compressed sensing as a way of image formation for other single detector systems.

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MS21

Compressive Sampling vs. Conventional Imaging

Compressive sampling (CS), or "Compressed Sensing", has recently generated a tremendous amount of excitement in the image processing community. CS involves taking a relatively small number of non-traditional samples in the form of randomized projections that are capable of capturing the most salient information in an image. If the image being sampled is compressible in a certain basis (e.g., wavelet), then under noiseless conditions the image can be much more accurately recovered from random projections than from conventional imaging (point samples or low frequency projections). However, the performance of CS can degrade markedly in the presence of noise and consequently in realistic imaging problems the advantages of CS are less clear. We compare CS to conventional imaging methods in the presence of noise by considering a canonical class of piecewise smooth images (images that are twice-continuously differentiable except along boundaries/edges that are twice continuously differentiable curves). It is shown that for this class of images, CS coupled with wavelet-based reconstruction offers no advantage over conventional imaging, despite the fact that piecewise smooth images are compressible using wavelets. However, CS combined with curvelet-based reconstruction can outperform conventional imaging methods in such cases. This is possible because piecewise smooth images are highly compressible using curvelets. Our general conclusion is that CS can be advantageous in practical (noisy) imaging problems if the underlying image is highly compressible.

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MS21

Sampling Moments and Reconstructing Signals with Finite Rate of Innovation: Shannon meets Strang-Fix

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 the band is not limited. Recently, it was shown that by using an adequate sampling kernel and a sampling rate greater or equal to the rate of innovation, it is possible to uniquely reconstruct such signals. These sampling schemes, however, use kernels with infinite support and this leads to complex and unstable reconstruction algorithms. In this talk, we show that many signals with finite rate of innovation can be sampled and perfectly reconstructed using kernels of compact support and a local reconstruction algorithm. The class of kernels that we can use is very rich and includes functions satisfying Strang-Fix conditions, Exponential Splines and functions with rational Fourier transforms. Our sampling schemes can be used for either 1-D or 2-D signals with finite rate of innovation.

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MS22

Quantitative Analysis Improvement in Optical Coherence Tomography

OCT is a rapidly emerging imaging technology that enables micron-resolution visualization of the cross sectional structure of the retina and anterior eye with higher resolutions than any other non invasive imaging modality. We present specific improvements in the quantitative analysis of the current commercial OCT system. With such quantification, it is possible to obtain earlier detection of pathology as well as improved monitoring of disease progression and response to therapy.

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MS22

Assessment of Retinal Vascular Development for Feedback Regulation of Retinopathy of Prematurity

We present an approach to the automated assessment of physiological indicators of proliferative retinopathy. Retinal images are smoothed and filtered using two-dimensional matched filters to extract vascular networks; the tortousity of individual length-thresholded vessels is then calculated to develop image-wide tortuosity profiles. Our method is verified using artificial vascular netwoks with known distributions of vessel geometry, and our software is calibrated to return diagnostic evaluations consistent with those of clinical physicians.

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MS22

Bayesian Approaches to Automated Analysis of Changes in Retinal Images

An integrated Bayesian method to detect and classify multiple structural and functional changes in longitudinal sequences of retinal imagery from multiple modalities including color and dual-wavelength images, and fluorescein angiograms. Changes indicate disease onset/progression, and/or response to treatment. Structural changes in the vasculature and the non-vascular regions are distinguished. Functional changes focus on blood oxygenation in retinal vessels. Applications include clinical practice, quantitative scoring of clinical trials, computer-assisted reading centers, and medical research.

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MS22

Feature-Based Fundus Image Registration and Mosaic Formation

Image registration is a fundamental problem in developing automated tools for retinal image analysis. High accuracy alignment enables construction of fundus-wide mosaics, multimodal visualization, and pixel-level, longitudinal change detection. We have developed a series of feature-based algorithms for solving both the image pair registration problem and the multi-image registration problem. This talk will give a summary of these methods, describe the highly accurate and reliable results, and discuss open problems.

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MS23

Current Problems

This talk will discuss some of the current problems in radar imaging.

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MS23

Radar Background

Radar imaging is a technology that has been developed, very successfully, within the engineering community during the last 50 years. The key component that makes radar imaging possible, however, is mathematics, and many of the open problems are mathematical ones. This tutorial will explain, in terms suitable for a mathematical audience, the basics of radar and the mathematics involved in producing high-resolution radar images.

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MS24

Structured Total Least Squares for Color Image Restoration

Color image restoration is considered. As the point spread function and the observed image are contaminated by noise, total least squares (TLS) methods are an appropriate approach to restoring the original image. The way in which the blurring matrices represent the errors leads toward a structured total least squares (STLS) approach to compensate for the contamination of the point spread function. The ill-conditioning of said blurring matrices requires Tikhanov regualization to stabilize the solution. Since the STLS method requires the solution of a nonlinear least squares problem based upon imposing Neumann boundary conditions, solving the large linear systems resulting from a Gauss-Newton iteration can be done very efficiently using a conjugate gradient method preconditioned by a Discrete Cosine Transform (DCT) based preconditioner.

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MS24

Implicit Regularization Using Discontinuous Galerkin Method

In this talk, we will discuss the one dimensional version of the exponentially ill-posed inverse problem of diffuse optical tomography using the Discontinuous Galerkin (DG) method. We will show that DG method acts as an implicit regularization for the inverse problem. We will present simulation results comparing Continuous Galerkin and the DG inverse solutions.

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MS24

Automatic Linguistic Indexing of Pictures by a Statistical Modeling Approach

A statistical modeling approach is developed for automatic annotation of pictures. Categorized images are used to train a dictionary of hundreds of 2-D multiresolution hidden Markov models, each representing a concept. During annotation, we first rank the likelihoods of an image under all the profiling models. Words are then selected from the annotation of the top ranked concepts. A prototype system has been implemented and tested on a photographic image database of 600 different concepts.

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MS24

Image Deblurring and Multiscale Feature Extraction Using a Tunable Besov Space Characterization Applied to PET Images

Established and new methods are used to improve PET scans. TV deconvolution is used, estimating the PSF from phantom scans, and blind deconvolution. A version of the $u + v$ algorithm decomposing the picture into bulk and details by imposing, traditionally $u \in BV$ and $v \in H^{-1}$ is considered. We replace BV by $B_1^{1,1}$ and H^{-1} by $H^{-\beta}$ using wavelet representations. β Is used to tune the space to highlight small changes or remove reconstruction artifacts.

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MS25

Diffusions, Wavelets, and Image Processing

Though the anisotropic diffusion approach is fundamental to the study of digital image noise reduction, various problems arise and have been addressed from different points of view. Of particular interest is the introduction of bilateral filtering. We will show that bilateral filtering is intimately related to the formulation of diffusion maps, and hence motivates a somewhat different approach to the investigation of diffusion wavelets

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MS25

Handling Anisotropy via Level Sets

Not available at time of publication.

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MS25

Exact Solutions of Some Variational Image Analysis Models

In this talk I present joint work with Selim Esedoglu on exact solutions to variational image analysis methods. These methods are nonlinear and typically difficult to deal with analytically. Computational methods though are slow, with convergence behavior that is still not carefully studied. Exact solutions are therefore of interest since they can be compared to computed minimizers or computed trajectories to the minimizers. I will focus on some properties of exact minimizers. Though the details are rather involved, the insights are very geometric and I will use this to give an intuitively accessible look at our results.

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MS25

A Novel Method of Edge Detection by the Super Fast Fourier Transform

We propose a novel method for recovering edges in piecewise smooth functions. Our approach is based on a sublinear super Fast Fourier Transform (sFFT), which is used to detect (finitely many) jump discontinuities. Instead of the usual Fourier bases, we extend the sFFT to more general concentrate kernels which enable us to process the spectral content by separation of scales. Numerical results are encouraging. This is a joint work with Dr. Eitan Tadmor.

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MS26

Segmentation And Quantitative Evaluation Of Brain MRI Data With Multiphase Three-Dimensional Implicit Deformable Models

We present the implementation and quantitative evaluation of a multiphase three-dimensional deformable model in a level set framework for automated segmentation of brain MRIs. The segmentation algorithm performs an optimal partitioning of three-dimensional data based on homogeneity measures that naturally evolves to the extraction of different tissue types in the brain. Random seed initialization is used to minimize the sensitivity of the method to initial conditions while avoiding the need for a priori information. This random initialization ensures robustness of the method with respect to the initialization and the minimization set up. Post processing corrections with morphological operators was applied to refine the details of the global segmentation method. Results from a clinical study on a database of 10 adult brain MRI volumes are presented, comparing the multiphase level-set segmentation to three other methods: idealized intensity thresholding, fuzzy connectedness and expectation maximization classification using hidden Markov random fields. Quantitative evaluation of segmentation accuracy was performed with comparison to manual segmentation computing true positive and false positive volume fractions. A statistical comparison of the segmentation methods was performed and showed very high quality and stability of the multiphase three-dimensional level set method. Two methodological extensions of the multi-phase level set segmentation methods are also presented: First we introduce a non convex homogeneity measure, enabling segmentation of brain MRI data sets with lower image quality.; Second, we derive a vectorial-based approach of the multiphase level set segmentation method with fusion rules suited for multi-protocol brain MRI segmentation. Experiments on clinical data are presented for both methodological extensions.

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MS26

Image Segmentation Using a Multilayer Level Set Approach with Application to MRI data

We propose a piecewise-constant image segmentation model based on a curve evolution approach in a variational formulation. The problem to be solved is a particular case of the minimal partition problem, as formulated by Mumford and Shah, and can be viewed as extensions of the Chan-Vese active-contour model. We represent the set of boundaries of the segmentation implicitly, by a multilayer of level-lines of a continuous function. In the standard approach of front propagation, only one level line is used to represent the boundary. The multilayer idea is inspired from previous work on island dynamics for epitaxial growth. Using a multilayer approach, the computational cost can be reduced in segmenting certain images. We demonstrate one application of our model to 3D MRI medical images. We then introduce an indicator function for the brain region so that we segment the brain region only, in White Matter, Gray Matter and CSF. This enables us to reduce the number of the level lines to be used, resulting in a further reduction of the computational cost. Validation of our model will be addressed as well via sensitivity and specificity analysis.

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MS26

Image Segmentation on Riemann Surfaces Using the Conformal Mapping and its Application to the Automatic Landmark Tracking

Anatomical features on the cortical surface are usually represented by landmark curves, called sulci/gyri curves. These landmark curves are important information for neuroscientists to study brain diseases and to match different cortical surfaces. Manual labeling of these landmark curves is time-consuming, especially when there is a large set of data. In this paper, we proposed an automatic way to detect the sulci landmark curves. This is done by extracting the high curvature region on the cortical surface using the Chan-Vese segmentation. This involves solving a PDE on the manifold using the global conformal parameterization. To do this, we have to define a new set of differential operators on the manifold such that they are coordinates invariant. Since the Jacobian of the conformal mapping is simply a multiplication of the conformal factor, the modified PDE on the parameter domain will be very simple and easy to solve. Experimental results show that the landmark curves detected by our algorithm can closely resemble to those manually labeled curves.

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MS26

Anatomical Structure Parsing for Brain Imaging

One of the problems in brain imaging is to design algorithm to perform anatomical structure parsing. The task is to automatically decompose an input 3D brain volume into anatomical objects such as caudate, thalamus, hippocampus. This requires to model the shapes and appearances of various objects, and to design efficient computing algorithm to make inference of them. We will present a method which integrates discriminative and generative models for anatomical structure parsing.

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MS27

New Families of Shift-invariant and Mathematically Exact Cone-beam Filtered Backprojection Algorithms Using Factorized Weighting Functions

Weighting function design is key to cone-beam image reconstruction algorithms. In this talk, using a novel factorized weighting function, we present how to develop infinitely many shift-invariant and mathematically exact filtered backprojection image reconstruction algorithms. Specifically, the general weighting function $w(\vec{x}, \hat{k}; t)$ was decomposed into three components $w_1(\vec{x}, \hat{k})$, $w_2(\vec{x}, t)$, and $sgn(\hat{k} \cdot \vec{y}'(t))$, viz. $w(\vec{x}, \hat{k}; t) = w_1(\vec{x}, \hat{k}) w_2(\vec{x}, t) sgn(\hat{k} \cdot \vec{y}'(t))$. Based upon the normalization condition of the weighting function, the first component $w_1(\vec{x}, \hat{k})$ may be calculated using the second component $w_2(\vec{x}, t)$. Thus, as long as the second component is specified, the weighting function is completely determined. After this weighting function has been specified, the Katsevich formula for a general source trajectory may be utilized to develop efficient FBP image reconstruction algorithms.

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MS27

Cone-beam Tomography from Truncated Projections Measured on a C-arm System

Not available at time of publication.

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MS27

Region of Interest Image Reconstruction from Truncated Data

In many applications of tomographic imaging, it may not be possible to acquire non-truncated projection data. Although it is impossible to reconstruct exactly the entire image function from truncated data, it is of practical significance to investigate image reconstruction in certain regions of interests (ROIs) within the object from truncated data. Conversely, in many applications, one is interested only in image reconstruction within an ROI. In this situation, it is also of practical significance to investigate whether it is possible to reconstruct exactly ROI images from truncated projection data covering only the ROI instead of the entire object. In this work, we investigate ROI-image reconstruction from truncated projection data. Our theoretical and numerical results indicate that it is possible to reconstruct exact ROI-images from truncated data.

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MS27

Development of Spiral Cone-Beam CT Methods

Because of the importance of the so-called long object problem, spiral cone-beam computed tomography (CT) has become a hot area in the CT field. As a main stream in the development of the next generation medical CT, spiral cone-beam CT has been greatly improved in terms of reconstruction methods since it was first proposed in 1991. Now, the state-of-the-art cone-beam algorithms can reconstruct images exactly from longitudinally truncated data collected along a rather general scanning trajectory. Here we present a brief overview of this area with an emphasis on the results achieved by our team. In our opinion, spiral cone-beam CT algorithms have been developed in four phases. In the practical reconstruction phase (1991-1996), various approximate algorithms were proposed. Among these are generalized Feldkamp algorithms. In the multi-turn-based reconstruction phase (1997-2001), quasi-exact/exact helical cone-beam algorithms were developed based on a generalized Grangeat condition. In these algorithms, longitudinally truncated data are needed from multiple helical turns, which prevent these theoretically exact solutions from being practically applicable. In the PI-line-based reconstruction phase (2002-2004), the Katsevich helical cone-beam CT method was invented to rely only on data associated with the PI-arc for exact reconstruction. Inspired by his filtered backprojection formulism, a backprojected filtration method was proposed by Zou and Pan, enabling the minimum data based reconstruction. In the general scanning based reconstruction phase (2004-present), there has been a remarkable surge in research on exact image reconstruction in the case of general cone-beam scanning. Our group generalized helical cone-beam BPF and FBP algorithms for exact reconstruction from data collected along a general smooth curve. Our general algorithms and others independent algorithms such as the M-line method by Noo et al. can work with truncated data and do not need to specify any weighting function. Further directions on spiral cone-beam CT are also discussed.

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MS27

Extension of the Reconstruction Field-of-view Using Sinogram Decomposition: Application to Cone

Beam CT

Sinogram truncation is a common problem in tomographic reconstruction; it occurs when a scanned object or patient extends outside the scan field-of-view. The truncation artifact propagates from the edge of truncation towards the center, resulting in unacceptable image quality. Several methods have been proposed recently to reconstruct the image artifact-free within the scan FOV; however it is often necessary to recover image outside the scan FOV. We propose a novel truncation correction algorithm that accurately completes unmeasured data outside of the scan field-of-view, which allows us to extend the reconstruction field-of-view. Contrary to a simple 1D extrapolation, we perform interpolation in the view direction along the so-called sinogram curves. First, we propose an approach to parameterize the family of sinogram curves for efficient sinogram decomposition. Secondly, we propose two ways to estimate the truncated data outside the field-of-view. Both methods are combined for more accurate sinogram completion. Our extensive evaluation shows the validity of our approach with image quality superior to the current correction methods. Even objects completely outside the FOV can be accurately reconstructed, which is impossible with any current method. The proposed method can be used with any modality where sinogram truncation occurs, such as CT, C-arm, PET/CT, etc.

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MS28

A Level Set Method for Constrained Object Segmentation

In a previous work we presented a approach to find in a 3D image the boundary surface of an object knowing two curves on this object. The surface was defined as a set of minimal paths that link the two curves together. We now extended this work to more than two curves. Also, we introduced a level set method that finds directly a surface that contains the given curves and all minimal paths between them.

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MS28

Distance Maps Computation on Parametric non-Euclidean Three-Dimensional Manifolds

We present an efficient numerical algorithm for computation of weighted distance maps on parametric three-dimensional manifolds. Our approach is based the fast marching method for solving the eikonal equation in O (n log n) steps by numerically simulating wavefront propagation. Two wave propagation models – the spherical and the planar, are presented and their suitability for different types of sources from which the distance is computed is discussed. Numerical simulations demonstrate the advantages and the disadvantages of each of the two schemes. We also show a simple solution that allows to handle tessellations with obtuse angles.

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MS28

Fast Marching and Deformable Models in Image Analysis

We have used minimal paths for finding multiple contours for contour completion in 2D or 3D images. Fast Marching can be used as well for segmentation of tubular shapes and finding central lines. Based on Fast Marching on a surface, we defined a remeshing algorithm on a given surface with an adaptive or uniform density of vertices. We show applications of these techniques to segmentation and tracking in biomedical images and virtual endoscopy.

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MS28

Flexible Local or Global Minima: Dual-Front Active Contours

Most variational active contour models are designed to find either the local minima or the completely global minima. However, sometimes the completely-global minimum is just as undesirable as a minimum that is too local. We propose a novel, fast, and flexible dual front implementation of active contours, motivated by minimal path techniques, which is easily manipulated to yield minima with variable "degrees" of localness and globalness. We illustrate various 2D/3D implementations of this model.

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MS28

O(N) Implementation of the Fast Marching

We present an implementation of the fast marching algorithm for solving Eikonal equations that reduces the original run-time from O(N log N) to linear. This lower run-time cost is obtained while keeping an error bound of the same order of magnitude as the original algorithm. This improvement is achieved introducing the straight forward untidy priority queue, obtained via a quantization of the priorities in the marching computation. We present the underlying framework, estimations on the error, and examples showing the usefulness of the proposed approach.

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MS29
Radar Detection and Imaging Using Waveforms with Spatial and Spectral Diversity

The talk will focus on exploiting signals from a transmitter that has both spatial and spectral diversity to form high resolution radar detection maps or images. We will examine cases where the transmitter antenna locations are sparse as well as when the waveform is sparse in frequency. A simple example is when each antenna transmits on a different frequency from a random location is space.

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MS29
Doppler-only Synthetic-Aperture Imaging

Conventional Synthetic Aperture Radar transmits high-range-
resolution waveforms from disparate directions/locations, and uses the scattered field to form an image. From a moving platform, however, there is a complementary imaging mode that uses a singe-frequency waveform and then relies on Doppler frequency shift measurements rather than on range measurements. The Doppler measurements from different directions/locations can be combined to form an image. The fact that high-resolution imaging can be done from these two extreme types of waveforms (high range resolution and high Doppler resolution) suggests that it may be possible to design high-resolution imaging systems for a wide variety of other waveforms as well.

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MS29
Wavelets and Radar

This paper considers the general wideband model for radar echoes from a continuous distribution of objects. The echo is an inverse wavelet transform of the reflectivity density function, where the role of the analyzing wavelet is played by the transmitted signal. The null space of the inverse wavelet transform is nontrivial, which leads us to consider transmitting an orthogonal basis – or, more generally, a frame – of signals

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MS29
Not available at time of publication

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MS30
Some Variations on Variational Image Smoothing

We ask a simple question: What happens when one replaces the first-order differences in BV variational image smoothing by second-order differences? Specifically, what do the algorithms and the resulting images look like? How can you interpret the results mathematically? We have some answers.

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MS30
On a Multiscale Representation of Images as Hierarchy of Edges

We discuss a multiscale image decomposition which offers hierarchical representations of general images. The starting point is a variational decomposition of an image, $f = u_0 + v_0$, where $[u_0, v_0]$ is the minimizer of a J-functional, $J(f, c_0; X, Y) = \inf_{u+v=f} \|u\|_X + c_0\|v\|_Y^2$. Such minimizers are standard tools for manipulations of images. Here, u_0 should capture 'essential features' of f which are to be separated from the spurious components in v_0, and c_0 is a fixed threshold which dictates separation of scales. To proceed, we iterate the refinement step $[u_{j+1}, v_{j+1}] = \text{arginf} J(v_j, c_0 * 2^j)$, leading to the nonlinear hierarchical decomposition, $f = \sum_{j=0}^{k} u_j + v_k$. We focus our attention onthe particular case of $(X, Y) = (BV, L^2)$-decomposition. The questions of convergence, energy decomposition, localization and adaptivity are discussed. Numerical results illustrate applications to synthetic and real images (both grayscale and colored images).

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MS30
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MS30
Total Variation-based Image Restoration and Cartoon-texture Decomposition via Second-order Cone Programming

We present methods for image restoration and cartoon-texture decomposition based on the total variation minimization framework of Rudin, Osher and Fatemi and second-order cone programming. Analyical results will be presented as well as computational results illustrating the effectiveness of our approach.

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MS31
Multiscale Methods in Geometric Detection

Multiscale approach has been proven to be effective in determining the state-of-the-art boundaries in detectability problems. We review some new results in this direction. More specifically, the existing results give the asymptotic rate of the boundaries. More precise distributional results can be derived, and they reveal more accurate properties of the detectability boundaries. Some of these results will be presented in my talk. Potential applications are described.

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MS31
Multiscale Strips and the Geometry of Sets of Local Filter Coefficients of Images

We describe the problem of characterizing a cloud of points centered around a curve in a Euclidean space in the presence of significant outliers. We suggest an algorithm (Multiscale Strip Construction) for solving this problem and describe its properties. We then explore the geometry of vectors corresponding to local filters of a given image (in particular local patches). This geometry fits into the cloud structure described above, where the outliers may correspond to edges in the original image. However, we emphasize the nontrivial geometry of outliers in this case and develop techniques to characterize and interpret them. This last part (geometry of outliers) is joint with G. Chen, whereas the rest of the talk is joint J. McQuown and B. Mishra.

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MS31
Multiscale Constructions Induced by Diffusions on Sets

We show how novel constructions of multiscale analyses and wavelets on graphs and point clouds allow to perform signal processing on such discrete structures. This is applied to image (2D,3D, hyper-spectral) analysis and processing by mapping (nonlinearly) images to high-dimensional graphs, and the multiscale structure of these can be used to perform nonlinear signal processing on the original image. This is joint work with R.R. Coifman and A.D. Szlam.

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MS31
Minimax Optimal Level Set Estimation

This talk addresses the identification of level sets of an image from noisy observations. Theoretical analysis reveals that the level set estimation criterion must be distinctly different from that typically used for image reconstruction to achieve optimal error decay rates. Using fundamental statistical concentration inequalities, it is possible to derive error performance bounds for the proposed estimator and demonstrate that it exhibits near-optimal minimax error decay rates for large classes of level set problems.

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MS32
Some Mathematical Problems of Thermoacoustic Tomography

Thermoacoustic tomography is one of newly developing and extremely promising modalities of medical imaging. Mathematically speaking it is about inversion of the generalized Radon transform that integrates functions over spheres centered at a given set. The talk will address the following tomographic issues: uniqueness of reconstruction, inversion procedures, limited data reconstructions, and range conditions. All of these have been resolved for the standard X-ray CT scan, but are only partially understood for the spherical transform.

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MS32

Identification and Utilization of Data Redundancies in Thermoacoustic Tomography

We review the existence of data redundancies in thermoacoustic tomography (TAT). A novel layer-stripping procedure is formulated, revealing two-fold data redundancy exists in a complete TAT data. Identified data redundancies can be exploited in various ways that may have significant implications for practical TAT imaging systems. In addition to reducing the amount of required measurement data, data redundancies can be exploited for the simultaneous reconstruction of both the electromagnetic and acoustic properties of the object.

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MS32

Thermoacoustic Tomography Using Integrating Area and Line Detectors

The usual approach in TCT is to use point like detectors to measure thermoacoustic pressure signals. In this case TCT is connected with the spherical Radon transform. Since small transducers are used to simulate point measurement data, this approximation limits the spatial resolution. Our new approach is to use large plane (long line) detectors. In that case we measure exact projections over planes (cylinders). We present experimental setups and reconstruction algorithms for some special configurations.

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MS32

Thermoacoustic Imaging: The Struggle to Become Clinically Relevant

While the underlying physical principles of thermoacoustic imaging have been applied to biologic systems over the past 25 years, clinical applications of the technology have yet to displace more established technologies, such as those based on ultrasound, magnetic resonance, and x-rays. There are three major reasons for this failure: poor image quality, non-disease-specific image contrast, and complex hardware implementation. These deficiencies can be addressed by developing: better instrumentation, improved reconstruction algorithms, and new molecular probes.

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MS33

Diversity Channels for Mitigation of Wavefront Ambiguity

Not available at time of publication.

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MS33

Biased CRB Calculations for Estimators Lacking Closed-form Expressions

Biased Cramr-Rao lower bound (CRB) theory produces lower bounds to the variances achievable by any algorithm that has the bias gradients used to generate those bounds. To calculate these bounds, an analytical expression for the estimator bias gradient is needed, an expression that is often not available. Here we present an approach to deriving an analytical expression for the biased CRBs when an analytical expression for the bias gradient is not available.

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MS33

Performance Analysis and Bounds for Registration, Fusion, and Super-resolution of Aliased Image Sequences

Recently, there has been much work developing super-resolution algorithms for combining a set of low quality images to produce a set of higher quality images. Either explicitly or implicitly such algorithms must perform the joint task of registration and fusing of the low quality image data. While many such algorithms have been proposed, very little work has addressed the performance bounds for such problems. In this work, we analyze the performance limits from statistical first principles using the Cramer-Rao inequality. Such analysis offers insight into the fundamental super-resolution performance bottlenecks as they relate to the subproblems of image registration, reconstruction, and image restoration.

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MS33

Taxonomy of Fisher Information Based Variance

Bounds and Their Application to Imaging

Fisher information (FI) defines a useful lower bound on the variance of any estimator based on statistical data. In the presence of multiple estimation parameters and prior knowledge, a number of FI based lower bounds can be derived. This talk will explore the inter-relationships among these various bounds, and will illustrate them with applications drawn from imaging.

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MS34
Adaptive Structure-Texture Image Decomposition

In this work, we explore new aspects of the image decomposition problem using modern variational techniques. We aim at splitting an original image f into two components u and v, where u holds the geometrical information and v holds the textural information. Our aim is to provide some necessary variational tools and suggest suitable functional spaces to extract specific types of textures. Our modeling uses the total-variation semi-norm for extracting the structural part and a new tunable norm, based on Gabor functions, for the textural part. A way to select the splitting parameter based on the orthogonality of structure and texture is also suggested.

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MS34
Image Decompositions Using Bounded Variation and Homogeneous Besov Spaces

This talk is devoted to the decomposition of an image f into $u + v$, with u a piecewise-smooth or "cartoon" component, and v an oscillatory component (texture or noise), in a variational approach. In 2001, Y. Meyer theoretically proposed weaker and more refined texture norms than the standard L^2 norm to model oscillatory components. Motivated by his remarks, we study cases where the oscillatory component v belongs to generalized homogeneous Besov spaces, while keeping the piecewise-smooth component u of bounded variation. Numerical results will be presented to validate the proposed models.

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MS34
Variational Methods in Cartoon + Texture Decomposition

Recently a number of interesting techniques have been proposed for decomposing an image into a piecewise smooth function, commonly referred to as a cartoon, and an oscillating function containing textures and noise. In this talk we give an overview of some of the new techniques based on Meyers variational formulation for cartoon + texture decomposition. We will also discuss a new model which uses an adaptive TV type energy to reconstruct a piecewise smooth cartoon (in particular, one that avoids staircasing) with a corresponding adaptive energy for the oscillating part that reduces the presence of structure in this component. Theoretical results demonstrate this method is mathematically sound, and numerical results to illustrate the effectiveness of the model in image decomposition.

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MS34
Nonlinear Inverse Scale Space Methods

We generalize the iterated refinement method, introduced by Osher, Burger, Goldfarb, Xu and Yin, to a time-continuous inverse scale-space formulation. The method arises as a limit for a penalization parameter tending to zero while the number of iteration steps tends to infinity. When a discrepancy principle is used as the stopping criterion, the error between the reconstruction and the noise-free image, in the sense of Bregman distance, decreases until termination, even if only the noisy image is available. We show that noise can be well removed with minimal loss of contrast. Also, following Chan-Esedoglu and Yin, Goldfarb Osher, we use this technique to get excellent BV/L1 cartoon/texture decompositions.

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MS34
High Order Dual Methods for Staircase Reduction

in Texture Extraction Problems

Not available at time of publication.

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MS35

DEM Compression Using Level Set Methods

We have developed a simple addon to standard image compression methods and have used it for digital terrain elevation data. The results are quite promising, especially in the retention of geometric features. Additionally we have combined this compression with new dynamic visibility algorithms to show that path planning using compressed data is feasible. This is joint work with: H-K Zhao, Y. H Tsai, and S. Chen

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MS35

A Novel Image Registration Scheme Based on Watershed Transform and Curve Matching

We propose a novel and robust image registration scheme. First, a novel modified watershed segmentation followed by a region merging process is performed for the image pair to be registered. This algorithm preserves salient regions as well as closed region boundaries. Then a scale-space curve matching algorithm is used to select pairs of matching regions. Mutual information registration is performed on matched regions subsequently. The curve matching algorithm will provide initial values for the registration parameters. Our results will show automatic, high-quality registration.

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MS35

Requirements for Mathematical Processing of Geospatial Data

NGA is exploring the applicability of advances made over the last decade in the mathematical analysis of images and fostering new developments for applications including image registration, compression, contouring and information extraction. Significant emphasis is placed on automation for robust, real-time applications. This presentation provides an overview of geospatial data, an examination of the processing currently performed, and processing requirements for the future. The presentation concludes with a summary of opportunities for research at NGA.

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MS35

Contouring Noisy DEMs Using PDE Techniques

We present a framework for smoothing grid-like digital terrain elevation data, which achieves fair shape by means of minimizing an energy functional. The minimization is performed under the side-condition of hard constraints which come from available horizontal and vertical accuracy bounds in the elevation specification. We introduce the framework and demonstrate the suitability of this method for the tasks of accuracy-constrained smoothing, feature-preserving smoothing, and filling of data voids.

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MS36

Bregman Iteration, Inverse Scale Space, Cartoon/texture Decomposition, Recovery of Signal from "Noise" and Other New Techniques in PDE Based Image Restoration

See minitutorial abstract.

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MS37

Image Invariants from Lie Group Representations

The effective use of harmonic analysis on non-commutative Lie groups for problems in computer vision and other applications requires a computationally effective means to find their operator-valued Fourier transform and its inverse. We present a general scheme for a class of Lie groups given by semidirect products that include the affine and euclidean motion groups. Our approach emphasizes induced representations and integral operators.

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MS37

3D Motion Recovery via Spherical Filtering

A multitude of computer vision applications are linked by the fundamental problem of matching, whether it be signal alignment for image mosaicing, point matching for laser scan alignment, and feature matching for 3D motion estimation. This talk will touch on the application of harmonic analysis techniques for all three examples, but the focus will be on the last one. We will present a novel approach for the estimation of 3D-motion directly from two images using the Radon transform. The feasibility of any camera motion is computed by integrating over all feature pairs that satisfy the epipolar constraint. This integration is equivalent to taking the inner product of a similarity function on feature pairs with a Dirac function embedding the epipolar constraint. The maxima in this five dimensional motion space will correspond to compatible rigid motions. The main novelty is in the realization that the Radon transform is a filtering operator: If we assume that the similarity and Dirac functions are defined on spheres and the epipolar constraint is a group action of rotations on spheres, then the Radon transform is a correlation integral. We propose a new algorithm to compute this integral from the spherical harmonics of the similarity and Dirac functions. Generating the similarity function now becomes a preprocessing step which reduces the complexity of the Radon computation by a factor equal to the number of feature pairs processed. The strength of the algorithm is in avoiding a commitment to correspondences, thus being robust to erroneous feature detection, outliers, and multiple motions.

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MS37

Spherical Convolution for Inverse Rendering in Computer Graphics

Realism in computer-generated images requires accurate input models for lighting and reflectance functions. One of the best ways of obtaining high-quality data is through measurements of scene attributes from real photographs by inverse rendering. This talk introduces a new signal-processing framework for inverse rendering under complex lighting. We describe the reflected light as a spherical convolution of lighting and the BRDF (bi-directional reflectance distribution function) or reflectance properties of the surface. Mathematically, we express the reflected light as a product of spherical harmonic coefficients of the lighting and BRDF. Within this theory, reflection can be viewed as taking the incident illumination signal, and filtering it by the BRDF kernel, with inverse rendering seen as deconvolution. We apply our theory to a number of inverse problems, understanding why certain problems are ill-posed or ill-conditioned and developing new frequency domain algorithms, including for lighting and BRDF estimation and deconvolution.

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MS37

Range-Doppler Target Estimation Using Harmonic Analysis of the Affine and Heisenberg Groups

This talk presents a new framework to simultaneously achieve multiple objectives in wideband radar signal processing. These objectives include high resolution range-Doppler imaging, clutter rejecting adaptive diversity waveform design, removal of range-Doppler clutter, and use of a priori knowledge. Our approach is based on the Fourier transform of the affine and Heisenberg group and a novel Wiener type spectral domain filtering for reconstruction. This approach leads to a framework in which the waveform design and imaging problems are naturally coupled. We will present several algorithms that exploit joint design of transmission and reception. The methods can be also viewed as a synthetic wideband imaging method using multiple antennas with limited aperture operating independently.

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MS38

Resolution Issues in Radar and X-ray CT

Radar imaging and X-ray Computed Tomography (CT) are both based on inverting the Radon transform. Yet radar can make images from as little as two degrees of aperture while X-ray CT typically requires an aperture of at least 120 degrees. This work examines the point spread function for limited-aperture imaging in order to determine the resolution in the two cases.

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MS38

Thermoacoustic Tomography

A mathematical idealization of the problem of thermoacoustic tomography is the recovery of the initial data (assuming only one datum is non-zero) of a solution of the wave equation in domain from the trace of the solution on a portion of the boundary. The boundary data is highly structured. We give a range characterization when the domain is a ball in an odd-dimensional space. We also discuss the problem of anisotropy of detector response, and show that for a special type of anistropy in three dimensions, inversion is still possible in the spherical geometry.

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MS38

Local Tomography in SPECT

The author will present a local algorithm and reconstructions for slant-hole SPECT. Using microlocal analysis, he will explore the ill-posedness of the problem. The talk will provide a short introduction to microlocal analysis and a quick overview of the other topics in the minisymposium.

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MS38

The Formula of Grangeat for Tensor Fields and its Consequences in Vector Field Tomography

The cone beam transform for symmetric tensor fields of order m reads as

$$\mathbf{Df}(\mathbf{a},\omega) = \int_{\mathbf{0}}^{\infty} \langle \mathbf{f}(\mathbf{a}+\mathbf{t}\omega), \omega^{\mathbf{m}} \rangle \, \mathrm{dt}\,.$$

The development of inversion methods for that transform is of large interest in vector field tomography where the X-ray sources a lie on a curve Γ which usually is a union of circles or a helix. To this end the generalization of Grangeats formula to symmetric tensor fields

$$\frac{\partial^{(n-2)}}{\partial s^{(n-2)}} \mathbf{Rf_a}(\omega, \langle \mathbf{a}, \omega \rangle) = (-\mathbf{1})^{(\mathbf{n-2})} \int_{\mathbf{S^{n-1}}} \mathbf{Df}(\mathbf{a},\theta)\, \delta^{(\mathbf{n-2})}(\langle \theta, \omega \rangle)\, \mathrm{d}\theta,$$

where $f_a(x) = \langle \mathbf{f(x)}, |\mathbf{x}-\mathbf{a}|^{-\mathbf{m}}(\mathbf{x}-\mathbf{a})^{\mathbf{m}} \rangle$ are projections of the tensor field $\mathbf{f}$ and $\mathbf{R}$ denotes the 3D Radon transform, promises to be a starting point for designing such methods. The talk discusses possibilities to compute reconstruction kernels or to develop inversion algorithms for $\mathbf{D}$ with the help of Grangeats and related formulas. But it also shows restrictions of this formula compared to that for scalar fields.

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MS39

A Boundary Parameterization Algorithm

Suppose R is a continuously differentiable region in the plane and G is a rectangular grid. Mark each point in the grid black if it is inside R and white otherwise. We give an algorithm for parameterizing the boundary of R and computing its arclength. The error in the arclength is at most a simple constant times the modulus of continuity of the boundary normal. In fact, a straightforward variation of the method works for parameterizing the boundary and computing the surface area of the boundary of a region in space.

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MS39

Feature Extraction from Severely Undersampled 3D Radiogaphic Muon Data

Background-muon signatures can be used for 3D imaging. While conceptually appealing for applications in homeland security, the sparsity of data makes imaging difficult in time sensitive applications. The problem of extracting features from effectively blurred and undersampled image data is considered through anisotropic data-dependent metrics applied to likelihood and clustering interpretation methods. Results show that some meaningful answers are obtainable within reasonable times.

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MS39

Segmentation of X-ray Images

This talk will present a novel method for image segmentation that is applicable in many scientific imaging contexts. The specific type of image that will be discussed is based on x-ray imaging. This work is also applicable to other types of radiographic images such as proton radiographs, where segmentation algorithms must be robust in the presence of noise.

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MS39

Comparing Simulation and Experimental Images via Shape Metrics

Geometric measure theory provides a strong theoretical basis for shape and image analysis that can be applied to the verification and validation process of computational science. This talk demonstrates the applicability of shape metrics and a suite of image processing tools to comparing simulated and experimental data for shocktube experiments. The application of measure theoretic densities as a shape metric to perform time registration of simulated data with the corresponding experimental results is discussed.

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MS40

Macromolecular Ultra-Structure Elucidation from Cryo-Electron Microscopy

Hybrid experimental approaches for capturing large macromolecular structures (henceforth, complexes), utilizing single particle cryo-electron microscopy (cryo-EM), and electron tomography (ET), need to be ably complemented with faster and more accurate image processing for ultrastructure elucidation at the best level of resolution that is possible. This talk shall describe some of our recent efforts in geometric and signal processing once a volumetric EM or ET map (henceforth a 3D Map) has been reconstructed, as essential steps towards an enhanced and automated computational structure refinement pipeline. In particular I shall address 3D Map filtering, automated structural feature determination including local symmetry detection, structural alignment, and helix and beta-sheet identification. This research is supported in part by NSF ITR grant EIA-0325550 and NIH grant 1R01-GM074258-021

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MS40

Maximum Likelihood 3-D Reconstruction from Noisy Projections with Unknown Orientations and Cryo Electron Microscopy of Viruses

Model-based statistical inference using maximum likelihood is a powerful method for dealing with uncertainty in data. Mathematical models for cryo electron microscopy (cryoEM) studies of viruses are described that include uncertainty in the 3-D orientation and 2-D center location of the virus particle, the noisy character of the image, the contrast transfer function, and uncertainty in the type of virus particle present (from among a known number of types). Model-based maximum likelihood 3-D reconstruction of the scattering intensity from cryoEM images and parallel computational methods will be presented.

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MS40

Non-uniform Fourier Transforms in Cryo-EM Data Processing

A key step in Cryo-Em data processing is the alignment of 2-D particle images to 2-D projections of a 3-D model volume. Unfortunately, interpolation error in the standard algorithms for both 2-D rotations and 3-D projections leads to notably degraded reconstructed images. We show how non-uniform fourier transforms (gridding) can be used to avoid such interpolation errors, thereby improving the fidelity of the reconstructed volume.

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MS40

A Quasi-Newton Method for Structure Determination from Cryo-EM Projections

Given a low resolution initial guess to the 3-D macromolecular structure to be reconstructed from a large set of 2-D cryo-electronic microscopy images (with unknown orientations), a higher resolution 3-D model can be computed by using a Quasi-Newton method to minimize the discrepancy between the experimental images and projections of the reconstructed 3-D model. The computational details of this approach, such as gradient calculation, the effect of noise, and contrast transfer function correction will be presented.

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MS42

Efficient Sampling in Helical Tomography

In tomography, the fan beam geometry symmetry yields a reflected lattice associated to each sampling lattice. In a recent work, Izen, Rohler and Sastry showed that the union of a standard lattice and its reflected lattice builds the union of shifted coarse standard lattices. Thus, generalized sampling theorems can be applied in order to exploit the reflected lattice for sampling in fan beam tomography. We present applications of these ideas to helical tomography.

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MS42

Sampling Theory and High-resolution Tomography

Tomography entails the reconstruction of a function from finitely many measurements of its line integrals. The Shannon sampling theorem and its generalizations can be used to determine data acquisition schemes allowing for optimal resolution. This first talk of the session provides an introduction to the area and presents recent progress in using periodic sampling theory for improving resolution in the commonly used fan-beam sampling geometry.

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MS42

Improving Resolution in Fan-beam Tomography through Non-periodic Sampling Theory

An interpolation algorithm based on the theorem for sampling on unions of shifted lattices is introduced which exploits the symmetry property in two-dimensional fan beam computed tomography and permits the reconstruction of images with twice the resolution as the standard reconstruction by increasing only the number of measured views per rotation. Numerical results are presented which demonstrate the improvement in the quality of images from real and simulated data.

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MS42

Asymptotics of Jacobi Polynomials and Sampling Requirements for Fan-beam Tomography

In the course of a sampling analysis of a commonly used fan-beam CT reconstruction algorithm, it was discovered that the region of essential support of the integral kernel's Fourier transform is governed by the asymptotic decay rate of a particular family of Jacobi Polynomials. That asymptotic behavior will be obtained theoretically, and illustrated numerically. Examples will be shown which confirm the predicted behavior of the Jacobi Polynomials and illustrate the application to fan-beam tomography.

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MS43

Image Registration Using RANSAC

Computing a low dimensional pixel map between images based on feature correspondence can fail due to feature mismatch. The random sample consensus (RANSAC) procedure was specifically developed for this problem. A short description of RANSAC is presented emphasizing efficient sample space search, post-processing quality assessment, and automatic parameter selection. New results are given in these areas and illustrated by registration problems for affine and homographic transforms with emphasis on the effects of model mismatch.

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MS43

Human Understandable Explanatory Models for Geospatial Imagery

In some fields such as optical character recognition it is not critical whether a mathematical model is human understandable or not. The analysis of geospatial vector data (maps) and raster imagery often requires that the model has explanatory power for an imagery analyst in addition to accuracy. In this talk we propose an approach to build explanatory models for geospatial imagery analysis based on abstract algebraic structures and the representative measurement theory.

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MS43

Bilinear Models of Natural Images

Our goal in this work is to understand how invariant representations of objects are formed in the visual system. Here we show how one can learn independent representations of 'what' (form) and 'where' (transformations) in natural images through the use of a bilinear model. The model shows promise for use in a variety of practical image analysis tasks where it is desired to factor apart the shape of an object from its transformation.

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MS43

Generalized Dual-Bootstrap Image Registration

A registration algorithm is described that reliably aligns a wide variety of image pairs, including multimodal pairs, pairs having low overlap, and pairs involving substantial changes in illumination or content. The algorithm generates initial transformation estimates using invariant indexing. These are refined using a combination of feature-based matching, robust estimation, region growing and model selection. A robust decision criteria determines which alignments are correct. Experimental results demonstrate the effectiveness of the algorithm and its individual components.

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MS44

Blind Deconvolution of Hubble Space Telescope Imagery

Astronomical images present challenging problems in image analysis, because of their delicate fine textures. Such images are very far from fitting the bounded variation image model, and cannot be handled by Perona-Malik or Total Variation approaches. This talk will discuss successful recent applications of APEX blind deconvolution to galaxy images, including some spectacular color Hubble Space Telescope imagery.

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MS44

Sparse Representations and EM Algorithm for Joint Image Decomposition and Inpainting

Representing the image to be inpainted in an appropriate sparse dictionary, and combining elements from bayesian statistics, we introduce an expectation-maximization (EM) algorithm for image inpainting. From a statistical point of view, the inpainting can be viewed as an estimation problem with missing data. Towards this goal, we propose the idea of using the EM mechanism in a bayesian framework, where a sparsity promoting prior penalty is imposed on the reconstructed coefficients. The EM framework gives a principled way to establish formally the idea that missing samples can be recovered based on sparse representations. We first introduce an easy and efficient sparse-representation-based iterative algorithm for image inpainting. A side effect of such an algorithm is decomposition of the inpainted image in different mophological components as recently introduced by Starck et al. We give a formal description of the problem and derive its theoretical convergence properties for a wide class of penalties. Particularly, we establish that it converges in a strong sense, and give sufficient conditions for convergence to a local or a global minimum. Compared to its competitors, this algorithms allows a high degree of flexibility to recover different structural components in the image (piece-wise smooth, curvilinear, texture, etc). We also describe some ideas to automatically find the regularization parameter.

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MS44

Image Restoration and Decomposition in Spatial and Frequency Domains

We present a new 'class' of models for image restoration and decomposition based on the Total-Variation-Minimization framework of Rudin-Osher-Fatemi. In our model, the data image f is decomposed into the sum of u and $v = f - u$, where u is the piecewise-smooth (cartoon) component of f and v the oscillatory (noisy and textured) part. Motivated by Y. Meyer's suggestions to model the v component with norms weaker than the L^2 norm, by Osher-Solé-Vese (BV, H^{-1}) model, and by Mumford-Gidas's work infering that generic images live in H^{-s} for some $s > 0$ and that Gaussian white noise is supported in $\cap_{\epsilon>0} H_{loc}^{-1-\epsilon}$, we impose in our model that u be in the space of bounded variations $BV(\Omega)$ and v be in the 'class' of negative-powered Hilbert spaces $H^{-s}(\mathbf{R}^2)$ with $s > 0$. Under these constraints, the derived energy functional is strictly convex, hence existence and uniqueness of solution is guaranteed. When $s = 0$, our model reduces to the (BV, L^2) decomposition of Rudin, Osher, and Fatemi. We present a numerical algorithm for computing the H^{-s} norm for images, as well as for computing the minimizer of the energy functional in our model. We give the definition for a semi-norm $|\cdot|_*$ with which we are able to give characterizations of minimizers. We also derive Neumann boundary condition for the solution via duality formulation of optimization problems.

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MS44

Edge Detection Using Spectral Data

We discuss the reconstruction of piecewise smooth data from (pseudo-) spectral information. Spectral projections enjoy superior resolution provided the data is globally smooth. The presence of jump discontinuities, however, is responsible for spurious O(1) Gibbs oscillations in the neighborhood of such jumps, and an overall deterioration to the unacceptable first-order convergence rate of spectral projections. The purpose is to regain the superior exponential accuracy in the piecewise smooth case, and this is achieved in two separate steps: (i) Localization. A detection procedure which based on appropriate choice of concentration factors which identify finitely many edges — both their location and their amplitudes. This is followed by (ii) Mollification. We present a two-parameter family of spectral mollifiers which recover the data between the edges with exponential accuracy. We conclude with examples for applications in image and geophysical data processing.

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MS44

Multi-frames and Thresholding Iterations for Nonlinear Inverse Problems in the Context of Image Restoration

Not available at time of publication.

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PP0

Inexact Newton Methods for Total Variation Minimization

We present Gauss-Newton-Krylov algorithms for Total-Variation models. Our methods employ Krylov solvers to determine inexact solutions of the approximated Gauss-Newton system. We devise positive-definite operators and promote efficiency by adopting a matrix free scheme. Line search in conjunction with multiscale and continuation strategies are used to achieve robustness. We present convergence results and compare our methods with other competitive approaches. Our algorithms are targeted at brain image processing and high resolution biomedical images.

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PP0

3-D Reconstructions of Viruses with Tails and Other Deviations from Symmetry

Because virus particles are typically large, greater than 250 Angstrom in diameter, the presence of symmetries in the protein shell of the virus particle is important to computational structural biology. The most common symmetry is icosahedral, which has 60 rotational symmetry operations. Statistical models for two classes of virus problem where less symmetry is present, a bacteriophage including its tail where the tail breaks the symmetry of the capsid and a virus where the nucleic acid core lacks symmetry are described and used in experimental design and 3-D reconstruction calculations.

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PP0

Speeding Up the Convergence of the Chan-Vese Segmentation Model

In this paper, a new level set method to optimize the active contour model with edges by Tony F. Chan and Luminita A. Vese in 2001 is presented. The foundation of our method is to incorporate Bing Song and Tony Chan's a fast algorithm for level set based optimization and Yonggang Shi and william Clem Karl's a fast level set method without solving PDEs. This method will directly calculate the energy to check if the energy is decreased by switching one point to another then use the convergence status to initialize the level set for narrowband method to insure the result from Bing Song's method has reached global minimum otherwise evolve the level set to global minimum. This method has speed of Bing Song's algorithm while the convergence to the global minimum is guaranteed by Yonggang Shi's method.

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PP0

Registration of Dti Images with a Built-in Reorientation

Diffusion Tensor Imaging (DTI) is a new 3-D imaging technique that measures the diffusion of water molecules. This new technique has generated much enthusiasm and high expectations. The registration of DTIs is a delicate problem, as a proper reorientation of the tensor-valued data has to be taken into account. Here, we present a novel scheme for non-rigid registration of DTI images with a built-in reorientation. The performance of the scheme is demonstrated for a variety of examples.

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PP0

Highly Accurate Segmentation Using Geometric Attraction-Driven Flow in Edge-Regions

We propose a highly accurate segmentation algorithm for objects in an image that has simple background colors. There are two main concepts, "geometric attraction-driven flow" and "edge-regions", which are combined to give an exact boundary. The method can be successfully done by a geometric analysis of eigenspace in a tensor field on a color image as a two-dimensional manifold and a statistical analysis of finding edge-regions.

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PP0

Image Enlargement Based on Adaptive Fuzzy Interpolation

In this paper we propose a novel interpolation algorithm based on adaptive fuzzy interpolation, in order to improve the resolution of a given image, i.e. enlarge a given image. Traditionally, Bi-linear interpolation algorithm is widely applied to enlarge a given image. But this method have a disadvantage that the edge of an enlarged image is usually blurred, whereas the edge of the image is the most important information of an image. Our adaptive interpolation algorithm effectively preserve the edge of an image during enlargement based on some rules.

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PP0

Heart Motion Analysis Using Spatio-Temporal Model and Tagged Mri

Heart motion can serve as an excellent indicator for the existence of cardiac pathological conditions. We present a new approach for describing tag-point trajectories in tagged MRI using a set of optimally designed spatio-temporal basis functions. We design the basis functions using potential stress-strain energy function of myocardium and asymptotic periodicity of heart motion. We estimate the unknown parameters using generalized multivariate analysis of variance and evaluate our results using three-dimensional tagged MR images.

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PP0

Reconstruction of Images with Sharp Edges with

Radial Basis Functions

Reconstructing a smooth surface with Radial Basis Function (RBF) yields accurate results. If the image has sharp edges, however, the Gibbs ringing artifacts contaminate the reconstructed image. To resolve this, we develop two methods: 1) the projection method which projects the reconstructed image to orthogonal polynomial space, and 2) the adaptive RBF method that exploits null shape parameters locally across the edges. Both reduce the Gibbs artifacts considerably. Results are demonstrated using real data.

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PP0

Structural Identification Using Digital Image Processing Techniques

This paper presents an experimental methodology developed to obtain the dynamic responses of structures that cannot be monitored by conventional sensors, based on the digital image processing techniques. The importance of this methodology is to perform large displacements measurement without making contact with the structure, therefore, not introducing undesirable modifications in the behavior of the structure. The numerical and experimental results were consistent, confirming the accuracy and versatility of the present methodology.

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PP0

Simulation of Highly Uneven Curves and Surfaces Using Fractal Interpolation

The present paper is about new construction methods of Coalescence Fractal Interpolation Functions and Coalescence Fractal Interpolation Surfaces,that may be specially suited to image compression, zooming problems and Fractal Terrain Modeling. The simulation of highly uneven curves or surfaces is successfuly achieved using our construction methods. Our approach of construction settles several open questions of Barnsley and Harrington [J. Approx. Theory, 1989] besides providing smoothness and being stable.

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PP0

Investigating The Resolution Properties of Double-Mirror Catadioptric Sensors

Obtaining a wide field of view is very desirable in image science, for many applications such as surveillance, photography, robot navigation. Catadioptric sensors which are combined of a reflective surface(catoptrics) and an optical component(dioptrics), present an effective solution to this problem A major property of catadioptric sensors are their lack of uniformity of resolution. In this work, we investigate resolution properties of double-mirror catadioptric sensors whose primary mirrors are surfaces of revolutions of conical sections.

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PP0

Non-Convex Diffusion and Texture-Free Residual Parameterization for Image Denoising and Edge Enhancement

Total variation-based models can easily lose fine structures during image denoising. To overcome the drawback, this talk introduces two strategies: the non-convex diffusion and the texture-free residual parameterization. A non-standard numerical procedure is suggested and its stability is analyzed to effectively solve the new model. It will be numerically verified that the resulting algorithm not only reduces the noise satisfactorily but also enhances edges effectively. Various numerical examples are shown to confirm the argument.

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PP0

Statistical Modeling of Images in the Fractal Domain

Fractal image compression works, there is no doubt about that. There is also little doubt that most people don't use it (or care about it). Since this is the way it is, what *else* can we do with fractal image techniques? Fortunately, the answer is: *Lots of things!* For example, it makes sense to use fractal (and/or fractal-wavelet) methods in image denoising. Another application area is Content Based Image Retrieval (CBIR). In this talk, we present some statistical models for images in the IFS fractal domain. We use Markov Random Fields to model the spatial correlation between individual fractal parameters. These models illuminate the meaning of IFS parameters and allow one to generate synthetic images.

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PP0

An Upwind Method for Optical Flow Velocity Estimation

Since the optical flow constraint is a hyperbolic equation, central-differencing-based techniques for estimating the optical flow velocity components (e.g., Horn and Schunck, Lucas-Kanade) are either unstable or produce spurious oscillations, especially near motion boundaries. For developing an upwind scheme one faces the question: How to upwind the flux computations when the velocity components are unknown? This paper shows that the local time derivative has the necessary information to develop an upwind scheme.

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PP0
Multiscale Image Registration

Often in image processing, images must be spatially aligned in order to perform quantitative analyses of the images; the process of determining the optimal transformation that maps one image to another is called image registration. Although numerous successful registration techniques have been published, ordinary methods fail when one or more of the images contains significant levels of noise. We present a multiscale image registration technique using the hierarchical multiscale image decomposition of Tadmor, Nezzar, and Vese. We demonstrate that this new technique provides accurate registration of images that contain noise levels significantly greater than those at which ordinary registration fails.

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PP0
Dicom Image Compression based on HVS using Wavelet Transform

DICOM grayscale and color images are disintegrated into luminance and chrominance attributes and to each of these, wavelet transform is applied. The obtained coefficients are weighted with perceptual weighting mask from contrast sensitivity function (CSF) of human visual system (HVS). Further, coefficients are quantized using SPIHT algorithm, followed by arithmetic coding. Upon reconstruction, got a lossy compressed version of the input image.Results are compared based on different compression ratios with jpeg2000 for Quantitative (PSNR evaluation) and Qualitative (subjective evaluation) performances.

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PP0
Optimal Multi-Channel Time-Sequential Sampling in Dynamic Parallel MRI

Spatio-temporal modeling with adaptive acquisition has been previously proposed for minimum-rate sampling and reconstruction of Fourier encoded signals, with applications in dynamic MRI. We extend the method to signals with mixed Fourier and spatial encoding. While allowing overlaps in the reciprocal domain, we provide conditions for reconstructibility. An efficient sampling design algorithm is proposed, bounding the reconstruction error in the resulting inverse problem. The theory is then applied to cardiac MRI with phased-array coils.

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PP0
A New Approach for Image Denoising Based on Directional Wavelet Transforms

This paper introduces an approach for image denoising based on the one-dimensional redundant wavelet transform computed along lines of the image and using adaptive or non adaptive thresholding. Denoising results are superior to methods like undecimated two-dimensional wavelet transform, curvelet transform, and wavelet-based Hidden Markov tree method. Redundancy of the wavelet transform and its property to detect singularities are used to remove noise without smearing edges. Denoising is improved at increased computational cost.

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PP0
Refraction-Based Computed Tomography from Viewpoint of Geometrical Optics

Conventional absorption-based x-ray computed tomography (CT) delineates an object cross-section using an imaginary part of the complex refractive index $n = 1 - \delta + i\beta$. However, β of low atomic-number elements such as hydrogen, carbon, nitrogen, and oxygen, does not produce sufficient contrast. In order to image a phase object with $\beta = 0$ such as biological sample in hard x-ray regions, it is much more advantageous to detect variations of the propagation direction of incident ray using analyzer of high angular sensitivity. So far, a variety of imaging schemes for a phase object have been proposed, while Maksimenko et al. recently devised a novel tomograhic imaging protocol based on a mathematically well-defined reconstruction algorithm using geometrical optics and paraxial-ray approximation to experimentally obtain satisfactory results. We outline the principle.

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PP0

Joint Prior Models of Mumford-Shah Regularization for Blur Image Deconvolution and Segmentation

We study the Mumford-Shah in the context of prior models for combining restoration and segmentation. A newly introduced prior solution space of point spread functions in Bayesian estimation supports good initial value for improving the results in the Mumford-Shah. A graph-theory is integrated into Mumford-Shah regularization to group blurred objects. The approach is robust in that it can handle images that are formed in different environments with different types of blur and amounts of noise.

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