IP1

Approximate Inference in Graphical Models: The Fenchel Duality Perspective

Quite a number of problems involving inference from data, whether visual data or otherwise, can be set as a problem of finding the most likely setting of variables of a joint distribution over locally interacting variables. These include stereopsis, figure-ground segmentation, model-to-image matching, super-resolution, and so forth. Inference over locally interacting variables can be naturally represented by a graphical model, however exact inference over general graphs is computationally unwieldy. In the context of approximate inference, I will describe a general scheme for message passing update rules based on the framework of Fenchel duality. Using the framework we derive all past inference algorithms like the Belief Propagation sum-product and max-product, the Tree-Re-Weighted (TRW) model as well as new convergent algorithms for maximum-a-posteriori (MAP) and marginal estimation using "convex free energies". Joint work with Tamir Hazan.

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IP2

Operator Splitting Techniques in Image Processing

Recently, operator splitting methods have been successfully applied to various image processing tasks like the denoising and deblurring of images also in the presence of non-additive noise, inpainting, sparse recovery problems and multi-task learning. Splitting methods allow us to decompose the original problem into subproblems which are easier to solve.The talk reviews and relates various of these optimization methods from the point of view of averaged operators, Bregman proximal point methods and primal-dual Lagrangian approaches. Attention is also paid to multistep methods. Then, various examples are presented how splitting algorithms can be successfully applied to image recovery problems.

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IP3

Data Don't Lie: Image Processing Via Learned Efficient Representations

In a large number of disciplines, image acquisition has advanced much faster than image analysis. This permits to replace a number of pre-defined concepts by learned ones. In particular, we can learn efficient image representations. Among these, sparse representations have recently drawn much attention from the signal processing and learning communities. The basic underlying model consist of considering that natural images, or signals in general, admit a sparse decomposition in some redundant dictionary. This means that we can find a linear combination of a few atoms from the dictionary that lead to an efficient representation of the original signal. Recent results have shown that learning (overcomplete) non-parametric dictionaries for image representations, instead of using off-the-shelf ones, significantly improves numerous image and video processing tasks. In this talk, I will first briefly present results on learning multiscale overcomplete dictionaries for color image and video restoration. I will present the framework and provide numerous examples showing state-of-the-art results. I will then briefly show how to extend this to image classification, deriving energies and optimization procedures that lead to learning non-parametric dictionaries for sparse representations optimized for classification. I will conclude by showing results on the extension of this to sensing and the learning of incoherent dictionaries. Models derived from universal coding are presented as well. The work I present in this talk is the result of great collaborations with J. Mairal, F. Rodriguez, J. Martin-Duarte, I. Ramirez, F. Lecumberry, F. Bach, M. Elad, J. Ponce, and A. Zisserman.

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IP4

From Shape Matching to Shape Mechanics: Geometry and Dynamics

During the last decades, the study of shape spaces has been driven by the accelerated development of imaging techniques in biomedical engineering and the emergence of computational anatomy. Starting from the basic and hard problems of shape comparison, shape matching and modeling shape populations, a fascinating landscape is appearing involving infinite dimensional manifolds, Lie groups, Riemannian geometry, Hamiltonian systems and Statistics. Its connection with many existing mathematical theories, sometimes outside the usual scope of the imaging community, and the growing need for effective tools in shape analysis, provide an exciting playground for inter-disciplinary research and collaborations. This talks will visit some hot spots in this landscape and some challenges driven by anatomical growth modeling.

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IP5

The Inverse Problem of Seismic Velocities

To reasonable approximation, the construction of structural images of the earth's interior, using seismic reflection data as input, boils down to an inverse problem for the wave equation. This inverse problem requires that the spatially varying wave velocity (a coefficient in the wave equation) be determined from samples of solutions near the boundary of the space-time domain of propagation. The data-fitting techniques that have proven effective in other science and engineering inverse problems encounter fundamental mathematical obstacles in application to this one. In response, the seismic prospecting industry has devised a collection of methods to extract earth structure from data, that appear at first glance to have little to do with data-fitting. I will describe the seismic inverse problem and the qualities that make it resistant to data-fitting, as well as an underlying mathematical structure that encompasses both the data-fitting and industrial approaches. This structure supports variational principles, more general than the data-fitting or least squares principle, which in some cases have proven effective tools for velocity estimation.

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IP6

Compressed Sensing in Astronomy

The spatial infrared astronomical satellite Herschel, launched on May 14 2009, is the first satellite which has a compressed sensing (CS) coder included in its on board software. We will present our motivations for using Compressed Sensing in this project. Then we will describe the practical implementation of our CS coder/decoder. We will show from simulations that CS enables to recover data with a spatial resolution enhanced up to 30% with similar sensitivity compared to the averaging technique proposed by ESA, and we will present preliminary results relative to the CS performances on real Herschel data. Finally we will show how other problems in astronomy such interferometric image deconvolution or gammay ray image reconstruction can be also handled differently using CS.

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CP1

Optimal Geometric Transformations of Compact Manifolds

A fundamental mathematical problem underlying the subject of matching and minimal morphing of images is the problem of minimal distortion bending and morphing of compact manifolds. We consider cost functionals that measure distortion of geometry produced by a diffeomorphism between two compact n-manifolds. Our cost functionals measure the distortion in volume or the first (metric) and the second (curvature) fundamental forms. We prove the existence of the least distortion energy maps.

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CP1

A Fourth Order Nonlinear Pde-Based Image Registration Model and Its Fast Algorithm

We first propose a new variational registration model using full curvature regularization, leading to superior results, for both smooth and nonsmooth deformations, to competitors including approximate curvatures of Fischer and Modersitzki (2003), Henn and Witsch (2005). Due to its nonlinearity and high order, multigrid methods with standard smoothers lead to non-convergence. We then propose a primal-dual fixed point method as a new smoother to enable fast convergence of a nonlinear multigrid. Various numerical experiments will be reported.

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CP1

Method of Micromirrors For Catadioptric Sensor Design

We present a novel method for catadioptric sensor design which consists of a micromirror array, asymmetric mirror and an orthographic camera. The micromirror method allows construction of any desired projection which was not possible with single-mirror systems. We use Frobenius Integrability Theorem to write a system of quasilinear PDEs, whose numerical solution is the camera projection and numerically integrate the normal vector field to compute the mirror surface.

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CP1

Topological Gradient for Image Restoration by Anisotropic Diffusion

Topological asymptotic analysis provides tools to detect edges and their orientation. The purpose of this work is to show the possibilities of anisotropic topological gradient in image restoration. Previous methods based on the topological gradient used isotropic diffusion to restore the image. These methods are improved here by using anisotropic diffusion, a texture detector and differentiating between principal and secondary edges. Numerical results are presented, including a comparison with Non-Local Means method.

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CP1

Robust Optical Flow for Modeling Dynamical Systems

Classical optical flow techniques assume conservation of intensity and a smoothness of the flow field. If these assumptions are dropped, such techniques can be used to compute apparent flows between time snapshots of data that does not come from images, even if these flows are turbulent and divergent. We present a variational optical flow approach based on the continuity equation and total-variation divcurl regularization for computing the flow fields between species densities generated from a two-species predatorprey model. Though the dynamics of the model system could be analyzed mathematically from the model itself, using an optical flow approach allows to apply dynamics analysis methods directly to measured data, even in the absence of an *a priori* model.

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CP1
The Image Editing Pde's

Poisson image editing techniques involve the solution of a Poisson equation where the second member is a modified gradient field. Application are numerous: adding, removing objects, fusing images, deblocking, local contrast adjustament, etc. In this communication we review the many recently proposed variants, give their asymptotic isotropic version, and show how all of them can recieve a fast implementation. The asymptotic equations results will be shown on several significant experiments.

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CP1
The Minkowski Functionals: An Objective Tool to Quantify Typeface Legibility

Text legibility is function of numerous elements such as the specific typeface (serif or sans serif), the character height or the interletter spacing. The experiments assessing legibility have been greatly impacted by the choice of human participants in the reading tests. We propose using Minkowski functionals, which are widely used to describe complex morphologies, to quantify the image of a text after erosion and dilatation. We bring out the role played by serifs.

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CP2
Optimal Dynamic Tomography for Wide-Sense Stationary Spatial Random Fields

We present a new method to reconstruct a time-varying object modeled as a wide-sense stationary spatial random field from its tomographic projections. The optimal reconstruction method combines aspects of the Kalman and Wiener filters, but the computational complexity is the same as filtered backprojection. Applications of this method include biomedical imaging under rigid-body patient motion and problems with motion described by linear shift-invariant partial differential equations, including advection and diffusion.

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CP2
Computing Tomographic Projection Operators on Unstructured Meshes

For tomography problems on unstructured meshes, e.g., those from limited angle tomography, it is desirable to compute algebraic solutions. Algebraic reconstruction techniques require computation of discrete approximations of projection operators, traditionally a difficult task on unstructured meshes. We present a novel ray tracing algorithm for computing such operators on a recursive mesh data structure. We show that this method works in arbitrary dimension and discuss its scalability relative to the mesh diameter. We also present a straightforward parallel extension to our algorithm.

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CP2
Time-Dependent Tomographic Imaging of the Solar Atmosphere

Solar coronal tomography is concerned with reconstructing the volumetric structure of the inner atmosphere of the Sun based on a series of 2-D projection observations. We use a Monte Carlo approximation to the Kalman filter to estimate time dependent 3-D reconstructions that are more physically correct and significantly more efficient to compute than those from classical time-invariant techniques. Empirical reconstructions of the coronal electron density distribution from this algorithm will be presented.

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CP2
Resistor Networks and Optimal Grids for the Electrical Impedance Tomography with Partial Boundary Measurements.

Electrical impedance tomography with partial boundary measurements is a problem of finding the electrical conductivity inside a domain from simultaneous measurements of voltages and currents on a part of its boundary. Even in the case of full boundary measurements the problem is severely ill-conditioned. We solve the EIT with partial measurements using a numerical method based on the theory of resistor networks and optimal grids, which does not require explicit regularization. Two distinct variations of the method based on different resistor network topologies and the theory of extremal quasiconformal mappings are presented.

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CP2
Detection and Imaging Objects Buried Under a Rough Interface Through Experimental Data

The inverse scattering problem whose aim is to detect and image the objects buried under a rough surface is solved and verified with the experimental data. By using the data which are collected through measurements performed on a line in the region not containing the bodies, it is first detected and located the objects via the surface impedance modelling. The surface impedance is calculated by analytically continuing the data to the rough interface. Then the contrast source extended Born approach is applied for the imaging of the objects, which requires to solve a coupled system of integral equations. The Green function of the background media containing rough interface,which appear in the integral equations, is calculated through Buried Object Approach.

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CP2
Shape-Based Methods for Vector-Valued Inverse Problems with Highly Inhomogeneous, Unknown Backgrounds

A variational formulation is developed for the recovery of multiple physical properties in an inverse problems context. A new, low-order parametric level set technique is employed to represent targets of interest embedded in an inhomogeneous unknown background. Accurate recovery of this background is achieved through the use of a novel regularization scheme coupling the multiple parameters of interest. The approach is validated for a dual energy X-ray CT problem arising in an airport security application.

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CP3
Construction of Boundary Wavelets

We present a new approach for constructing boundary functions for wavelets and multiwavelets on a finite interval. The construction is unique up to the choice of some arbitrary orthogonal matrices. In the preceding talk *Regularity Properties of Boundary Wavelets* we derived conditions for continuity and approximation order. We show how to use these conditions to reduce the arbitrariness, and to construct boundary functions with desired properties.

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CP3
Discrete Symbol Calculus, a New Numerical Tool for Wave-Based Imaging

Most linear operators that are somehow related to wave propagation have an oscillatory integral representation that can be compressed by means of low-rank expansions of so-called symbols. We start by explaining this idea and its implication for the numerical precomputation of functions of operators. We then show that this strategy yields a sensible way of numerically inverting the so-called normal operator, or wave-equation Hessian, in reflection seismology. Work in collaboration with Lexing Ying (UT Austin) and Nicolas Boumal (MIT).

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CP3
Regularity Properties of Boundary Wavelets

Boundary functions for wavelets and multiwavelets on a finite interval are usually constructed as linear combinations of standard (interior) scaling functions. Such boundary functions obviously inherit the smoothness properties of the interior functions. Boundary functions can also be constructed directly from recursion relations. We derive continuity and approximation order conditions for this case. This approach leads to new kinds of boundary functions, and lays the groundwork for the following talk on construction of boundary wavelets.

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CP3
Optimal Design for Imaging

Experimental design is an important topic for imaging science. It has broad applications in the areas of physics, biology and engineering. In this talk, we examine the Bayesian A and A_π optimal designs. Our methods have the capability to improve the image quality while maintaining low experimental cost. Several imaging experiments, such as super resolution will be presented. Moreover, we explore efficient methods for large scale design problems.

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CP3

A Segmentation Boosted Denoising Scheme for Images with Excessive and Inhomogeneous Noise

Image denoising is an important pre-processing step. It becomes a challenging task when the image contains excessive and inhomogeous noise. It is especially hard to balance the preservation of features and removal of spatially variant noise. To remove excessive noise, a single image denoising scheme usually leads to blurry images. We propose a method to take full advantage of information from segmentation. The idea is explained using NL-Means framework. We use the original NL-Means to obtain an intermediate result on which to apply segementation. The intensities and noise variances inside and outside the segmented objects are then used to adaptive define search windows and smoothing parameters. They are utilied to the noisy image to obtain a clean and sharp image. The search windows do not have a fixed geometry, they are however adaptively chosen inside or outside the objects to ensure identically idenpendent distributed assumption to be better satisfied. Noise variances are calculated pointwisely to deal with inhomogenity of noise. The proposed denoising scheme is fast and results in sharper images while removing excessive noise.

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CP3

Analytical and Computational Methods for Transmission Eigenvalues

The interior transmission problem is a boundary value problem that arises in the scattering of time-harmonic waves by an inhomogeneous medium of compact support. The associated transmission eigenvalue problem has important applications in qualitative methods in inverse scattering theory. In this talk, we first establish optimal conditions for the existence of transmission eigenvalues for a spherically stratified medium and give numerical examples of the existence of both real and complex transmission eigenvalues in this case. We then propose three finite element methods for the computation of the transmission eigenvalues for the cases of a general non-stratified medium and use these methods to determine the accuracy of recently established inequalities for transmission eigenvalues.

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CP3

Reconstruction from Non-Uniform Spectral Data

We discuss the reconstruction of compactly supported piecewise-smooth functions from non-uniform samples of their Fourier transform. This problem is of relevance in applications such as magnetic resonance imaging (MRI). We address the issue of non-uniform sampling density and its effect on reconstruction quality. We compare classical reconstruction approaches with alternate methods such as spectral re-projection and methods incorporating jump information.

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CP4

Parametric Level Set Methods for Inverse Problems

PDE-based level set methods have difficulties in determining object structure for ill-posed inverse problems. A lack of sensitivity can slow convergence. Grid-based representations lead to frequent re-initialization or the use of additional terms in the underlying cost function. We employ a parametric representation of the level set function using an adaptive expansion of compactly supported radial basis function that addresses these difficulties. Results are presented using an electrical impedance tomography problem arising in environmental remediation.

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CP4

Recovering the Location, Size, and Grade of a Cardiac Ischemia Using Level Set Methods

We present a level set strategy for recovering the characteristics of a cardiac ischemic region. Cardiac electrical activity is modeled in 2-D with diffusion-reaction equations with different electrical behavior for the ischemic region and for the surrounding healthy tissue. Measurements are taken by electrodes outside of the cardiac membrane. Numerical experiments show that the proposed strategy may stand for a practical algorithm to extract the diagnosis information of cardiac ischemia.

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CP4

Imaging Localized Scatterers with Singular Value Decomposition and ℓ_1 Optimization

We consider narrow band array imaging of localized scatterers using the singular value decomposition (SVD) and ℓ_1 minimization and compare the results with other imaging methods such as multiple signal classification (MUSIC). We show that well-separated point scatterers can be recovered exactly with ℓ_1 optimization. Moreover, using the SVD we determine optimally subsampled array data for the ℓ_1 optimization. Numerical simulations indicate that this imaging approach is robust with respect to additive noise. If time permits, I will discuss comparison of different imaging methods in random medium.

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CP4

Regularization Parameter Selection for Penalized-Maximum Likelihood Estimation Methods in Pet.

PET data consists of counts of photons originating from random events, resulting in data-noise that is well-modeled by a Poisson distribution. Since the associated Poisson maximum likelihood estimation problem is ill-posed, regularization is needed. Regularized Poisson maximum likelihood estimation has been extensively studied by the authors, however, the essential problem of choosing the regularization parameter remains unaddressed. In this talk, we present three statistically motivated methods for choosing the regularization parameter. Numerical examples will be presented to test these methods.

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CP4

Numerical Inversion of the Spherical Mean Value Operator

We are concerned with the numerical inversion of the spherical mean value operator on the torus, which is the cornerstone of some recent imaging methods like photoacoustic tomography. We give a singular value decomposition of the this operator and characterize its range in terms of Sobolev spaces. Furthermore, we present a fast, Fourier based algorithm for its numerical evaluation, give bounds for the discretization error, and compare our algorithm to quadrature based algorithms.

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CP4

A Level Set Approach for Fluorescence Lifetime Tomography in Turbid Media

The problem of fluorescence lifetime imaging involves the reconstruction of the spatial distribution of the fluorescence decay rates within the tissue simples from boundary data. In several centimiter thick tissue this problem poses several challenges. In the direct problem one must account for multiple scattering of light in tissue, and in the inverse problem for the deconvolution of the pulse dispersion in the tissue and the fluorescence decay rates. In this talk we present an algorithm that is a hybridization of the level set technique for recovering the distributions of distinct fluorescent markers with a gradient method for estimating their lifetimes.

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CP5

Image Processing Techniques for Assessing Contractility in Isolated Adult and Neonatal Cardiac Myocytes

We describe two computational frameworks to assess the contractile responses of enzymatically dissociated adult and neonatal cardiac myocytes. Our results demonstrate the effectiveness of the approaches in characterizing the true "shortening" in the contraction process. The methods provide comprehensive assessment of the contraction process, and can potentially eliminate errors caused by rotation or translation. Changes due to drug intervention, disease modeling, transgeneity, or other common applications to mammalian cardiocytes can be evaluated.

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CP5
Atlas Based Mri Segmentation Using Both Magnitude and Phase Information

We present a new framework for MR image segmentation based on deformable template using both the magnitude and phase information. In VASO MRI, the phase depends on tissue type, provides extra information about object boundaries. Hence using phase information will improve the segmentation and analysis of MR images. Finding the optimal mapping is formulated as a variational problem over a vector field.

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CP5
Physics-Based Image Segmentation for Endoscopic Images

We propose a new mathematical model for analyzing endoscopic images, which are obtained in vivo by chromoscopic colonoscopy. The model is based on a PDE-constrained optimization problem, in which the state equation represents the chromoscopy process and the objective function uses the Chan and Vese segmentation model.

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CP5
Probabilistic Identification and Estimation of Noise (piesno): Mathematical Features and Challenges

PIESNO is a recent technique of noise assessment for magnetic resonance imaging that has provided new approach to identifying noise-only pixels and to estimating noise level in magnitude images. This technique embodies common features from different fields such as probability and dynamical system. Here, we will outline these interesting features and discuss key mathematical challenges associated with this framework that are currently not tractable through analytical means.

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CP5
Detecting Jump Discontinuities Given Noisy Fourier Data

The detection of jump discontinuities in physical space using frequency (Fourier) data is an essential aspect of Medical Resonance Image processing. The difficulty of the task lies in extracting local information from the global Fourier data, and is further complicated by noise. In this talk, we discuss a recently developed algorithm that uses frequency data to recover the jump discontinuities. The expected accuracy of the detector has been modeled using statistical hypothesis testing.

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CP5
A Study of Chiari Malformations Using Magnetic Resonance Elastography

Magnetic Resonance Elastography (MRE), also called palpation by imaging, is a non-invasive, in vivo imaging technique used to measure the elasticity of a biological tissue subject to dynamic or static mechanical stress. The resulting strains are measured using magnetic resonance imaging (MRI) and the related elastic modulus is computed from models of tissue mechanics. Such a technique can be used not only as a non-invasive diagnostic tool for tumor detection, but also for gaining fundamental knowledge about the in vivo mechanical properties of normal biological tissues. In particular, brain MRE using the natural pulsations of the brain will help us better understand the brain mechanics. The present proposal will involve using magnetic resonance images from Hershey College of Medicine of brains of patients with chiari malformations. We plan to analyze how the presence of this malformation changes the stiffness of the brain tissue in the vicinity of the malformation. The design aim of the proposal is to develop a computational tool in Matlab capable to study the mechanical properties of the brain tissue with chiari malformations before and after the surgery using medical images and appropriate mechanical models for the brain.

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CP5

Fast Algorithm for Sensitivity Encoding with Arbitrary K-Space Trajectories

Speed is a crucial issue in MR imaging for clinical applications. We propose a fast numerical algorithm for Sensitivity Encoding in partial parallel imaging with arbitrary k-space trajectories. The proposed method is an integration of the variable-splitting and penalty techniques (VSP) with Barzilai-Borwein (BB) gradient method. VSP formulates the original model as an unconstrained minimization problem, which can be split into two subproblems: TV denoising and linear inversion. The former can be solved efficiently using recently developed methods, whereas the optimal solution for the latter can be quickly approximated by using BB method. Continuation scheme is also used to improve the practical performance. Comparisons with various recently proposed methods indicate the outstanding efficiency of our algorithm with state-of-the-art reconstruction effects. Our method can be extended to any TV/L1 image reconstruction problems.

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CP6

A New Model for Deblurring Images

We propose a new model for recovering an image from a blurry observation. This model is based on a new form of the blur operator and consists to solve a particular optimization problem which is intimately linked to *the moment problem*. We combine recent mathematical results on moments and semidefinite programming to provide a reliable skill for deblurring images. The methodology allows to handle isotropic and anisotropic blur.

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CP6

Counterexamples in Image Deconvolution

Image deconvolution requires regularization. This talk will survey a number of reasonable regularization approaches that nevertheless lead to unsatisfactory results.

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CP6

Parallel Denoising

New frontiers of science are creating huge demands on computational imaging. Biological studies aiming to reveal the inner works of cells and cell-to-cell interactions rely on ultra resolution images to observe when, where, and how a cell develops so we can understand with the help of factual observations the entire mechanisms of cell regulation. Astronomy will enourmesly benefit from the planned 3.2 Gigapixel camera of the Large Synoptic Survey Telescope. The project will generate images of the sky covering billions of galaxies and stars at a rate of 15 Terabytes per night. In both situations fast and reliable image processing is required to render solutions in a reasonable time. To cope with such challenging processing demands we developed NOIR, Nonlinear Image Restoration software. NOIR is a parallel image denoising algorithm and software capable of filtering images at an approximate rate of 3.5 million pixels per second on a commodity 16 cores computer. It is based on our rewriting of the nonlocal means filter. We will present our algorithm and show how we make such a remarkable filter useful for projects in Biology, Astronomy, and Materials Science.

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CP6

A Robust Method for Joint Correction of Nonuniform Illumination and Blind Deconvolution of Barcode Signals

This paper deals with a joint nonuniform illumination estimation and blind deconvolution for barcode signals. Such optimization problems are highly non convex. A robust method is needed in case of noisy and blurred signals and uneven illumination. Here, we present a novel method based on a genetic algorithm combining discrete and continuous optimization. It is successfully applied to real datas with strong noise. A comparison with a non local gradient based method is also provided.

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CP6

Image Denoising and Restoration by Constrained Regularization

In this work we present a new iterative algorithm for image deblurring and denoising. The algorithm is based on the solution of the constrained least squares problem:

$$\min \|Hx - y^{\delta}\|_2 \quad s.t.\ \ \mathcal{R}(\S) \leq \gamma,\ \gamma > \prime$$

where the smoothness constraint γ is computed by an efficient low pass filtered version of the noisy data y^{δ}. The iterations compute an approximate value of the Lagrange multiplier λ and the solution $x(\lambda)$. The method has been widely tested with different regularization functions $\mathcal{R}(\S)$ in case of gray levels and color images.

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CP6

Blind Restoration from Mild Blur and Heavy Noise

We present a non-iterative algorithm for blind restoration of an image which has been corrupted by mild blur, and strong noise. The most successful deblurring algorithms to date address the problem in a setting where the corrupting noise is assumed so small as to be essentially negligible. Unfortunately, in practical applications, much stronger noise is often present, which renders most algorithms useless. Furthermore, it is often the case that most images we wish to enhance in practice suffer from mild, rather than severe blur. This motivates our study, where we develop a locally adaptive and non-parametric method for high fidelity enhancement of such distorted images. We illustrate that our algorithm can produce state of the art results under practical imaging conditions.

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CP7

Tracking and Autofocus in Synthetic Aperture Radar Imaging

From first principles, we develop a synthetic aperture radar imaging method that includes both motion estimation of targets and radar platform trajectory estimation. The method uses both the Wigner transform and ambiguity function of the radar data and preliminary images, properly segmented over sub-apertures, to derive estimates for the target motion and platform perturbations. This approach produces an iterative method to construct autofocused high-resolution images over wide apertures, applicable to X-band persistent surveillance SAR.

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CP7

Compressed Sensing Synthetic Aperture Radar Imaging

We introduce a new Synthetic Aperture Radar (SAR) imaging modality which can provide a high resolution map of the spatial distribution of targets and terrain based on using a significantly reduced number of needed transmitted and/or received electromagnetic waveforms. This new scheme allows the aperture to be compressed and presents many new advantages which include strong resistance to countermeasures and interception, imaging much wider swaths, and reduced on board storage constraints.

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CP7

Multiple Measurement Vector Problem with Subspace-Based Algorithm

In multiple measurement vector problem, we consider the problem of the recovery of vectors which have common sparsity patterns. First, when we have sufficient number of measurements, we can recover the jointly sparse vectors with a MUSIC-style algorithm. Then we propose a variation of MUSIC-style subspace-based algorithm to recover the jointly sparse vectors efficiently when we have insufficient number of random measurements or noisy measurements.

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CP7

Sparse and Fast Fourier Transforms in Biomedical Imaging

A straightforward discretization of high dimensional problems often leads to a serious growth in the number of degrees of freedom and thus even efficient algorithms like the fast Fourier transform have high computational costs. Utilizing sparsity allows for a severe decrease of the problem size but asks for the customization of efficient algorithms to these thinner discretization. We discuss modern generalizations of the FFT and their application in emerging imaging modalities like photoacoustic tomography.

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CP7

Compressive Radar Imaging

In this article, far-field space-time radar imaging problems are formulated in the framework of compressive sensing. The recoverability of detecting point scatterers, located on a lattice searching plane, is analyzed by the mutual coherence of the sensing matrix which is constructed from designing signal waveform and radar imaging formulation. It is shown that the coherence of the sensing matrix is highly related to the choice of the waveform, and the sensing position due to the grid structure. Numerical experiments of recoverability by pursuits are also provided.

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CP8

A New Variational Edge Representation for Image Segmentation Using Active Contours

We consider an approach to segmentation motivated by the Chan-Vese idea of minimizing a linear combination of the pixel variances inside and outside a contour. Our method maximizes the contrast between inside and outside pixel averages relative to an adaptively defined intermediate value. The model is easier to configure the free parameters than that of Chan-Vese while demonstrating the efficiency and comparing the performances on a range of image data.

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CP8

Spectral Segmentation of Polygonized Images with Normalized Cuts

We present an implementation of the Normalized Cuts method adapted for spectral segmentation of polygonized images. We make novel observations regarding the effects of the rounding errors on the Fiedler solution and other eigenvectros of the affinity matrix when computations are carried out in finite precision. These observations motivate us to partition the image in the multidimensional space spanned by the transposed matrix of the few of the lowest eigenvectors of the affinity matrix. We develop a new low complexity implementation of the Mean Shift method in order to produce meaningful and efficient clustering of the computed eigenvector subspace. We conduct a comparative study of the developed method with the Multiscale Normalized Cuts and Segmentation by Weighted Aggregation methods that demonstrates comparable and even superior performance of the proposed method.

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CP8

A Soft Segmentation Model Using Functionals with Variable Exponent

We propose here an efficient soft Mumford-Shah stochastic model for segmentation of a mixture patterns image. We construct a functional with variable exponent which allows each pixel to belong to each image pattern with different probability and combines the TV-based and isotropic diffusion. By taking different Gaussian means and variances on each image pattern, the segmentation becomes more accurate. Numerical examples of natural and synthetic images are presented to illustrate the use of the model.

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CP8

Supervised Segmentation of Multi-Banded Image Data Using Statistically-Based Methods

Both spatial and non-spatial statistically-based classification methods are explored on the problem of segmenting imagery. For the learning step, in which training data is used to build the classifier, we use quadratic discriminant analysis. Training data is obtained from the image we wish to classify using a MATLAB graphical user interface (GUI) created by us for this purpose. Post classification smoothing is implemented using nonlinear filtering, probability label relaxation, and Markov random fields.

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CP8

Nonparametric Image Segmentation Using Rényi's Statistical Dependence Measure

We present a novel nonparametric image segmentation approach, which partitions an image by maximizing the similarity between that image and its label image. Rényi's statistical dependence measure, maximum cross correlation (MCC), is employed to measure the similarity. MCC deals only with samples and does not need to estimate the continuous joint probability density function, which is sensitive to image quantization and makes the optimization process complex. The computation is further simplified by the theory of reproducing kernel Hilbert spaces.

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MS1
Distributed Compressive Imaging

We consider the problem of compressive imaging for distributed imaging sensors. Distributed Compressive Imaging offers joint image compression/reconstruction from imaging sensors which have overlapping fields-of-view. When viewed as a composite image sampling mechanism, a network of imaging sensors could transmit dramatically less data than current technologies while maintaining or surpassing image reconstruction quality of the underlying scene. We present performance results as a function of the number of cameras, transmission bandwidth, and camera perspective registration accuracy.

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MS1
CS Imaging Applications and Challenges

We developed an optical imaging technique based on compressive sensing. One area where we have implemented this system is infrared imaging where the advantages include lower costs and higher sensitivity. The same system architecture is also employed in hyperspectral compressive sensing imaging with the potential to go directly from measurements to identification without the need to reconstruct the entire hyper cube. Lastly, a compressive sensing echelle spectrometer has been also been built.

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MS1
Compressive Imaging for Target Tracking

We consider the application of compressive imaging theory to the problem of persistent surveillance. As compressive sensing enjoys significant research attention, application areas for compressive imaging are becoming clearer. We highlight several prospective compressive imaging applications which could increase current performance by orders of magnitude. Each application has algorithm and hardware implications which will be discussed. Specifically, we present expanded field-of-view imaging, expanded frame rate video, exploitation while sensing, and multiplatform image fusion.

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MS1
A Multiscale Framework for Compressive Sensing of Video

We consider the application of Compressive Sensing (CS) to video signals. In standard video compression, motion compensation techniques have led to improved sparse representations; we adapt these techniques for CS recovery. Using a coarse-to-fine reconstruction algorithm, we alternate between motion estimation and motion-compensated wavelet-domain signal recovery. Our algorithm allows the recovery of video sequences from fewer measurements than either frame-by-frame or inter-frame difference recovery methods.

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MS2
Full Wave Equation Depth Extrapolation for Migration

Using the full wave equation for depth wave-field extrapolation leads to an ill-posed problem. In avoiding the blow-up of evanescent waves, a typical downward extrapolation in a variable background uses approximate one-way propagators and partially suppresses useful propagating waves, e.g., generated by steep reflectors. Recently, we developed a new algorithm for downward extrapolation which removes only the evanescent waves and leaves all propagating modes intact. Numerical experiments confirm significant improvements in seismic migration using our approach.

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MS2
Imaging with Multiply Scattered Waves: Removing Artifacts

The majority of seismic imaging assumes the single-scattering approximation, which linearizes the inverse problem. When recorded data do not satisfy this assumption artifacts appear in the computed images. In specific methods for imaging using multiply-scattered waves, singly scattered waves produce similar artifacts in the resulting images. We will discuss new techniques for estimating and removing these artifacts in the context of one-way methods for seismic imaging.

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MS2
Operator Upscaling for Seismic Inversion

While upscaling has been studied extensively for reservoir simulation, its use for wave propagation is less common, despite the inherent multiscale character of the subsurface. Inversion studies typically rely on settling on a single scale of interest in estimated material parameters. We investigate using a two-scale solution algorithm for the acoustic wave equation as a forward simulator for inversion. The two-scale algorithm parallelizes with almost no communication and captures sub-wavelength heterogeneities on the coarse scale.

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MS2
Image Amplitudes in Wave Equation Imaging/inversion

Wave equation imaging often yields structurally correct images of the Earth. However, it is more difficult to obtain the correct amplitude for the structures in the image. Here I present recent progress in this problem. Topics will be (1) the estimation of position and direction dependent scaling factors by which to correct image amplitudes, and (2) the case of a single source, where we can derive a microlocal inverse.

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MS3
Improved Dynamic PET via Kinetic Models and Operator Splitting

Dynamic Positron Emission Tomography allows monitoring physiological processes within the body that can be described by kinetic parameters. However, recovery of these parameters often requires the solution of complex and nonlinear operator equations. Advanced operator splitting techniques allow incorporating a-priori knowledge, e.g. sparsity of minimizers with respect to an exponential basis, into the reconstruction process.

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MS3
An Explicit Primal-Dual Algorithm for Large Non-Differentiable Convex Problems

In this talk, based on joint work with Xiaoqun Zhang and Tony Chan, I will discuss a modification of the primal-dual hybrid gradient (PDHG) algorithm proposed by Zhu and Chan. The PDHG method applied to a saddle point formulation of a convex minimization problem proceeds by alternating proximal steps that maximize and minimize penalized forms of the saddle function. This can be useful for producing explicit algorithms for large non-differentiable convex problems, and a slight modification to the method can be made to guarantee convergence. For the problem of minimizing sums of convex functionals composed with linear operators, I will show how to use operator splitting techniques that allow the modified PDHG method to be effectively applied. Specific applications to constrained TV deblurring and compressive sensing problems will be presented.

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MS3
Subspace Correction Methods for ℓ_1 and Total Variation Minimization

In the context of compressed sensing and sparse recovery, it has been clarified that the minimization of ℓ_1-norms occupies a fundamental role for the promotion of sparse solutions. This understanding furnishes an important interpretation for total variation minimization, i.e., the minimization of the L_1-norm of derivatives, as a regularization technique for image restoration. These minimizations are typically nonsmooth and are performed with algorithms whose convergence is usually proved by compactness arguments; in particular there are no guaranteed rates of convergence in general. For very large scale problems sequential algorithms fail to approximate minimal solutions in acceptable computational time. Therefore it is desirable to consider domain decomposition or subspace correction strategies. In presence of nonsmooth convex constraints which are not splitting additively with respect to a decomposition, it is well known that such strategies will fail to converge to minimizers in general. In this talk we present several new results of convergence for domain decomposition and subspace correction methods specifically tailored for ℓ_1-norm and total variation minimization. We will also present counterexamples for situations where this strategy fails. We illustrate the theoretical results by presenting several numerical examples.

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MS3
Recent Numerical Methods for Large-scale Problems in Imaging Applications

In this presentation I shall give an overview about recent advances in the efficient numerical solution of total variation minimization for large-scale imaging applications.

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MS4
Diffeomorphic Image Registration using Gauss-Newton Optimisation

This work frames image registration in terms of estimating MAP or regularised maximum likelihood solutions for the deformations. Diffeomorphic deformations are parameterised by their initial velocities, which are estimated via a Gauss-Newton optimisation scheme. At each iteration, the coefficients parameterising the initial velocity are incremented by a matrix division of the first derivatives by the (expectation of the) second derivatives. The solution for this division is obtained using a multigrid approach.

Images are assumed to consist of binary labelled regions, and the template encodes the mean of the multinomial distributions from which the images are drawn. The template is modelled by a Gaussian process (over 3D space) that is "squashed" using a softmax function.

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MS4

Statistical Analysis of Neuroanatomy

A primary goal of Computational Anatomy is the statistical analysis of anatomical variability. A natural question that arises is how does one define the image of an "Average Anatomy". Such an "average" must represent the intrinsic geometric anatomical variability present. Large Deformation Diffeomorphic transformations have been shown to accommodate the geometric variability but performing statistics of Diffeomorphic transformations remains a challenge. In this lecture I will further extend this notion of averaging for studying change of anatomy on average from a cross sectional study of growth. Regression analysis is a powerful tool for the study of changes in a dependent variable as a function of an independent regressor variable, and in particular it is applicable to the study of anatomical growth and shape change. When the underlying process can be modeled by parameters in a Euclidean space, classical regression techniques are applicable and have been studied extensively. However, recent work suggests that attempts to describe anatomical shapes using *flat Euclidean spaces* undermines our ability to represent natural biological variability. In this lecture I will develop a method for regression analysis of general, manifold-valued data. Further more I will extend the notion of Robust estimation to Manifold valued data. The Median is a classic robust estimator of centrality for data. In this lecture I will formulate the geometric median of data on a Riemannian manifold as the minimizer of the sum of geodesic distances to the data points. I will exemplify the robustness of the estimation technique by applying the procedure to various manifolds commonly used in the analysis of medical images. Using this approach, we also present a robust brain atlas estimation technique based on the geometric median in the space of deformable images.

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MS4

Statistical Analysis of Image Warping Issues with M-estimation

A current trend is the study of probabilistic and statistical aspects of deformation models, and the development of consistent statistical procedure for the estimation of template images. We consider a set of images randomly warped from a mean template which has to be recovered. For this, we fisrt consider a semiparametric framework and show that minimization a well-suited contrast can lead to efficient estimatots; then in a non parametric framework, under an appropriate statistical parametric model to generate random diffeomorphic deformations in two-dimensions, we focus on the problem of estimating the mean pattern when the images are observed with noise.

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MS4

Statistical Analysis of Anisotropic Brownian Image Textures

In this talk, I focus on the analysis of anisotropy in image textures. To deal mathematically with this issue, I present a statistical framework gathering some anisotropic extensions of the fractional Brownian field. In this framework, I give several asymptotic results about the estimation of model parameters and the testing of anisotropy. I also present some applications to bone X-ray images and mammograms.

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MS5

A Variational Approach to Blind Image Deconvolution

Blind Image Deconvolution is a challenging problem on which much recent progress has been made. In my talk I will describe a regularization scheme based on image-gradient priors and explain its use in a variational framework. I will to explain why conventional MAP formulations yield degenerate solutions and how a variational approaches can avoid them, enabling good quality results to be recovered.

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MS5

Variational Formulation for Nonlocal Image Deblurring with Collaborative l_0-Norm Prior

Non-local patch-based estimation is currently one of the most promising directions in image processing. Within this framework, a number algorithms has been developed for different imaging problems and particularly for image denoising, where the BM3D filters represent the state-of-the-art in terms of quality (Katkovnik et al., Int. J. Computer Vision, 86(1) 1-32, 2010). We recently proposed a special prior which allows to reformulate the multistage BM3D hard-thresholding as minimization of a global energy criterion (Katkovnik, TICSP Series 47, 305-319, 2009). This prior was further developed as a tool for the design of very efficient deblurring algorithms in which the collaborative l0-norm penalty works as a spatially adaptive regularizator (Katkovnik and Egiazarian, Proc. LNLA2009). The main contribution presented in this talk concerns the development and testing of a frequency-domain recursive algorithm minimizing the collaborative nonlocal l0-norm criterion. Simulations demonstrate a very good performance of the algorithm.

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MS5

Optimizing the Blur-Noise Tradeoff with Multiple-Photo Capture

Capturing multiple photos at different focus settings is a powerful approach for reducing optical blur, but how many photos should we capture within a fixed time budget? We develop a framework to analyze optimal capture strategies balancing the tradeoff between defocus and sensor noise, incorporating uncertainty in resolving scene depth. We derive analytic formulas for restoration error and use Monte Carlo integration over depth to derive optimal capture strategies for different camera designs, under a wide range of photographic scenarios. We also derive a new upper bound on how well spatial frequencies can be preserved over the depth of field. Our results show that by capturing the optimal number of photos, a standard camera can achieve performance at the level of more complex computational cameras, in all but the most demanding of cases. We also show that computational cameras, although specifically designed to improve one-shot performance, generally benefit from capturing multiple photos as well. http://www.cs.toronto.edu/ hasinoff/timecon/

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MS5

Deblurring with Advanced Optimization

We present a deblurring method using advanced optimization to alternate between blur kernel estimation and unblurred image restoration. We present an analysis of the causes of common artifacts found in current deblurring methods, and then introduce several terms that are useful in deblurring. These terms include a model of the spatial randomness of noise in the blurred image, as well a local smoothness prior that reduces ringing artifacts by constraining contrast in the unblurred image wherever the blurred image exhibits low contrast. Finally, we describe an efficient optimization scheme.

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MS5

Superresolution and Blind Deconvolution of Video

In many real applications, traditional superresolution methods fail to provide high-resolution images due to objectionable blur and inaccurate registration of input low-resolution images. In this talk, we present a method of superresolution and blind deconvolution of video sequences and address problems of misregistration, local motion and change of illumination. The method processes the video by applying temporal windows, masking out regions of misregistration, and minimizing a regularized energy function with respect to the high-resolution frame and blurs, where regularization is carried out in both the image and blur domains. Experiments on real video sequences illustrate robustness of the method.

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MS6

Impact of JPEG Compression and Resolution Decreasing in Stereo Accuracy

In this work, we quantitatively study the impact of JPEG compression in stereo accuracy. We compare this accuracy with the one obtained by a convolution+subsampling compression strategy. We show that for the same rate of compression a better accuracy is obtained by this latter strategy.

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MS6

Variational Methods Stereo and Multi-view Reconstruction

I will address the shape optimization challenges in stereo and multiview reconstruction by means of variational methods. I will show that multiple view reconstruction and stereo depth estimation can be solved by minimizing convex functionals over convex domains. This allows to compute globally optimal solutions which are independent of initialization and of the choice of minimization strategy. Furthermore, I will present the first super-resolution algorithm for texture estimation in the multiview context.

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MS6

A Contrario Image Matching: Shape-elements, Shape-Context, SIFT, PCA

In image matching problems we are confronted to decide whether two descriptors are alike or not. In situations where a model of the structure to be detected cannot be estimated, the a-contrario methodology based on controling the number of false alarms (NFA) leads automatic detection thresholds. In this talk we present a general technique to obtain accurate estimates of the NFA, and its application to secure matches of image level lines, patches, SIFT or Shape-Context.

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MS6

Optimal Stereo Matching Reaches Theoretical Accuracy Bounds

This talk will focus on accuracy in block-matching for stereo-rectified images and how the disparity map can be computed for a majority of image points up to a 1/20 pixel precision. A theoretical prediction of the errors caused by noise will be given, and it will be proved on several simulated and real experiments that this bound is reached by the proposed algorithm. Experiments on the Middlebury benchmark show that the presented method improves the precision of the ground truth.

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MS7

Estimating Suitable Metrics for an Empirical Manifold of Shapes

We propose a framework to learn shape metrics from a set of examples of shapes, able to handle sparse sets of highly varying shapes, like human silhouettes. The tangent space of a shape being the set of all infinitesimal deformations that can be applied to it, an inner product in a tangent space can be seen as a deformation prior, and thus as a Gaussian distribution. We formulate the task of finding the optimal metrics, i.e. the inner products in tangent spaces which suit the best a given empirical manifold of shapes, as a classical minimization problem. The energy to be minimized involves the inner product cost of observed local deformations (reliable matchings between close shapes) as well as a regularization term based on transport of deformations and Kullback-Leibler divergence. Surprisingly, the global minimum of this functional on metrics is related to principal component analyses and is easy to compute.

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MS7

Spatiotemporal Atlas Building via Frechet Means of Diffeomorphisms

The construction of average models of anatomy, as well as regression analysis of anatomical structures, are key issues in medical research, e.g., in the study of brain development and disease progression. However, anatomical shape change is often modeled using transformations—such as the group of diffeomorphisms—that do not form a linear space. This talk describes methods for defining averages and kernel-based regression for anatomical structures via the Fréchet mean and a diffeomorphism-based metric.

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MS7

Conformal and Multi-scale Metrics on Shape Spaces

We will present several families of metrics on curves and surfaces, each of which is based on some multi-scale representation and is equivalent to a Sobolev-type norm. These metrics measure local regularity of a curve or surface, with explicit recognition of the role played by scale. We will present both theoretical and experimental results.

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MS7

A Computable Formulation of Curvature for the Riemannian Manifold of Landmarks

In the past few years there has been a growing interest, in diverse scientific communities, in endowing "shape spaces" with Riemannian metrics, so to be able to measure similarities between shapes and perform statistical analysis on data sets (e.g. for object recognition, target detection and tracking, classification, and automated medical diagnostics). The geometry of such spaces has started to emerge only very recently; in this talk we will explore the sectional curvature for the Riemannian manifold of landmark points (which is one of the simplest, in that it is finite-dimensional) and discuss its effects on applications.

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MS8

Fast Sensitivity Encoding with Arbitrary k-space

Trajectories in Partial Parallel Imaging

Speed is a crucial issue in MR imaging in many clinical applications. This paper presents a fast reconstruction algorithm of Sensitivity Encoding with arbitrary k-space trajectories to improve the clinical applicability of partial parallel imaging (PPI). The proposed method combines the variable-splitting and quadratic penalty techniques in optimizations with an accelerated gradient method. By using variable-splitting and penalty techniques the original model can be reformulated as an unconstrained minimization problem, whose minimizers can be computed by solving a TV denoising problem and a linear inverse problem separately and iteratively. TV denoising problem can be solved efficiently by several re cently developed numerical methods. While due to the nature of PPI the inverse problem can be ill-conditioned to a degree that increases with reduction factor in data acquisition. This makes the inversion much more unstable and time consuming. To overcome this difficulty an optimal first order gradient method in the sense of complexity analysis developed by Nesterov is applied in our scheme. M oreover, a gridding preprocess, that shifts the non-Cartesian data onto Cartesian grids, is used to avoid the inverse gridding in each iteration for further reduction of computational time. Comparisons with various recently proposed methods indicate the outstanding efficiency of our algorithm with state-of-the-art reconstruction effects.

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MS8

Variational Properties of a Functional for Multiphase Segmentation

We consider a functional for multiphase image segmentation which has been proposed by Sandberg, Kang and Chan. The functional is a modified version of the Mumford and Shah functional for the partition problem. In the new functional the length term of the Mumford and Shah functional is multiplied by the sum of the ratios perimeter/area of the sets of the partition. We prove the existence of minimizers for a weak version of the functional defined on the class of sets with finite perimeter. Then we study the regularity of boundaries of sets which constitute a weak minimizer. Technical tools used in the proofs are adapted from the analysis of the Mumford and Shah functional in the piecewise constant case.

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MS8

Efficient Global Optimization for the Multiphase Chan-Vese Model of Image Segmentation by Graph Cuts

The Mumford-Shah model is an important variational image segmentation model. A popular multiphase level set approach, the Chan-Vese model, was developed for this model by representing the phases by several overlapping level set functions. Recently, binary level set functions were proposed as a variant representation of the Chan-Vese model. In both approaches, the gradient descent equations had to be solved numerically, a procedure which is slow and has the potential of getting stuck in a local minima. In this work, we develop an ecient and global minimization method for the binary level set representation of multiphase Chan-Vese model based on graph cuts. If the average intensity values of the dierent phases are suciently evenly distributed, the energy function becomes submodular. Otherwise, a novel method for minimizing nonsubmodular functions is proposed with particular emphasis on this energy function. We also show that non-local extensions of the multiphase Chan-Vese model can be globally minimized by our method.

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MS8

Dual Norm Based Iterative Methods for Image Restoration

Proximal point methods have been employed to stabilize ill-posed problems in the last decades (see Osher et al., He et al.) which employ L^2-quadratic and L^1 data-fitting terms, respectively. Recently, Iusem-Resmerita proposed a proximal point method for minimizing a convex function defined on a non-reflexive Banach space which is the dual of another Banach space. Our aim here is to investigate, based on that method, several approaches to image restoration.

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MS8

Mean Curvature Based Image Denoising

We propose a new variational model for image denoising, which employs mean curvature information of the image surface $(x, f(x))$ induced by the given image $f : \Omega \to \mathbf{R}$.

Besides eliminating noise and preserving edges of objects efficiently, our method can keep corners of objects and grey-scale intensity contrasts of images, and also remove the staircase effect. We apply the proposed model for the denoising of curves and plane images, and also compare the results with those by using the classical Rudin-Osher-Fatemi model.

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MS9

Imaging and Time Reversal in Scattering Environments

This minitutorial will provide an introduction to sensor array imaging in cluttered media. We will analyze how wave scattering by the inhomogeneities of the medium can affect the resolution and the signal-to-noise ratio in imaging an object from far-field measurements. We will show how novel image-enhancement techniques have been obtained using tools from statistics and wave propagation in random media. We will clarify the relations between time reversal experiments, active sensor imaging using migration or backpropagation of the array data set, and passive sensor imaging using cross correlations of ambient noise signals.

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MS10

Methods for Confocal Microscpic 3D Image Restoration

We propose methods for the iterative restoration of fluorescence Confocal Laser Scanning Microscope (CLSM) images which are degraded by both blur and Poisson noise. The restoration is obtained as the minimization of the sum of a data term (given by the Poisson distribution) and a prior term, which is a TV prior term, or a complex wavelet L1 norm. We investigated two possibilities: a criterion written in the image domain (analysis case) or in the wavelet domain (synthesis case) . Results will be shown on biological 3D images.

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MS10

Multilevel Algorithm for a Poisson Noise Removal Model with Total-Variation Regularization

Many commonly used models for the fundamental image processing task of noise removal can deal with Gaussian white noise. However such Gaussian models are not effective to restore images with Poisson noise, which is ubiquitous in certain applications. Recently Le-Chartrand-Asaki derived a new data-fitting term in the variational model for Poisson noise. This paper proposes a multilevel algorithm for efficiently solving this variational model. As expected of a multilevel method, it delivers the same numerical solution many orders of magnitude faster than the standard single-level method of coordinate descent time-marching. Supporting numerical experiments on 2D gray scale images are presented.

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MS10

Fast Bayesian Reconstruction For Fully-3D Positron Emission Tomography

3D Positron Emission Tomography is an ill-posed inverse problem that can be solved by penalized likelihood optimization, to account for both noise and object statistics. However, solving such a large-scale, space-variant problem remains a computational challenge. Our contribution is a new approximation of the Hessian of the Poisson likelihood, which yields a substantial acceleration of inexact Newton algorithms. It also facilitates the prior weights tuning to produce a reconstructed image with uniform and isotropic spatial resolution.

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MS10

Total Variation Processing of Images with Poisson Statistics

This talk deals with denoising of density images with poor Poisson statistics. We propose total variation (TV) based regularization techniques adapted to the case of Poisson data, which we derive from approximations of logarithmic a-posteriori probabilities. In order to guarantee sharp edges we avoid the smoothing of TV and use a dual approach for the numerical solution. We illustrate the feasibility of our approaches for the reconstructions of cardiac data in positron emission tomography.

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MS11

Diffusion Generated Motion for Evolving Interfaces in Imaging and Vision

I will describe a class of algorithms for generating a variety of geometric motions of curves in 2D and surfaces in 3D. These algorithms reduce the desired geometric motion to alternating two very simple operations for which fast algorithms already exist: Convolution with a kernel, and construction of the signed distance function to a set. In particular, the resulting algorithms are unconditionally stable, allowing for arbitrarily large time steps constrained only by accuracy considerations. Applications include image segmentation and high order models in image inpainting, as well as certain problems of materials science that involve multiphase flow.

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MS11

A Multilevel Decomposition Method for Fast L1 Regularized Deconvolution

Abstract not available at time of publication.

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MS11

A Nonlinear PDE-based Method for Sparse Deconvolution

In this paper, we introduce a new nonlinear evolution partial differential equation for sparse deconvolution problems. We show that our PDE preserves the l_1 norm while lowering the measurement residual. More importantly the solution of the PDE becomes sparser asymptotically. Therefore, it can be treated as a natural and helpful plug-in to some algorithms for l_1 minimization problems, e.g. Bregman iterative methods introduced to sparse reconstruction problems.

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MS11

Tensor-valued Image Processing Using Splitting Methods

Tensor-valued data have gained significant importance in recent years, e.g., in diffusion tensor magnetic resonance imaging. Our aim is to transfer successful variational techniques for the restoration of scalar-valued images to the tensor-valued setting. We propose an operator-based approach which makes use of the trace norm of matrices. Furthermore, we combine different regularizers including higher-order terms via the infimal convolution functional. Interestingly, the alternating split Bregman or Douglas-Rachford splitting method can be used to decouple these regularizers. This gives rise to an efficient minimization algorithm.

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MS12

Patch-based Fluorescence Video-microscopy Image Restoration

The noise represents one of the main limiting factor for the spatial and temporal resolution of live fluorescence microscopy. We present here an approach to reduce the noise level and improve the spatial resolution of the images. Following the work of Kindermann and Osher (2005), we propose to minimize a non-local patch-based functional to derive a point estimate. The performances of the estimator are then improved by adapting its parameters using a bias-variance trade-off criterion.

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MS12

4D Image Reconstruction via Optimal Transport

We discuss models and efficient algorithms for 4D reconstruction in photonic imaging. Standard reconstruction methods do not incorporate time dependent information or kinetics. This can lead to deficient accuracy particularly at object boundaries, e.g. at cardiac walls. We present joint models combining Poisson-TV reconstruction and concepts of optimal transport (mass conservation). The numerical realization is based on operator splitting techniques and Uzawa methods. Dynamic deconvolution and PET results illustrate the performance of the proposed methods.

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MS12

Statistical Multi-scale Strategies for Inverse Problems

In this talk, we present a novel class of statistical multiresolution (SMR) estimators for statistical linear inverse problems in Hilbert spaces. These SMR-estimators can be computed in a completely data-driven way. We discuss consistency and convergence rates results in a very general setting. In particular, we consider deconvolution problems in biophotonic imaging and show that our estimators can be designed in order to control the trade-off between regularization and fit-to-data in a locally-adaptive way. Examples from fluorescence microscopy illustrate our approach.

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MS12

Statistical Issues from Single-molecule Biophysics

Recent advances in nanotechnology allow scientists for the first time to follow a biological process on a single molecule basis. These advances also raise many challenging statistical inference problems. First, on the single-molecule level, by the law of statistical and quantum mechanics, the dynamics/process of a biomolecule is stochastic. Second, since the experiments focus on and study only a few molecules, the data in single-molecule experiments are much noisier than those in the traditional ensemble experiments in that one cannot use the actions of thousands of molecules to average out the noise. Third, inferring the underlying stochastic dynamics is usually complicated by the presence of latent processes. In this talk we will use the inference of DNA hairpin kinetics to illustrate the statistical and probabilistic challenges in single-molecule biophysics, and introduce a Bayesian data augmentation method to address the inference difficulties.

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MS13

Numerical Resolution of Variational Problems Involving Geodesic Distances

Various problems in imaging require to find metric that minimizes under some constraints the geodesic lengths between points. In this talk, I will present the Subgradient Marching Algorithm that computes a sub-gradient of a discretized geodesic distance. It allows one to solve numericaly by projected sub-gradient descent variational problems involving geodesic distances. I will show application to traffic congestion, landscape optimization and travel time tomography in seismic imaging. This is a joint work with Fethallah Benmansour, Guillaume Carlier and Filippo Santambrogio.

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MS13

Fast High-Dimensional Data Clustering with Total Variation

In this talk, I will introduce an algorithm for graph clustering. Graph clustering aims at grouping similar high-dimensional data s.a. images. The main problem of graph clustering is to minimize the cut of a graph. Popular cuts are the normalized cut of Shi-Malik (3000 citations) and the Cheeger's cut, which are NP-hard problems. We introduce a continuous relaxation of the Cheeger's cut problem and we show that the relaxation is actually equivalent to the original problem, which is not the case with the Shi-Malik's relaxation. We also give an algorithm which is experimentally very efficient on some clustering benchmarks since the algorithm can cluster 10,000 high-dimensional points in a few seconds. This is joint work with A. Szlam (NYU), T.F. Chan, T. Goldstein, and S. Osher (UCLA)

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MS13

Convex Relaxation Methods for Multilabel Optimization

In my presentation, I will introduce convex relaxation methods to solve minimal parition problems and related multi-label optimization problems. In contrast to commonly employed level set methods, the proposed algorithms do not require an initialization. Moreover the solutions are either globally optimal or within a per-instance bound of the optimum. Furthermore I will present novel and provably convergent algorithms which allow to efficiently compute minimizers of the convex problems by means of projected gradient descent /ascent strategies. The class of functionals considered includes the piecewise constant and piecewise smooth Mumford-Shah functional.

This is joint work with Thomas Pock and Antonin Chambolle.

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MS13

Using Mathematical Morphology to (Approximately) Solve the TVL1 Model

Since the seminal work by Rudin-Osher-Fatemi in 1992, total variation models have become very popular. For the last 10 years, the understanding of the behavior of the total variation denoising models used in image processing has dramatically improved, as a consequence of the works of W. K. Allard, G. Belletini, V. Caselles, A. Chambolle, S. Esedoglu, M. Novaga, and others... Using tools developed in these works, we will describe the geometrical behavior of the TVL1 model and its connection with the Cheeger problem. In the convex case, exact solutions of the TVL1 problem are given by an opening followed by a simple test over the ratio perimeter/area. Shapes remain or suddenly vanish depending on this test. This particular behavior has allowed us to design an efficient numerical scheme based on morphological operators to simulate the TVL1 model. This work has been supported by the French "Agence Nationale de la Recherche" (ANR), under grants

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MS14

Image Processing with Higher-order Statistics on Grassmannians

We identify a subspace, i.e. a point on a Grassmannian, that best describes a collection of images by simultaneously accounting for variation in cumulants of all orders. For comparison, PCA-based techniques (e.g. Eigenfaces and Fisherfaces) take into account only the second order cumulant, i.e. covariance. While ICA-based techniques do use higher-order cumulants, they invariably make strong assumptions on the higher-order cumulants (e.g. E[XYZ]=0). We try to model such irreducible higher-order dependence rather than assuming it is zero. A limited-memory quasi-Newton method on Grassmannian is used to perform the requisite optimization.

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MS14

Multi-manifold Semi-supervised Learning

Semi-supervised learning on a single manifold has been the subject of intense study. I will discuss the setting of multiple manifolds, in which it is assumed that the target function is smooth with respect to the geodesic distance on each manifold, and the manifolds can intersect or partly overlap. I will discuss a semi-supervised learning algorithm that separates different manifolds into decision sets, and performs supervised learning within each set. Using a finite sample analysis, it is possible to quantify the potential gain of using unlabeled data in this multi-manifold setting. I will also present a practical version of the algorithm that involves a novel application of Hellinger distance and size-constrained spectral clustering.

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MS14

Hybrid Linear Modeling by Multiscale Geometric Analysis

The hybrid linear modeling problem is to identify a set of d-dimensional affine sets in a D-dimensional Euclidean space. It arises, for example, in object tracking and structure from motion. The hybrid linear model can be considered as the second simplest (behind linear) manifold model of data. In this paper we will present a very simple geometric method for hybrid linear modeling based on selecting a set of local best fit flats that minimize a global l1 error measure. The size of the local neighborhoods is determined automatically using Jones' l2 beta numbers; it is proven under certain geometric conditions that good local neighborhoods exist and are found by our method. We give extensive experimental evidence demonstrating the state of the art accuracy and speed of the algorithm on synthetic and real hybrid linear data.

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MS14

Robust Recovery of Low-Rank Structure from Imagery Data

Principal component analysis is a fundamental operation in computational data analysis, with myriad applications ranging from web search to bioinformatics to computer vision and image analysis. However, its performance and applicability in real scenarios are limited by a lack of robustness to outlying or corrupted observations. This problem can be formally stated as one of recovering a low rank matrix from large but sparse corruption. In this talk, we discuss recent progress on this problem. Recent theoretical results show that under fairly broad circumstances it can be exactly and efficiently solved by convex programming. We discuss fast and scalable solutions to this convex program, via proximal gradient algorithms as well as duality. We then show how these new tools impact real imaging applications, including automatic face recognition and optic flow estimation from video. These applications show the power of the tools, but also demand non-trivial extensions to nonlinear and manifold structure (e.g., due to transformations of domain).

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MS15

Fast Algorithms for Large-scale Diffusion-type Imaging Problems

In this work, we address a 2d tomography problem, where we try to reconstruct the absorption coefficient of an elliptic PDE from boundary measurements induced by a large number of sources. We consider a square geometry where the light sources and measurements are located regularly on opposite sides of the domain. The problem in this form requires solving a large nonlinear inverse problem, where the forward problem is given by multiple elliptic PDEs, and is thus computationally intensive. To address this, we propose to solve a linearized version of the problem based on the Born approximation and show that substantial gains can be made in computation. By revealing the special structure of the problem, we design fast methods to assemble the coefficient matrix for the linearized problem. We also propose fast matrix-vector product routines that can be used to solve the linear system with iterative methods or sparse SVD. Finally we introduce a fast inversion algorithm that produces the solution of the inverse problem by solving a sequence of small systems. We demonstrate the effectiveness of our method with several examples.

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MS15

Regularizing Kaczmarz Iterations: Analysis and Application to Photoacoustic Tomography

We analyze regularizing Kaczmarz methods for solving systems of linear ill-posed equations

$$A_i x = y_i \quad \text{for i} = 0, \ldots, \text{N} - 1\,,$$

which use each of the equations separately. Here A_i are operators between spaces X and Y_i. We are mainly interested in the case where we have only noisy data $y_i^\delta \in Y_i$ satisfying $\|y_i^\delta - y_i\| \leq \delta_i$ with $\delta_i > 0$ (noise levels). Numerical experiments are presented related to inverse problems in photoacoustic tomography.

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MS15

Multiphase Image Segmentation and Modulation Recovery Based on Shape and Topological Sensitivity

Topological sensitivity analysis is performed for the piecewise constant Mumford-Shah functional. Topological and shape derivatives are combined in order to derive an algorithm for image segmentation with fully automatized initialization. Segmentation of 2D and 3D data is presented. Further, a generalized Mumford-Shah functional is proposed and numerically investigated for the segmentation of images modulated due to, e.g., coil sensitivities.

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MS15

A Mumford-Shah Level-set Approach for Tomography Data - Reconstruction and Regularization

We deal with a level-set based approach for the simultaneous reconstruction and segmentation of density and/or activity distributions from tomography data. SPECT/CT is a hybrid imaging technique enabling a direct correlation of anatomical information (density distribution) from CT (Computerized Tomography) and functional information (activity distribution) from SPECT (Single Photon Emission Computerized Tomography). We model activity and density distributions as piecewise constant functions. The segmenting contours and the corresponding function values of both the activity and the density distribution are found simultaneously as minimizers of a Mumford-Shah like functional over the set of admissible contours and for fixed contours over the spaces of piecewise constant density and activity distributions which may be discontinuous across their corresponding contours. For the latter step we use a Newton method to solve the nonlinear optimality system. We use shape sensitivity calculus to find a descent direction for the cost functional with respect to the geometrical variable which leads to an update formula for the contours in the level-set framework. The identification of density and/or activity distributions from tomography data is an ill-posed problem. After introducing a proper notion of convergence for the space of piecewise constant functions, we present results on the existence and convergence of minimizers for the Mumford-Shah like functional for linear operators. We present reconstructions from synthetic SPECT/CT data with different noise levels as well as regularization theory for the Mumford-Shah like method for linear operators.

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MS16

Model Based Compressive Imaging

Compressive sensing is an alternative to Shannon sampling for acquisition of sparse or compressible signals that can be well approximated by just K ¡¡ N elements from an N-dimensional basis. The standard CS theory dictates that robust signal recovery is possible from M = O(K log(N/K)) measurements. We demonstrate that it is possible to substantially decrease M without sacrificing robustness by leveraging more realistic signal models that go beyond simple sparsity by including dependencies between values and locations of the signal coefficients.

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MS16

A Fast Reconstruction Algorithm for Deterministic Compressive Sensing

We propose a deterministic compressed sensing matrix that comes by design with a very fast reconstruction algorithm, in the sense that its complexity depends only on the number of measurements n and not on the signal dimension N. The matrix construction is based on the second order Reed-Muller codes. This matrix does not have RIP uniformly with respect to all k-sparse vectors, but it acts as a near isometry with very high probability.

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MS16

Compressive Sensing on Manifolds

Nonparametric Bayesian methods are employed to constitute a mixture of low-rank Gaussians, for high dimensional data constrained to a low-dimensional subregion. The number of mixture components and rank are inferred from the data. The resulting algorithm can be used for learning manifolds and reconstructing signals from manifolds, based on compressive sensing (CS) projection measurements. The statistical CS inversion is performed analytically. We derive the required number of CS measurements needed for successful reconstruction.

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MS16

Sparse Learning via Iterative Minimization

We present a regularized approach to sparse signal recovery. Sparse Learning via Iterative Minimization, or SLIM, follows an lq-norm constraint (for 0 ¡ q = 1), and can thus be used to provide increased sparsity compared to existing l1-norm based approaches. We compare SLIM to several well-known sparse methods, including the widely-used CoSaMP approach. Without significantly increasing computational cost, as compared to CoSaMP, we show that SLIM provides superior performance for sparse signal recovery applications.

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MS17

Non-Additive Noise Removal Using Variable Splitting and Augmented Lagrangian Optimization

We propose a new approach to handle non-additive noise models (namely multiplicative and Poissonian) in image recovery problems. Our approach uses two main building blocks: variable splitting, yielding a constrained optimization problem; handling this optimization problem using an augmented Lagrangian method. We show that the resulting algorithms are instances of the alternating direction method of multipliers and that the conditions guaranteeing its convergence are satisfied. Experiments show that our approach yields state-of-the-art performance.

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MS17

Multiplicative Noise Removal Using L1 Fidelity on Frame Coefficients

Classical multiplicative noise removal approaches use either the raw data or its log transform and apply filtering, Bayesian, variational, or shrinkage methods. We propose a specialized hybrid method combining the advantages of these approaches. The restored log-image minimizes a criterion combining L1 data-fidelity on the coefficients of a hard-thresholded curvelet transform of the log-data and TV regularization on the log-image. We derive a convergent fast scheme based on Douglas-Rachford splitting. The numerical results are promising.

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MS17

Frame-based Proximal Algorithms for Poisson Data Recovery

We consider convex optimization techniques for data recovery aiming at minimizing a criterion mixing a spatial domain regularization (e.g. isotropic or anisotropic total variation using various gradient filters), and a transform domain regularization (e.g. a term promoting sparsity). An accelerated version of the Parallel ProXimal Algorithm (PPXA) is proposed that avoids to invert a large-size linear operator as required by some alternative numerical solutions, e.g. the split Bregman method.

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MS17

A Comparative Review of SAR Images Speckle Denoising Methods Based on Functional Minimization

Synthetic aperture radar (SAR) as a coherent imaging modality leads to multiplicative speckle noise. We focus here on discrete MRF energy mimimization-based approaches to filter speckle and on their continuous, variational counterpart. Investigations proposed so far involve in particular: logarithm of the image, variational and augmented Lagrangian methods, generalized $L^p + L^q$ model and graph cuts (joint interferometric phase and amplitude image filtering). Those are compared on selected images with a common evaluation protocol. This work is funded by French Defence Agency contract DGA REI 2008.34.00.42

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MS17

Gamma and Poissonian Noise Removal

We consider a variational restoration model consisting of the I-divergence as data fitting term and the total variation semi-norm or nonlocal means as regularizer for removing multiplicative Gamma noise. Although the I-divergence is the typical data fitting term when dealing with Poisson noise we substantiate why it is also appropriate for cleaning Gamma noise. We propose to compute the minimizer of our restoration functional by applying Douglas-Rachford splitting techniques, resp. alternating direction methods of multipliers, combined with an efficient algorithm to solve the involved nonlinear systems of equations. We prove the Q-linear convergence of the latter algorithm. Finally, we demonstrate the performance of our whole scheme by numerical examples. (The talk is considered as a possible 'fill-in-talk'.)

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MS18

High-resolution Image Reconstruction for Parallel MR Imaging

Parallel magnetic resonance imaging (pMRI) is a technique which uses multiple receiver coils to speed up data acquisition time. Traditionally, down-sampling is applied in the k_y-direction in frequency domain. The missing information is recovered from those parallel receiver coils, and an unliasing inversion is needed for reconstruction. Here, we propose another parallel imaging technique. We scan only a small region in the frequency domain while maintaining the same size of field-of-view. We acquire data from a sequence of receiver coils. Each gives a low-resolution image. The missing high-resolution image can be recovered from these low-resolution images due to the spatial independence of the sensitivity functions of these receiver coils.

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MS18

An Image Space Approach to Cartesian Based Parallel MR Imaging with Total Variation Regularization

The Cartesian parallel magnetic imaging problem is formulated variationally using a high order penalty for modulations and a total variation like penalty for the image. Then the optimality system is derived and numerically discretized. The full problem is first considered in terms of the subproblems of modulation correction and aliasing correction. The cost functional used is non-convex, but the derivative of the cost has a bilinear residual term, and the functional is convex in each single argument. Thus, convex analysis is used to formulate the optimality condition for the image in terms of a primal-dual system. Also, a nonlinear Gauss-Seidel iteration is used to minimize with respect to one variable after the other using Newton's method. Favorable computational results are shown for artifical phantoms as well as for realistic magnetic resonance images.

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MS18

Human Brain Mapping using Computational Quasiconformal Geometry

In Human Brain Mapping, neuroscientists commonly aim to identify structural differences between healthy and unhealthy brains, in order to detect systematic patterns of alterations in brain diseases. Surface-based cortical analysis is an important strategy and has found useful applications in disease analysis. The main obstacle is that the human brain cortical surface is a very complicated manifold with difficult geometry. In this talk, I will describe how conformal and quasiconformal geometry can be used to analyze brain surfaces accurately and systematically. I will firstly describe how conformal and quasiconformal maps can be computed. These maps give the best global parameterizations of cortical surfaces which align landmarks and can be used for various applications such as surface registration, feature detection, computation on surfaces, etc. Secondly, different surfaces with landmarks correspondence have different conformal structures. This gives "signatures" for different brain surfaces for shape analysis. In the second part of my talk, I will describe how conformal structure of the brain surface can be used for shape analysis, using Teichmuller theory as a tool. Specifically, I will describe how different conformal modules can be computed and used for abnormality detection in brain surfaces.

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MS18

Auto-Probing System for Breast Cancer Detection in Magnetic Resonance Imaging (MRI)

This project aims to develop a breast cancer detection system with the invention of auto-probing methodology to localize and visualize the region of cancerous lesion. This system can reduce the analysis time and enables more thorough examination for breast screening. The lesion will be coloured and exposed out on the MR images for better identification and verification of the lesions characteristics. The region of interest selection enables the system to generate a graph which contains clearer details about the lesion. Furthermore, higher sensitivity and specificity is expected to be achieved with this system in comparison to the current practice where random probing is applied.

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MS19

Comparing Shape Properties by Multidimensional Persistent Topology

In this talk we shall briefly illustrate the use of multidimensional persistence for shape comparison. Moreover, we shall present some recent theoretical results that we have obtained about multidimensional persistent topology, proving the stability of multidimensional persistent homology and showing how its discontinuities can be localized.

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MS19

Metric Geometry in Shape Analysis

The problem of object matching under invariances can be studied using certain tools from Metric Geometry. The main idea is to regard objects as metric spaces (or measure metric spaces). The type of invariance one wishes to have in the matching is encoded in the choice of the metrics with which we endow the objects. The standard example is matching objects in Euclidean space under rigid isometries: in this situation one would endow the objects with the Euclidean metric. More general scenarios are possible in which the desired invariance cannot be reflected by the preservation of an ambient space metric. Several ideas due to M. Gromov are useful for approaching this problem. In this talk we discuss different adaptations of these, and in particular we construct an L^p version of the Gromov-Hausdorff distance using mass transportation ideas.

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MS19

Spectral Approaches to Shape Matching, Segmentation and Statistical Shape Analysis

Complex geometric objects have gained much importance in many different application fields such as medicine, computer aided design or engineering. Modern sensor technologies produce large amounts of 3D (or higher dimensional) data, that need to be analyzed and processed automatically. Methods to compare, recognize and process shape (2D surfaces or 3D solid objects) are essential ingredients to achieve this goal. This talk will give an overview on different applications of spectral methods in shape analysis. I will demonstrate how the eigenvalues and eigenfunctions of the Laplace-Beltrami operator yield powerful tools to describe and analyze shape. Due to their isometry invariance they are optimally suited to deal with non-rigid shapes often found in nature, such as a body in different postures. The normed beginning sequence of the spectrum can be used as a global signature for shape matching and database retrieval, while the eigenfunctions and their topological analysis, employing the Morse-Smale complex, persistence diagram or the Reeb graph, can be applied for shape registration, segmentation and local shape analysis. Examples of applications such as database retrieval of near isometric shapes, statistical shape analysis of subcortical structures and hierarchical segmentation of articulated shapes will be presented.

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MS19

Multiscale Signature Based on Heat Diffusion

We propose a novel point signature based on the properties of the heat diffusion process on a shape. Our signature, called the Heat Kernel signature (or HKS), is obtained by restricting the well-known heat kernel to the temporal domain. Remarkably we show that under certain mild assumptions, HKS captures all of the information contained in the heat kernel, and characterizes the shape up to isometry. This means that the restriction to the temporal domain, on the one hand, makes HKS much more concise and easily commensurable, while on the other hand, it preserves all of the information about the intrinsic geometry of the shape. In addition, HKS inherits many useful properties from the heat kernel, which means, in particular, that it is stable under perturbations of the shape. Our signature also provides a natural and efficiently computable multi-scale way to capture information about neighborhoods of a given point, which can be extremely useful in many applications. To demonstrate the practical relevance of our signature, we present several methods for non-rigid multi-scale matching based on the HKS and use it to detect repeated structure within the same shape and across a collection of shapes.

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MS20

Image Compression with Anisotropic Geodesic Triangulations

We propose to compress images using anisotropic Delaunay triangulations generated from a Riemannian farthest point seeding strategy. This seeding forces triangles to follow sharp edges and directional features. The compression is achieved by approximating images by linear splines over the triangulations, and by coding both the spline coefficients and the deviation of the anisotropic triangulations from the Euclidean Delaunay triangulation. The resulting encoder competes well, on geometric images, with wavelet-based encoders such as JPEG-2000.

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MS20

A Tubular Model for Orientation Dependent Vessel Segmentation Using Anisotropic Fast Marching

We present a new interactive method for tubular structure extraction, like vessels in 2D and 3D images. The basic tools are minimal paths solved using the fast marching algorithm. Our method is based on a variant of the minimal path method that models the vessel as a centerline and surface. The crucial step of our method is the definition of the local metrics to minimize. We have chosen to exploit the tubular structure of the vessels one wants to extract to built an anisotropic metric. The designed metric is well oriented along the direction of the vessel, admits higher velocity on the centerline, and provides a good estimate of the vessel radius. Based on the optimally oriented flux this measure is required to be robust against the disturbance introduced by noise or adjacent structures with intensity similar to the target vessel.

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MS20

Brain Connectivity Mapping Using Riemannian Geometry, Control Theory and PDEs

We introduce an original approach for the mapping of the cerebral white matter connectivity from diffusion tensor imaging (DTI). Our method relies on a global modeling of the acquired MRI volume as a Riemannian manifold whose metric directly derives from the diffusion tensor. These tensors will be used to measure physical three-dimensional distances between different locations of a brain diffusion tensor image. The key concept is the notion of geodesic distance that will allow us to find optimal paths in the white matter. Such optimal paths are reasonable approximations of neural fiber bundles. The geodesic distance function can be seen as the solution of two theoretically equivalent but, in practice, significantly different problems in the partial differential equation framework: an initial value problem which is intrinsically dynamic, and a boundary value problem which is, on the contrary, intrinsically stationary. The two approaches have very different properties which make them more or less adequate for our problem and more or less computationally efficient. The dynamic formulation is quite easy to implement but has several practical drawbacks. On the contrary, the stationary formulation is much more tedious to implement; we will show, however, that it has many virtues which make it more suitable for our connectivity mapping problem.

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MS20

Restrictions of the Fast-marching-method for the Anisotropic Eikonal Equation

In many applications one wants to solve the anisotropic eikonal equation on a given cartesian grid. Using the 8-point (or the 4-point) neighborhood discretisation one looses the causality property of the update formulae if the anisotropy has certain properties. We discuss this situation and state cirteria to decide wether the discretization is suitable for the given problem or not. Furthermore we present a method which can deal in general with anisotropy. This method uses virtual updates, analogue to the virtual updates on unstructured triangulations [James A. Sethian. Level set methods and fast marching methods. Evolving interfaces in computational geometry, fluid mechanics, computer vision, and materials science. Cambridge Monographs on Applied and Computational Mathematics, 1999] and it uses the same idea to handle anisotropy as it is done in [Folkmar Bornemann and Christian Rasch. Finite-element discretization of static Hamilton-Jacobi equations based on a local variational principle. Comput. Visual Sci., 9:57; 69, 2006].

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MS20

Anisotropic Fast Marching in Pathophysiological Modeling

Bridging the gap between clinical applications and pathophysiological models is one of the new challenges of medical image analysis. In this work, we propose an efficient and accurate algorithm to solve anisotropic Eikonal equations, in order to link mathematical models using reaction-diffusion equations to sparse clinical observations, such as medical images. We use the proposed algorithm in two different modelling applications: tumour growth and cardiac electrophysiology.

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MS21

FaIMS: A Fast Algorithm for the Inverse Medium Problem in Acoustic Scattering

We consider the inverse medium problem for the time-harmonic wave equation with broadband and multi-point illumination in the low frequency regime. Such a problem finds many applications in geosciences (e.g. ground penetrating radar), non-destructive evaluation (acoustics), and medicine (optical tomography). We use an integral-equation (Lippmann-Schwinger) formulation, which we discretize using a quadrature method. We consider only small perturbations (Born approximation). To solve this inverse problem, we use a least-squares formulation. We present a new fast algorithm for the efficient solution of this particular least-squares problem. If N_f is the number of excitation frequencies, N_s the number of the different source locations of the point illuminations, N_d the number of detectors, and N the discretization size for the scatterer, a dense singular value decomposition for the overall input-output map will have $[\min(N_sN_fN_d, N)]^2 \times \max(N_sN_fN_d, N)$ cost. We have developed a fast SVD-based preconditioner that brings the cost down to $O(N_sN_fN_dN)$ thus, providing orders of magnitude improvements over a black-box dense SVD or an unpreconditioned linear iterative solver.

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MS21

Regularization in a Multichannel Framework for Problems Arising in Image Processing Applications

Ill-posed inverse problems arise in a variety of significant applications in image processing, and efficient regularization methods are needed to compute meaningful solutions. The algorithms for image reconstruction that are discussed here are based on transforming an image into some frequency domain and incorporating regularized inversion and wavelet filtering methods within a multichannel framework. Numerical algorithms for the choice of the regularization and filtering parameters will be discussed, and examples from image deblurring will be presented.

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MS21

Obtaining Better Images - Design in Imaging

Obtaining better images can be done by combining software and hardware. In this talk we present a general framework that allows for designing better instrumentation and reconstruction algorithms. We show that such framework leads to a large scale stochastic optimization problem. We then suggest a few approaches for the solution of the problem. We show the effectiveness of our method using a few imaging methods such as limited angle tomography and super resolution

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MS21

Deblurring for Related Images Using Hybrid Regularization for Multiple Right Hand Systems

Image deblurring is ill-posed, even for blur described by a spatially invariant linear operator. In this talk we focus on deblurring of large scale problems using Tikhonov regularization applied at the local level as part of a domain decomposition algorithm. The global iterative approach requires that solutions are obtained of the subproblem system for multiple right hand sides, where each right hand side depends on the current global iterative solution. The algorithm is made more efficient by using updating of the initial local Krylov subspaces per problem with minimal restarts. Our numerical results illustrate the feasibility of the approach.

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MS22

Variational Photometric Stereo

It is well-known that photometric stereo data provides local information surface normals and the depth data must subsequently be reconsidered via an integration process. In this talk, we shall discuss ways to combine the use of local data and surface integration into a single depth from photometric stereo variational functional.

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MS22

Multigrid Narrow Band Surface Reconstruction via Level Set Functions

In this talk I will discuss a new method for implicit surface reconstruction from unorganized point clouds. Our algorithm employs a multigrid solver on a narrow band, which greatly improves the computational efficiency of surface reconstruction process. The new model can reconstruct surfaces from noisy unorganized point clouds that also have missing information. Comparing to traditional methods, our method is significantly faster and the reconstructed surfaces have detailed information.

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MS22

Surface Reconstruction and Shading from Sparse Gradient Fields Based on Vector Inpainting

We propose vector inpainting methods for reconstructing a surface from given strokes which usually make a shape of object to look like 3D surface. After initial vectors are assigned on the stokes, the vectors are distributed via a functional minimization with the incompressibility constraint which is the alternative condition of forcing the integrability condition in typical surface reconstruction. We apply the proposed method to generate anime-like shading.

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MS22

Augmented Largrangian Method, Dual Methods and Split Bregman Iteration for ROF, Vectorial TV and High Order Models

In this talk, the augmented Lagrangian method is applied to overcome the non-differentiability and to make fast numerical schemes of the ROF model. We observe close connections between the method proposed here and some of the existing methods, such as the dual method of CGM and Chambolle, split Bregman iteration, and splitting and penalty based method. Moreover, our method are easily extended to vectorial TV and high order models.

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MS23

Microlocal Analysis of the Geometric Separation Problem

Images are often composed of two or more geometrically distinct constituents; in neurobiological imaging, for instance, point-structures (spines) and curve-structures (dendrites) are mixed. We will present a theoretical analysis showing that accurate geometric separation of point and curve singularities can be achieved by minimizing the ℓ_1-norm or thresholding the coefficients of a wavelet-curvelet/shearlet-dictionary. Driving our analysis is the clustered sparsity of the ideal coefficients in microlocal phase space.

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MS23

Characterization of Singularities and Edge Detection using the Continuous Shearlet Transform

Directional multiscale systems such as the Shearlet Transform were recently introduced to overcome the limitations of the traditional wavelet transform in dealing with multidimensional data. In fact, while the continuous wavelet transform is able to identify the location of singularities of functions and distributions through its asymptotic behavior at fine scale, it lacks the ability to capture the geometry of the singularity set. In this talk, we show that the Shearlet Transform has the ability to precisely characterize both the location and orientation of the set of singularities of 2D and 3D functions. This is relevant in imaging applications such as edge detection and feature extraction.

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MS23

Microlocal Analysis and Travel Time Tomography

We consider the problem of determining the anisotropic index of refraction of a medium by measuring the travel times of waves going through the medium. We consider both the case of transmission tomography and reflection tomography.

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MS23

Doppler Synthetic Aperture Hitchhiker Imaging

In this talk, we consider passive airborne receivers that use backscattered signals from sources of opportunity transmitting fixed-frequency waveforms. Due to its combined passive synthetic aperture and the fixedfrequency nature of the transmitted waveforms, we refer to the system under consideration as Doppler Synthetic Aperture Hitchhiker (DSAH). We present a novel image formation method for DSAH. Our method first correlates the windowed signal obtained from one receiver with the windowed, filtered, scaled and translated version of the received signal from another receiver. This processing removes the transmitter related variables from the phase of the Fourier integral operator that maps the radiance of the scene to the correlated signal. We, next, use the microlocal analysis to reconstruct the scene radiance by the weighted-backprojection of the correlated signal. The image reconstruction method is applicable with both cooperative and non-cooperative sources of opportunity using one or more airborne receivers. It has the desirable property of preserving the visible edges of the scene radiance. Additionally, it is an analytic reconstruction technique which can be made computationally efficient. We present numerical simulations to demonstrate the performance of the image reconstruction method and to verify the theoretical results.

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MS24

Non-local Filtering of Images Using Data-driven Transforms

We consider the so-called grouping and collaborative filtering approach: similar patches in an image or video are collected and jointly transformed using a higher-dimensional transform, sparsity is then enforced by shrinkage of the higher-dimensional spectrum. This approach has proved to be very successful, especially as the core element of denoising, deblurring, and other inverse filtering algorithms. We discuss various aspects related to the adaptivity of the transforms used in collaborative filtering, with particular emphasis on the geometrical adaptation and on the learning of basis elements from noisy data.

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MS24

Another Role for Sparsity in Pattern Matching: A Simple, First-principle Derivation Based on Computational Complexity

We consider pattern matching problems where a pattern library, a set consisting of a large number of vectors, is to be queried for the presence of user-provided patterns in a Neyman-Pearson setting. Without any constraints on computational complexity, it is clear that one can answer such queries with arbitrarily high accuracy. Establishing computational complexity as the fundamental resource that needs to be traded with matching accuracy, our approach formulates the search problem as the maximization of accuracy for a given constraint in computational complexity. In effect, our work represents the pattern library in terms of its computational-complexity-dependent approximations, where coarser approximations are computationally easier to search but lead to less accurate results. Our solutions naturally lead to sparse approximations, establishing a duality between sparse decompositions and pattern matching problems: (a) Patterns that are easy to find must be sparse in some domain, (b) with low computational complexity, one can only hope to reliably find sparse approximations of patterns.

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MS24

Local and Non-local Similarity for Visual Recognition From a Single Example

We present a novel framework for detection/recognition of visual (2-D and 3-D) objects without training. The proposed framework operates using one example (query) of an object of interest to find similar matches; does not require prior knowledge (learning) about objects being sought; and does not require any pre-processing step or segmentation of a target image/video. Our method is based on the computation of local regression kernels as descriptors from a query, which measure the likeness of a pixel, voxel, or patch, to its surroundings. State of the art performance is demonstrated on challenging datasets in several visual processing tasks including generic detection and recognition of visual objects in 2-D and actions in 3-D, in diverse contexts and under varying imaging conditions. In addition, using the patch-based framework, we are able to robustly and accurately capture visually salient objects and their boundaries, closely mimicking human fixation data in both static and dynamic scenes.

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MS24

Universal Sparse Modeling

The goal of this talk is to make formal connections between sparse modeling and information theory, and in particular, universal coding and MDL. We will show how this leads to novel sparsity-inducing priors which have a number of advantages over more classical l_0 and l_1 ones. Joint work with I. Ramirez and F. Lecumberry.

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MS25

Analytic Sensing: A New Approach to Source Imaging and Its Application to EEG

Electroencephalography (EEG) provides us with a non-invasive way to access information about the brain's cortical activity. Mapping back the electrical potential measured on the scalp to the underlying source configuration is known as "source imaging". To render the problem well-posed, additional constraints on the solution are needed. Specifically, we use a parametric source model (sum of dipoles) and we propose a new framework termed "analytic sensing," that lead to a non-iterative technique for multi-dipole fitting. The key contribution is to apply analytic test functions that "sense" the influence of the source distribution around virtual sensors. The choice of these sensors allows us to estimate the dipoles' positions by finding an annihilation filter similar to "finite rate of innovation" techniques. We show how to apply analytic sensing to 3D and to EEG in particular. Preliminary results demonstrate the technique's potential to retrieve multiple dipoles at once, a problem that is difficult to solve by (numerical) least-squares fitting due to the many local minima. Joint work with: D. Kandaswamy, D. Van De Ville

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MS25

High Order Vector-valued Models for Image Restoration

Variational techniques for gray-scale image restoration have been deeply investigated for many years, however, little research has been done for the vector-valued case and the very few existent works are total-variation-based models [P. Blomgren and T.F. Chan. Color TV: total variation methods for restoration of vector-valued images. *IEEE Transactions on Image Processing*, 7(3):304-309,1998; X. Bresson and T.F. Chan. Fast dual minimization of the vectorial total variation norm and applications to color image processing. *Inverse Problems and Imaging*, 2(4):455-484, 2008; G. Sapiro and D.L. Ringach. Anisotropic diffusion of multivalued images with applications to color filtering. *IEEE Transactions on Image Processing*, 5(11):1582-1586, 1996; Wei Zhu and T. F. Chan. Image denoising using mean curvature. Preprint available from http://www.math.nyu.edu/∼wzhu/]. For instance, it is known that TV models (and variants including graph cuts based models) suffer from staircasing effect in image denoising and fail to deliver a visually satisfactory reconstruction in many situations in image inpainting where images cannot be assumed to be piecewise constants. Further, the same arguments carry over to the vector-valued models. High order models, on the contrary, do not present staircasing in image denoising, and allow large distance reconnection and smooth recovery of missing parts in image inpainting. In this work we first propose and analyze two high order and curvature-based denoising models for vector-valued images which allow stronger coupling among different channels than a channel-by-channel approach for a given noisy vector-valued image u^0

$$\min_{u_1,\ldots,u_m}\left\{\int_\Omega \sqrt{\sum_{\ell=1}^m \Phi_\ell(\kappa_\ell)}\ dx + \frac{\lambda}{2}\int_\Omega |u-u^0|^2\ dx\right\}$$

$$\min_{u_1,\ldots,u_m}\left\{\sqrt{\int_\Omega \sum_{\ell=1}^m \Phi_\ell(\kappa_\ell)\ dx} + \frac{\lambda}{2}\int_\Omega |u-u^0|^2\ dx\right\}$$

where $u = \Omega \subset \mathbf{R}^n \to \mathbf{R}^m$ i.e., $u = (u_1,\ldots,u_m)$ with $u_\ell = u_\ell(x_1,\ldots,x_n)\ \forall\ \ell = 1,\ldots,m,\ dx = (dx_1,\ldots,dx_m)$, κ_ℓ the curvature of ℓ^{th} image channel and Φ a given function. Then a fast multigrid algorithm for the numerical solution is developed and tested. Advantages over TV based and other coupling models are illustrated. Finally extension of these techniques to color image inpainting is considered and some preliminary results are reported.

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MS25

Iterative Methods for Image Reconstruction and Applications to Bioluminescence Tomography

Iterative methods for image reconstruction have become very popular today for imaging research and applications. The Landweber method and EM algorithm are widely used methods for image reconstruction. I will first introduce the Landweber method and the EM algorithm. Then I will report our progress about bioluminescence tomography (BLT). BLT is an emerging molecular imaging technique in the form of an ill-posed inverse source problem subject to Cauchy data of the diffusion equation.

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MS25

Source Reconstruction for Spectrally-resolved Bioluminescence Tomography with Sparse A priori Information

We develop a new tomographic algorithm for spectrally-resolved bioluminescence tomography. This method uses the nature of the source sparsity to improve the reconstruction quality with a regularization implementation. Based on verification of the inverse crime, the proposed algorithm is validated with Monte Carlo-based synthetic data and the popular Tikhonov regulariz ion method. Testing with different noise levels and single/multiple source settings at different depths demonstrates the improved performance of this algorithm. Experimental reconstruction with a mouse-shaped phantom further shows the potential of the proposed algorithm.

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MS26

Regularizing with Anisotropic Total Variation

Total variation regularization has been used for image denoising for about twenty years now. These regularizations have other uses as well; in particular, they can be used to detect differences in scales in data. I have been studying the geometric and regularity properties of minimizers for the associated variational problems with the goal of better understanding them. In this talk I will describe some new results in this area. Some of these results describe minimizers where total variation is defined using an anisotropic norm for the gradient; the motivation for this work, which is joint with Kevin Vixie, is that some computational schemes for computing minimizers naturally use a polygonal approximation to the standard Euclidean metric to define total variation.

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MS26

Calibrable Sets and Scales for TV-L2 and TV-L1 Models

In this talk, we address the problem of scale definition, based on the notion of calibrable set. In a first part, we explain how the TV-L2 model can be used to define the scale of an object. In a second part, we consider the TV-L1 model, and we show how this functional discriminates between structure and texture according to the previous definition of scale. This work has been supported by the French "Agence Nationale de la Recherche" (ANR), under grants NATIMAGES (ANR-08-EMER-009) "Adaptivity for natural images and texture representations" and FREEDOM (ANR07-JCJC-0048-01),"Movies, restoration and missing data".

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MS26

Multiscale Image Representation Using a Novel Integro-differential Equations

We propose a novel integro-differential equation (IDE) for a multiscale image representation. To this end, one integrates in inverse scale space a succession of refined 'slices' of the image, which are balanced by a typical curvature term at the finer scale. The original motivation came from a variational-based hierarchical decomposition of images. We then use standard techniques from PDE-based image processing - filtering, edge preserving and tangential smoothing, to yield a family of modified IDE models with applications to image denoising and deblurring problems. The IDE models depend on a user scaling function which is shown to dictate the BV properties of the residual error. Numerical experiments demonstrate applications of our new IDE approach.

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MS26

Image Restoration Using One-dimensional Profiles of Sobolev Norms for Noise and Texture

We propose a variational model for image denoising and deblurring, using total variation and Sobolev norms of negative degree of differentiability. The unknown image is recovered as the sum of two components, cartoon and texture. We impose prior information on the texture and on the noise, by learning one-dimensional profiles of Sobolev norms of textures and noise components. These profiles assign to each negative exponent, the Sobolev norm of the texture or of the noise. Experimental results for joint deblurring and denoising are shown.

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MS27

New Theory and Algorithms for Nonsmooth, Nonconvex Minimization

In recent years, nonsmooth, nonconvex minimization has become essential in image restoration. In this talk, we discuss some new algorithms for solving nonsmooth, nonconvex optimization. Moreover, we present a lower bound theory for the absolute value of nonzero entries in every local minimizer of an objective function composed of a quadratic data-fidelity term and a nonconvex, non-Lipschitz regularization term. This theory can be used to eliminate zero entries precisely in any numerical solution. Furthermore, it clearly shows the relationship between the sparsity of the solution and the choice of the regularization parameters, so that the lower bound theory can be used for selecting desired model parameters. We also develop error bounds for verifying the accuracy of numerical minimizers. To demonstrate applications of our theory, we propose an orthogonal matching pursuit-smoothing conjugate gradient (OMP-SCG) hybrid method for solving the nonconvex, non-Lipschitz minimization problem. Computational results show the effectiveness of the lower bounds for identifying nonzero entries in numerical solutions and the OMP-SCG method for finding a high quality numerical solution.

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MS27

Lower Semi-Continuity of Non-Local Functionals

We recall a few of the recent non-local methods used in imaging analysis such as the non-local mean filter and the derivative-free formulation of the total variation functional. Such non-local methods for filtering images have proven to handle especially repetitive structures as for instance textures much better than classical PDE-based approaches. Trying to formulate these methods as energy minimisation problems, we typically end up with energy functionals of the form $\mathcal{J}(\sqcap) = \int_{\mathcal{X}}\int_{\mathcal{X}} \{(\S, \dagger, \sqcap(\S), \sqcap(\dagger))\mathrm{dxdy}$ on some Lebesgue spaces. We give a criterion for these energy functionals to possess a minimising point. The crucial part thereby is the weak sequential lower semi-continuity of the functionals which essentially reduces to the separate convexity of the function f in the last two variables.

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MS27

Sparse Regularization with Non-convex Regularization Terms

We consider the stable solution of ill-posed operator equations by means of non-convex Tikhonov regularization, where the regularization term acts separately on the coefficients of an expansion with respect to a given basis, for instance a Fourier or wavelet basis. We discuss conditions that guarantee that such an approach yields a well-posed regularization method. In addition, we derive a linear convergence rate under the assumption of infinitely fast growth at zero, a condition that can only be satisfied with nonconvex regularization terms.

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MS27

Convex Relaxations of Metrics for Imaging with Missing Data

The usual presentation of missing data/compressive sensing problems is to consider the function $\|\cdot\|_0$ as the limit of the p-metrics as $p \searrow 0$. The problem with $p < 1$ is that the metric is nonconvex and convergence results for numerical algorithms based on this are difficult at the very least. We present an alternative approach based on regularization of the Fenchel conjugates of these metrics. We propose solving

$$\min_{x \in R^n} \; I_{\varphi^*_{\epsilon,L}}(x) \textit{ such that } Ax = b \qquad (1)$$

where $I_{\varphi^*_{\epsilon,L}}(x)$ is an *entropy* with integrand $\varphi^*_{\epsilon,L}$ and relaxation parameters ϵ and L that corresponds to a symmetric scaled Fermi-Dirac entropy. This is a smooth convex relaxation of the conventional ℓ_p optimization for $0 \le p \le 1$ and amenable to rigorous analysis and efficient algorithms.

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MS28

Joint Manifolds for Data Fusion

The emergence of low-cost sensing architectures for diverse modalities has made it possible to deploy camera networks that capture a single event from a large number of vantage points and using multiple modalities. In many scenarios, these networks acquire large amounts of very high-dimensional data. Even a relatively small network of cameras can generate massive amounts of high-dimensional image and video data. One way to cope with such a data deluge is to develop low-dimensional data models. Manifold models provide a particularly powerful theoretical and algorithmic framework for capturing the structure of data governed by a low-dimensional set of parameters, as is often the case in a sensor network. However, these models do not typically take into account dependencies among multiple sensors. We thus propose a new joint manifold framework for data ensembles that exploits such dependencies. We show that joint manifold structure can lead to improved performance for a variety of signal processing algorithms for applications including classification and manifold learning. Additionally, recent results concerning random projections of manifolds enable us to formulate a network-scalable dimensionality reduction scheme that efficiently fuses the data from all sensors.

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MS28

Distilled Sensing for Imaging

With the recent emergence of sparsity-exploiting technologies (as in compressive sensing), a renewed emphasis has been placed on techniques that make judicious use of sampling resources. In particular, adaptive sampling techniques, where the sampling process is allowed to adapt or focus as a function of measurements previously obtained, are promising approaches for mitigating the effects of additive noise in sparse recovery problems. In this talk I will discuss our recent work on Distilled Sensing (DS), which quantifies the surprising and dramatic improvements that are achievable using adaptivity. For example, we show that adaptivity enables the reliable recovery (detection and estimation) of sparse signals in prohibitively-low SNR regimes where the best methods based on non-adaptive sampling fail. In the context of imaging, DS can lead to significant improvements in estimation accuracy.

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MS28

Compressive Sensing and Underwater Acoustics

We will discuss the application of the theory of compressive sensing to two problems encountered in acoustics: source localization/tracking and communication over an uncertain channel. For the first problem, we show how a randomized group testing can significantly reduce the number of acoustic simulations needed to locate and then track a source. For the second problem, we treat the scenario of communicating over an unknown channel as a blind deconvolution problem, and show that if the (unknown) channel is sparse and a random encoding scheme with a small amount of redundancy is used by the source, then the receiver can discover both the message and the channel response by solving a well-posed optimization program.

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MS28

Finding Structure with Randomness: Stochastic Algorithms for Constructing Low-rank Matrix Decompositions

Computer scientists have long known that randomness can be used to improve the performance of algorithms. A familiar application is the process of dimension reduction, in which a random map transports data from a high-dimensional space to a lower-dimensional space while approximately preserving some geometric properties. By operating with the compact representation of the data, it is theoretically possible to produce approximate solutions to certain large problems very efficiently. Recently, it has been observed that dimension reduction has powerful applications in numerical linear algebra and numerical analysis. This talk provides a high-level introduction to randomized methods for computing standard matrix approximations, and it summarizes a new analysis that offers (nearly) optimal bounds on the performance of these methods. In practice, the techniques are so effective that they compete with—or even outperform—classical algorithms. Since matrix approximations play a ubiquitous role in areas ranging from information processing to scientific computing, it seems certain that randomized algorithms will eventually supplant the standard methods in some application domains.

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MS29

Exploiting the Structure of Regularizers for Rapid Solution of Euler-Lagrange Equations in Variational Image Registration

Variational image registration techniques combine image similarity measures with regularization terms in order to guarantee that the resulting functional minimization problem is well-posed. In practice, typical regularization terms are quadratic differential forms that can be either spatially homogeneous or adaptive. In this talk, we describe two different rapid computing paradigms for estimating the solution to the Euler-Lagrange equations resulting from various families of regularizers; one paradigm uses Fourier series solutions of the discretized Euler-Lagrange equations; the second employs convolution with a discretized Gaussian kernel to mimic the Green's function solution to coupled PDE systems related to the Euler-Lagrange equations.

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MS29

A PDE Approach to Coupled Super-Resolution with Non-Parametric Motion

The problem of recovering a high-resolution image from a set of distorted low-resolution images is known as super-resolution. Accurate motion estimation among the low-resolution measurements is a fundamental challenge of the super-resolution problem. Some recent advances in this area have been focused on coupling the super-resolution reconstruction and the motion estimation. However, the existing approach is limited to parametric motion models. We will address the coupled super-resolution problem with a non-parametric motion model in a variational formulation. A PDE-approach will be proposed to yield a numerical scheme.

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MS29

Numerical Optimization for Constrained Image Registration

Image registration is a technique to establish meaningful correspondences between points in different scenes. It is an inevitable tool for various applications in medicine, geoscience, and other disciplines. However, obtaining reasonable deformations is a complex task. For example, many applications require that the transformation is locally invertible, or even harder, keeps volumes changes within a reasonable bandwidth. In this work, solutions to the registration problem are obtained by directly imposing a volume constraint on each voxel in a discretized domain. The focus is on the development of an efficient and robust numerical algorithm and in particular, the study of an Augmented Lagrangian method with a multigrid as preconditioned. We demonstrate that this combination yields an almost optimal solver (i.e. linear time) for the problem.

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MS29

Accelerating Non-Rigid Image Registration on Gpus

Non-rigid image registration tries to find a suitable deformation field between two images that map one image into the other. This is widely used in medical imaging applications. Here, it is important to have fast image registration algorithms, e.g. in order to reduce the waiting time for the patient or to be able to register images during a surgery. We show how compute intensive parts of the image registration algorithm can be parallelized and ported to GPUs and how the GPU code can be coupled to the FAIR (Flexible Algorithms for Image Registration) software package.

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MS30

Numerical Geometry of Non-Rigid Shapes

Non-rigid shapes are ubiquitous in the world surrounding us, at all levels from micro to macro. The need to study such shapes and model their behavior arises in the fields of computer vision, pattern recognition, and graphics in a wide spectrum of applications ranging from medical imaging to security. The tutorial is a self-contained comprehensive introduction to analysis and synthesis of non-rigid shapes, with a good balance between theory, numeric methods, and applications. One of the main emphases will be on practical methods. Examples of applications from computer vision and pattern recognition, computer graphics, and geometry processing will be shown.

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MS31

Exemplar-based Inpainting from a Variational Point of View

Among all methods for reconstructing missing regions in a digital image, the so-called exemplar-based algorithms are very efficient and often produce striking results. They are based on the simple idea – initially used for texture synthesis – that the unknown part of an image can be reconstructed by simply copying samples extracted from the known part. Many variants have been proposed whose performances vary according to the type of image. Beyond heuristic considerations, very little has been done in the literature to explain the performances of this class of algorithms from a theoretical point of view. With a particular focus on the ability to reconstruct the geometry, we discuss in this paper a variational interpretation in $\mathbf{R}^N$ of these methods. We propose an optimization model and several variants, and prove the existence of minimizers in the framework of functions of bounded variation. Focusing on a simple 2D situation, we provide experimental evidences that these global variational models are more efficient than a basic patch-based algorithm for reconstructing certain long-range geometric features without any loss of quality for the texture reconstruction. We eventually propose additional variants that fulfill a couple of axiomatic requirements and have a better asymptotic behaviour as the patch size goes to zero. This is a joint work with Simon Masnou and Said Ladjal. This work has been done with the support of the French "Agence Nationale de la Recherche" (ANR) under grant Freedom (ANR07-JCJC-0048-01).

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MS31

MRI Superresolution Using High Resolution Anatomical Priors

In Magnetic Resonance Imaging low-resolution images are routinely interpolated to decrease voxel size and improve apparent resolution. However, classical interpolation techniques are not able to recover the high frequency information lost during the acquisition process. In the present paper a new superresolution method is proposed to recover such information using coplanar high resolution images. The proposed methodology takes benefit from the fact that in typical clinical settings both high and low-resolution images of different types are taken from the same subject. These available high resolution images can be used to improve effectively the resolution of other coplanar lower resolution images. Experiments on synthetic and real data are supplied to show the effectiveness of the proposed approach. A comparison with classical interpolation techniques is presented to demonstrate the improved performance of the proposed methodology over previous State-of-the-art methods.

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MS31

Image Denoising with Nonlocal Spectral Graph Wavelets

We present a new method for denoising photographic images based on a novel nonlocal spectral graph wavelet transform. We employ the transform formed using the graph Laplacian corresponding to a nonlocal image graph measuring similarities between image regions, yielding wavelets at multiple scales with the interesting property that they diffuse among regions of similar image content. Denoising by soft thresholding with threshold determined from a simple Laplacian model for the clean coefficients yields good results.

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MS31

Neighborhod Filters and Novel Bayesian Approximations for Non-local Image Regularization

In this talk, I will present formal connections between non-parametric estimation approaches, neighborhood filters and block estimators in the Bayesian framework. I will provide a statistical interpretation to current patch-based methods and justify the Bayesian inference that needs to explicitly accounts for discrepancies between the model and the data. I will present a recent method recommended in situations where the posterior or the likelihood are intractable or too prohibitive to calculate. In particular, the proposed approximations are suited for the analysis of large-dimensional distribution of patches and enable to denoise images corrupted by non-Gaussian noises. We demonstrate our algorithms on both artificial and real examples.

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MS31

Modeling Locally Parellel Textures

In this talk I will present a new adaptive framework for locally parallel texture modeling. Oscillating patterns are modeled with functionals that constrain the local Fourier decomposition of the texture. We introduce a first convex texture functional which is a weighted Hilbert norm. The weights on the local Fourier atoms are optimized to match the local orientation and frequency of the texture. This adaptive convex model is then used to solve inverse problems in image processing, such as image decomposition and inpainting. The local texture orientation and frequency of the texture component are adaptively estimated during the minimization process. Furthermore, in the inpainting case, convex models present the issue of attenuation inside large missing parts. The amplitude of the reconstructed oscillating patterns tends indeed to vanish inside large holes. To deal with this difficult problem, a non convex generalization of our model is designed. This new model enables to impose the amplitude of the oscillating patterns inside the reconstructed parts and to cope with the inpainting of general oscillations profiles. Numerical results show that our method improves state of the art algorithms for directional textures. This is a joint work with Pierre Maurel and Jean-Francois Aujol.

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MS32

Scales Coming from K-functionals

In image decomposition, an image f is decomposed into u+v, where u and v are in some function spaces X and Y respectively. This can be seen as viewing f to belong to an interpolating space between X and Y. Given the choices for X and Y, we will discuss and analyze the choice for this interpolating space, which provides us with an automatic decomposition of f.

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MS32

Edge-enhanced Image Reconstruction Using Total Variation Norm and High-order Edge-preserving Up-sampling Operators

We have introduced an image resolution enhancement method for multidimensional images based on a variational approach that uses the total variation norm as regularizing functional. Given an appropriate down-sampling operator, the reconstruction problem is posed using a deconvolution model under the assumption of Gaussian noise. In this research work we explore different edge-preserving up-sampling operators with different orders of spatial accuracy. The operators are defined using nonlinear local functions to preserve edges automatically when they are present. We analyze the behavior and robustness of those operators under noisy data. Numerical results are presented using those operators in conjunction with our variational model for image enhancement.

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MS32
Fast TV based Segmentation and Surface Interpolation

Variational globally convex segmentation results involving total variation minimization have been devised in recent years by Chan, Esedoglu and Nikolova, for segmentation and by Chambolle for geometric motion. These can be used for classical geometric problems in vision, however they were believed to be slow to implement. Recently developed fast algorithms involving Bregman methods turn out to be very effective for these problems. We'll descibe progress in this area.

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MS32
Nonlinear Iterative Algorithms for Total Variation Denoising and Deblurring

We propose nonlinear Jacobi and Gauss-Seidel iterative procedures for approximating the solution of the Euler-Lagrange equations associated to the TV minimization denoising and deblurring problems. The algorithms are formulated from a suitable discretization of the Euler-Lagrange equation associated to the specific variational problem. The iteration functions are constructed as a nonlinear convex combination of neighboring values allowing the solution to satisfy a maximum principle. We propose a specific stopping criterion that allows convergence in a finite number of iterations. We present numerical examples of two-dimensional denoising and deblurring-denoising problems.

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MS33
Convex Formulation and Exact Global Solutions for Multi-phase Piecewise Constant Mumford-Shah Image Segmentation

Most variational models for multi-phase image segmentation are non-convex and possess multiple local minima, which makes solving for a global solution an extremely difficult task. In this work, we provide a method for computing a global solution for the (non-convex) multi-phase piecewise constant Mumford-Shah (spatially continuous Potts) image segmentation problem. Our approach is based on using a specific representation of the problem due to Lie et al. We then establish an augmented Lagrangian method to reduce the problem to a sequence of non-convex minimization problems, each of which can globally solved using a convexification technique due to Pock et al. Unlike some recent methods in this direction, our method can guarantee that a global solution is obtained. We believe our method to be the first in the literature that can make this claim.

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MS33
Local Scales in Images

We propose a linear approach to extract local scales of oscillatory patterns in images in a multi-scale fashion. We will discuss the relation of local scales to the theory of function spaces and the extension to nontangential local scales and non-linear evolution equations.

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MS33

A Variational Model for Infinite Perimeter Segmentations Based on Lipschitz Level Set Functions: Denoising While Keeping Finely Oscillatory Boundaries

We propose a new model for segmenting piecewise constant images with irregular object boundaries: a variant of the Chan-Vese model, where the length penalization of the boundaries is replaced by the area of their neighborhood of thickness ϵ. Our aim is to keep fine details and irregularities of the boundaries while denoising additive Gaussian noise. For the numerical computation we revisit the classical BV level set formulation considering suitable Lipschitz level set functions instead of BV ones.

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MS33

Adapted Local Scales and Smoothness, and NL-means

The NL-means algorithm and its cousins represent a grayscale image not as a function of R^2, but as a function of the set of patches of the image. On this set of patches, the algorithm simply becomes a linear diffusion, with the standard associated scale space. I will discuss why this point of view is useful and give examples from image and audio analysis.

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MS34

Optimization with Total Generalized Variation Penalty

In the talk, we focus on the solution of minimization problems involving a total generalized variation penalty term. Total generalized variation is a novel nonsmooth concept which involves and balances derivatives up to a certain order. Applied to mathematical imaging, it usually leads to nonsmooth and nonconvex minimization problems. Their numerical solution is discussed and examples are presented, showing in particular the absence of staircasing effects for this approach.

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MS34

DC Programming Approaches for Image Restoration and Image Segmentation

We present an efficient approach in nonconvex nonsmooth programming called DC (Difference of Convex functions) programming and DC algorithms (DCA) for two classes of problems in image processing: the image restoration by globally minimizing the Gibbs energy function via a Markov random field model, and the image segmentation via Fuzzy C-Means (FCM) clustering model. Experimental results on noisy images have illustrated the effectiveness of the proposed algorithm and its superiority with respect to the standard GNC algorithm (for image restoration) and FCM algorithm (for image segmentation).

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MS34

DC (Difference of Convex functions) Programming and DCA (DC Algorithms) for Smooth/ Nonsmooth Nonconvex Programming

The DC programming and DCA address the problem of minimizing a function $f = g-h$, (g, h being lower semicontinuous proper convex functions on the Euclidean space) on a closed convex set. The DCA, based on local optimality conditions and DC duality, has been successfully applied to a lot of different and various smooth/nonsmooth nonconvex programs. Moreover it has quite often given global solutions and proved to be more robust and more efficient than related standard methods, especially in the large-scale setting.

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MS34

Linear Convergence Method for a Non-convex Variational Model

In this talk, we consider a non-convex variational model. We propose to use strictly convex optimization models to approximate the non-convex functional. We show that the solutions of these strictly convex optimization models will converge to the global minimizer of the original non-convex functional. We show that the solution of the strictly convex optimization model can be determined by using an iterative algorithm, and the convergence rate is linear. Numerical examples are presented to show the efficiency of the proposed method.

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MS35

Synthetic Aperture Radar Imaging with Motion Estimation and Autofocus

We introduce from first principles a synthetic aperture radar (SAR) imaging and motion estimation method that is combined with radar platform trajectory estimation. This method segments the data into properly calibrated small apertures and uses space-time phase methods (Wigner transforms and ambiguity functions) to estimate target motion and trajectory perturbations. X-band persistent surveillance SAR is a specific application that is covered by our analysis. This is joint work with Thomas Callaghan and George Papanicolaou.

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MS35

Transmission Eigenvalues and Their Application in Inverse Scattering Theory

We consider the scattering problem for an inhomogeneous medium and discuss a new related eigenvalue problem known as the interior transmission eigenvalue problem. We first prove that there exists a countable set of transmission eigenvalues and then show that these eigenvalues can be determined from the far field data. Finally, we obtain Faber-Krahn type inequalities for transmission eigenvalues which, if D is known, provide lower and upper bounds on the index of refraction n(x).

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MS35

Direct and Inverse Obstacle Scattering Over Rough Surfaces

We develop a theory for direct obstacle scattering of obstacles over a rough surface. Using that theory, we address the inverse obstacle scattering problem in which measurements of the wave field are collected on a planar array over a spectrum of wavelengths. For applications in single molecule detection and characterization, we seek to recover the number and locations of the scatterers as well as each of their spectral properties.

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MS35

Passive Imaging Using Distributed Apertures in Multi-path Environments

We present a new passive image formation method capable of exploiting information about multi-path scattering in the environment using measurements from a sparse array of receivers that rely on illumination sources of opportunity. We use a statistical and physics-based approach to model multi-path propagation and formulate the imaging problem as a spatially resolved binary hypothesis testing problem. Our imaging method is applicable in the presence of both cooperative and non-cooperative sources of opportunity.

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MS36

Statistical Methods for Manifold Learning

It has recently been recognized that if the signal of interest to an inverse problem is known to reside on a manifold, the number of required measurements needed for accurate inference may be reduced substantially. This is closely related to the new field of compressive sensing (CS). In this talk we discuss development of new nonparametric statistical methods to learn the statistical properties of a low-dimensional manifold. We show how this technique may be employed in several applications, including CS.

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MS36

Bayesian Hypermodels in Medical Imaging

In this talk, we review the hierarchical Bayesian models in medical applications. In the literature, it has been demonstrated in the context of machine learning and in image processing that Bayesian hierarchical model provide a flexible framework for implementing a priori information such as sparsity of the image or its gradient, and the interest in compressed sensing has increased the need to work out further the possibilities of hierarchical models. We discuss various medical imaging applications where the hierarchical models turn out to be useful and improve the quality of the reconstructions.

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MS36

Using Learning and Posterior Modeling to Segment Images

This talk proposes a direct posterior modeling methodology for segmenting images. The methodology provides a canonical way of using machine-learning techniques, such as kernel-based methods, in a level-set segmentation. One advantage of this approach is that it is possible to learn to segment complex images, such as ultrasound images, which have significant spatial inhomogeneity. This talk will present the methodology as well experimental results of using the posterior modeling technique.

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MS36

Expectation-Maximization Algorithm with Local Adaptivity for Image Analysis

In this work we develop an Expectation-Maximization (EM) algorithm with local adaptivity that can combine global statistics, local statistics, and and geometric information. In particular we apply our algorithm to image segmentation and classification. The key idea is to couple global statistics extracted from proper statistic model with local statistical and geometrical information. These combined information are used to design an adaptive local classification strategy that can both improve robustness and keep fine features.

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MS37

Pan Sharpening and Multimodal Data Fusion in Remote Sensing Applications

There has been significant research on pan-sharpening multispectral imagery with a high resolution image, but there has been little work extending the procedure to high dimensional hyperspectral imagery. We present a wavelet-based variational method for fusing a high resolution image and a hyperspectral image with an arbitrary number of bands. To ensure that the fused image can be used for tasks such as classification and detection, we explicitly enforce spectral coherence in the fusion process. This procedure produces images with both high spatial and spectral quality. We demonstrate this procedure on several AVIRIS and HYDICE images.

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MS37

Dictionary Learning Methods for Hyperspectral Image Classification

We investigate the application of sparse reconstruction and dictionary learning methods to hyperspectral image analysis. After training dictionaries for specific classes, we classify unknown pixels by comparing reconstruction errors across the different class dictionaries. We also discuss a novel method for the pixel unmixing problem that yields sparse abundance vectors.

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MS37

Unsupervised Clustering of High Dimensional Subspaces

A clustering framework within the sparse modeling and dictionary learning setting is introduced in this work. We optimize for a set of dictionaries for which the signals are best reconstructed in a sparse coding manner (subspaces). The proposed clustering uses a novel measurement for the quality of the sparse representation. We illustrate state-of-the-art results for supervised classification and unsupervised clustering on standard standard datasets and texture images.

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MS37

Multiscale Representations for Point Cloud Data

We shall describe a progressive encoder for Lidar point cloud data based on local PCA, adaptive partitioning, Hausdorff distance, and implicit representation of the point cloud surface. This encoder has as its goal best distortion in the Hausdorff metric for a given bit budget. Applications of the encoder will be given for point cloud data. The encoder is designed to handle noisy data by utilizing learning theory for the Hausdorff metric.

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MS38

Data Reduction Methods for Optical Tomography of Large DataSets

A current topic in Optical Tomography is the acquisition of data using camera detectors. The data can be obtained in a rotating scanning geometry and can include time resolved data, leading to large 4 or 5 dimensional data sets of size up to $10^8 - 10^{10}$. Due to the inherent low resolution of the method (stemming from its severe ill-posedness) much of this data is redundant. In this talk we consider some metohds for compressing the information content in these data sets and the commensurate improvement in image reconstruction performance.

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MS38

Approximation Errors and Model Reduction in 3D Diffuse Optical Tomography

Model reduction is often required in diffuse optical tomography (DOT), typically due to limited available computation time or computer memory. In practice, this means that one is bound to use coarse mesh and truncated computation domain in the model for the forward problem. In this talk we apply the Bayesian approximation error model for the compensation of modeling errors caused by domain truncation and a coarse computation mesh in DOT. The approach is tested using experimental data. The results show that when the approximation error model is employed, it is possible to use mesh densities and computation domains that would be unacceptable with a conventional measurement error model.

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MS38

Optical Tomography with the Discontinuous Galerkin Method

We present a discontinuous Galerkin (DG) formulation of the diffusion equation to tackle the meshing issues associated with finite element formulations. DG method has also been employed to solve the diffusion equation on a multi-layered highly diffusive domain with refractive index mismatch between consecutive layers. Numerical studies are presented for the forward problem and reconstructions employing DG method on both experimental and simulated data. These results show that DG formulations are as accurate as finite element formulations and are better equipped to tackle discontinuities in the solution.

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MS38

Numerical Solutions of Inverse Transport Problems with Interior Data for Imaging Applications

Inverse problems related to the linear radiative transport equation find applications in medical imaging such as optical tomography and optical molecular imaging. In tranditional optical tomography, the data used for imaging are only collected on the boundary of the imaging domain. We consider in this talk some inverse transport problems where we can collect interior data. We will present some numerical algorithms as well as some reconstructions with synthetic interior data.

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MS39

Integro Differential Equation Schemes Based on (BV, L1) Decomposition

The hierarchical multiscale image representation of Tadmor, Nezzar and Vese, gives rise to an integro-differential equation (IDE) for a multiscale image representation. One can obtain a similar IDE using (BV,L1) multiscale hierarchical decomposition. To this end, one integrates in inverse scale space a succession of refined, recursive 'slices' of the image, which are balanced by a typical curvature term at the finer scale. Once the IDE is obtained we can modify it based on our image processing needs. We will discuss various (BV, L1) IDE schemes incorporating filtering, edge enhancing and deblurring. We will also examine qualitative differences between (BV, L1) and (BV,L2) IDE schemes.

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MS39

Modeling Locally Parallel Oscillating Patterns

Since the seminal work by Y. Meyer in 2001, image decomposition into geometry + texture has drawn a lot of attention. In particular, it was shown by Osher-Sole-Vese, and later by Aujol-Gilboa, that using a Hilbert space to model texture is quite effective. In this work, we extend these ideas to build a spatially adaptive texture norm. Experiments in image decomposition and in image inpainting are shown to validate the approach. This work has been supported by the French "Agence Nationale de la Recherche" (ANR), under grant NATIMAGES (ANR-08-EMER-009) "Adaptivity for natural images and texture representations".

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MS39

Fast Gradient-Based Schemes for Total Variation Minimization

We present fast gradient-based schemes for image denoising and deblurring problems based on the discretized total variation (TV) minimization model with constraints. Our approach relies on combining a novel monotone version of the fast iterative shrinkage/ thresholding algorithm (FISTA) we recently introduced, with the well known dual approach to the denoising problem. We derive a fast algorithm for the constrained TV-based image deblurring problem. The proposed scheme is remarkably simple and is proven to exhibit a global rate of convergence which is significantly better than currently known gradient based methods. Our results are applicable to both the anisotropic and isotropic discretized TV functionals. Initial numerical results confirm the predicted underlying theoretical convergence rate results, and demonstrate the viability and efficiency of the proposed algorithms on image deblurring problems with box constraints. This talk is based on a joint work with Marc Teboulle.

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MS39

Inverse Free-discontinuity Problems and Iterative Thresholding Algorithms

Free-discontinuity problems describe situations where the solution of interest is defined by a function and a lower dimensional set consisting of the discontinuities of the function. Hence, the derivative of the solution is assumed to be a "small function" almost everywhere except on sets where it concentrates as a singular measure. This is the case, for instance, in certain digital image segmentation problems. 1) In presence of an inverse problem, no existence results were available so far. First of all we show preliminary new results on the existence of minimizers for inverse free-discontinuity problems, by restricting the solutions to a class of functions which we called the Rondi's class. 2) If we discretize such situations for numerical purposes, the inverse free-discontinuity problem in the discrete setting can be re-formulated as that of finding a derivative vector with small components at all but a few entries that exceed a certain threshold. This problem is similar to those encountered in the field of "sparse recovery", where vectors with a small number of dominating components in absolute value are recovered from a few given linear measurements via the minimization of related energy functionals. As a second result, we show that the computation of global minimizers in the discrete setting is an NP-hard problem. 3) With the aim of formulating efficient computational approaches in such a complicated situation, we address iterative thresholding algorithms that intertwine gradient-type iterations with thresholding steps which were designed to recover sparse solutions. It is natural to wonder how such algorithms can be used towards solving discrete free-discontinuity problems. This talk explores also this connection, and, by establishing an iterative thresholding algorithm for discrete inverse free-discontinuity problems, provides new insights on properties of minimizing solutions thereof. This is partially a joint work with Riccardo March (CNR, Italy) and Rachel Ward (Courant Institute, NYU, USA).

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MS40

ShapeGoogle: Geometric Words and Expressions for Invariant Shape Retrieval

Large databases of 3D models available in public domain have created the demand for shape search and retrieval algorithms capable of finding similar shapes in the same way a search engine responds to text quires. Since many shapes manifest rich variability, shape retrieval is often required to be invariant to different classes of transformations and shape variations. One of the most challenging settings in the case of non-rigid shapes, in which the class of transformations may be very wide due to the capability of such shapes to bend and assume different forms. In this talk, we will apply modern methods in computer vision to problems of non-rigid shape analysis. Feature-based representation such as the Scale-Invariant Feature Transform (SIFT) and metric learning methods have recently gained popularity in computer vision, while remaining largely unknown in the shape analysis community. We will show analogous approaches in the 3D world applied to the problem of non-rigid shape retrieval in large (potentially Internet-scale) databases. This will allow us to adopt methods employed in search engines for efficient indexing and search of shapes.

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MS40

Exploiting BoW Paradigm for 3D Shape Description and Matching

The Bag of Words (BoW) paradigm has been introduced originally for natural language processing and it has been successfully applied in several other domains. For instance in Computer Vision the BoW approach has been proposed for object categorization, image retrieval and human action recognition. Here, we show the effectiveness of the BoW onto the 3D domain by exploiting both i) region-based, and ii) point-based techniques to characterize local parts of a 3D shape. Region-based approaches build the visual vocabulary starting from the regions extracted by a 3D object segmentation process. Point-based techniques are instead oriented to the detection of few feature points from the 3D surface. Moreover, we show how the spatial relations between object subparts can be easily encoded by combining the BoW paradigm with shape context (i.e., local descriptors and global context). Several experiments are reported on different applications namely object retrieval and categorization, point-to-point matching, and 3D partial views registration.

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MS40

Geodesic Shape Retrieval with Optimal Transport

In this talk, I will review several geodesic representations for shapes and surfaces, and their use for retrieval with invariance to bendings and articulations. I will present a new familly of high dimensional geodesic shape signatures, that extend several previous proposals. These new geodesic representations take into account the interplay between several geodesic caracteristics. It is defined as high dimensional histograms of several key geodesic features, that detect global caracteristics of shapes and surfaces. The retrival is performed with a nearest neighbor query according to the Wasserstein distance between these multi-dimensional signatures. The search is performed with a fast approximated optimal transport algorithm. This a joint work with Julien Rabin and Laurent Cohen.

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MS40

Surface Feature Detection and Description with Applications to Mesh Matching

We revisit local feature detectors/descriptors developed for 2D images and extend them to the more general framework of scalar fields defined on 2D manifolds. We provide methods and tools to detect and describe features on surfaces equiped with scalar functions, such as photometric information. This is motivated by the growing need for matching and tracking photometric surfaces over temporal sequences, due to recent advancements in multiple camera 3D reconstruction. We propose a 3D feature detector (MeshDOG) and a 3D feature descriptor (MeshHOG) for uniformly triangulated meshes, invariant to changes in rotation, translation, and scale. The descriptor is able to capture the local geometric and/or photometric properties in a succinct fashion. Moreover, the method is defined generically for any scalar function, e.g., local curvature. Results with matching rigid and non-rigid meshes demonstrate the interest of the proposed framework.

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MS41

Elasticity in Image Registration Revisited

We present a general hyperelasticity regularization framework for image registration. The framework is demonstrated on a number of synthetic and real image registration applications.

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MS41

On Multiple Level-set Regularization Methods for Inverse Problems

We analyze a multiple level-set method for solving inverse problems with piecewise constant solutions. This method corresponds to an iterated Tikhonov method for a particular Tikhonov functional based on TV-H1 penalization. We define generalized minimizers for our Tikhonov functional and establish an existence result. Moreover, we prove convergence and stability results of the proposed Tikhonov method. A multiple level-set algorithm is derived from the first-order optimality conditions for the Tikhonov functional, similarly as the iterated Tikhonov method. The proposed multiple level-set method is tested on an inverse potential problem. Numerical experiments show that the method is able to recover multiple objects as well as multiple contrast levels. This is a joint work with A DeCezaro and A Leitão.

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MS41

Image Registration and Segmentation Using a Nonlinear Elasticity Smoother

We present a new non-parametric registration-segmentation method. The problem is cast as an optimization one, combining a matching criterion based on the active contour without edges for segmentation, and a nonlinear-elasticity-based smoother on the displacement vector field. This modeling is twofold: first, registration is jointly performed with segmentation since guided by the segmentation process; it means that the algorithm produces both a smooth mapping between the two shapes and the segmentation of the object contained in the reference image. Secondly, the use of a nonlinearelasticity-type regularizer allows large deformations to occur, which makes the model comparable in this point with the viscous fluid registration method. Several applications are proposed to demonstrate the potential of this method to both segmentation of one single image and to registration between two images.

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MS41

Continuous Models for Rigid and Nonrigid Registration

We will present a robust continuous mutual information model for multimodality registration. The probability and joint probability density functions for the continuous images are defined analytically. This model leads to a smooth mutual information which does not have the typical interpolation artifacts, resulting in much higher success rates. Moreover, we will propose a nonrigid registration model formulated in a particle framework. Our model can accommodate both small and large deformations, with sharper edges and clearer texture achieved at less computational cost. Numerical results on a variety of images are presented.

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MS42

Inverse Scattering by Compressed Sensing

Inverse scattering problem is analyzed from the perspective of compressed sensing. It is shown that with appropriately designed bases and sampling methods the number of measurements/sensors can be significantly reduced in comparison to traditional methods.

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MS42

Imaging Localized Scatterers with L1 Optimization

I will give a detailed comparison of resolution and robustness for array imaging with L1 and L2 optimization criteria, including results from numerical simulations. Joint L1 and L2 criteria will also be considered. This is work with Anwei Chai.

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MS42

Imaging and Detection in Cluttered Media

We consider sensor imaging in a noisy environment by suitably migrating the cross correlations of the recorded signals. We analyze the properties of the imaging functional in the high-frequency regime. We identify the scaling assumptions that allow us to image respectively, the support of random sources and smooth or rough medium variations.

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MS42

Data Filtering for Coherent Array Imaging in Heavy Clutter

We consider the problem of coherent array imaging reflectors embedded in strongly scattering media. This problem appears in applications such as exploration geophysics and non-destructive testing of materials. Coherent imaging results in such media are not satisfactory because the coherent signal that arrives at the array is too weak. To extend the applicability range of coherent imaging techniques to stronger scattering environments we propose to perform appropriate filtering on the data prior to imaging.

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MS43

Total Variation Methods for 3D Lidar Image Denoising

New imaging capabilities have given rise to higher dimensional image processing. This paper presents a generalization of total variation (TV) based denoising model with specific application to three-dimensional flash lidar imagery. The generalization uses a weighted norm, rather than the standard Euclidean measure, that accounts for sampling differences that may exist along different axes. We compare this new method against successive two-dimensional denoising and three-dimensional TV denoising.

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MS43

Visibility Optimization Using Variational Methods

Confined areas, such as those found in littoral regions, restrict the maneuvering and sensing capabilities of Naval vessels. We introduce a solution to the confined area search problem based on the calculus of variations which we implement using the level-set framework. The resulting algorithm is completely autonomous and can be extended to account for: incomplete maps, sensor limitations (range, resolution, etc.), as well as other factors. We also introduce an algorithm for positioning n-sensors to achieve maximal coverage of a confined area.

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MS43

Crowd Counting: Modeling Abnormal Events for the Detection of Suicide Bombers

We present some recent results on the problem of counting the number of people in a crowded scene. These results are obtained with a system for estimating the size of inhomogeneous crowds, composed of pedestrians that travel in different directions, without using explicit object segmentation or tracking. First, the crowd is segmented into components of homogeneous motion, using the mixture of dynamic textures motion model. Second, a set of simple holistic features is extracted from each segmented region, and the correspondence between features and the number of people per segment is learned with Gaussian Process regression. We validate both the crowd segmentation the crowd counting algorithms on hours of video.

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MS43

Object Classification and Identification from Acoustic Color Images

We introduce a method of enhancing a sonar image with acoustic color. Our method emphasizes the discriminative properties of the returned spectrum for the purpose of object discrimination. This is achieved by analyzing the discriminating power of different frequency bands and associating the appropriate ones with a color map.

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MS44

Kronecker Compressive Sensing

Compressive sensing (CS) is an emerging approach for acquisition of signals having a sparse or compressible representation in some basis. While the CS literature has mostly focused on problems involving 1-D signals and 2-D images, many important applications involve signals that are multidimensional; in this case, CS works best with representations that encapsulate the structure of such signals in every dimension. We propose the use of Kronecker product matrices in CS for two purposes. First, we can use such matrices as sparsifying bases that jointly model the different types of structure present in the signal. Second, the measurement matrices used in distributed measurement settings can be easily expressed as Kronecker product matrices. The Kronecker product formulation in these two settings enables the derivation of analytical bounds for sparse approximation of multidimensional signals and CS recovery performance, as well as a means to evaluate novel distributed measurement schemes.

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MS44

Edge Guided Compressive Imaging Reconstruction

Compressive imaging aims at reconstructing faithful images from a small number of measurements. We strive for sharper images from less measurements through efficiently using edge information. Accurate edge detection from undersampled data is very challenging due to existence of ubiquitious artifacts and noise. Start with sampled data with overwhelming small size, the proposed method is two folded: i) to detect edges from a not-so-perfect first round reconstruction; ii) to run an edge guided reconstruction.

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MS44

Edge Detection in Blurred Data from Fourier Space Using Higher-Order Edge Detectors

A novel approach is presented that allows the detection of edges in piece wise smooth signals from partial Fourier data. Detection of edges has many important application e.g. in medical image analysis or image reconstruction. Our approach combines a method to find jump discontinuities in Fourier data and ideas from compressed sensing. It is able to detect edges in Fourier data without the presence of ringing artifacts common to higher order edge detection methods.

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MS44

Compressive Sensing via Iterative Support Detection

We present a new compressive sensing reconstruction method "ISD', aiming to achieve fast reconstruction and a reduced requirement on the number of measurements compared to the classical ℓ_1 minimization approach. ISD addresses failed cases of ℓ_1–based construction due to insufficient measurements, in which the returned signals are not equal or even close to the true signals. Specifically, given an incorrect signal, ISD detects an index set I that includes components most likely to be true nonzeros and solves $\min\{\sum_{i\notin I}|x_i| : Ax = b\}$ for a new signal x, and it iterates these two steps alternatively using latest x and I from one another until convergence.

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MS44

Effective Compressive Sensing with Toeplitz and Circulant Matrices

Compressive sensing requires a small number of incoherent measurements of the unknown signal as the input. To achieve the co-incoherence, random linear projections are often among the best choices. However, they are difficult to implement physically or the implementation would cause a prohibitive overhead. We describe how random Toeplitz and circulant matrices can be easily (or even naturally) realized in various imaging applications and introduce fast algorithms for their corresponding signal reconstruction problems. Results show that they are not only as effective as random matrices but also permit much faster signal reconstruction in one, two, and higher dimensions.

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MS45
On Globally Optimal Local Modeling: From Moving Least Square to Overparametrization

This paper discusses a spectrum of methods for signal, curve, image and surface denoising, adaptive smoothing and reconstruction from noisy samples that involve locally modeling the data while performing local, semi-local and/or global optimization. We show that the same methodolgy yields many of the previously proposed algorithms, from the popular moving least squares methods to the globally optimal overparametrization methods recently published for smoothing and optic-flow estimation. However, the unified look at the spectrum of problems and methods also suggests a wealth of novel global functionals and local modeling possibilities.

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MS45
Image Super-Resolution using Sparse-Representation

Scaling up a single image while preserving is sharpness and visual-quality is a difficult and highly ill-posed inverse problem. A series of algorithms have been proposed over the years for its solution, with varying degrees of success. In CVPR 2008, Yang, Wright, Huang and Ma proposed a solution to this problem based on sparse representation modeling and dictionary learning. In this talk I present a variant of their method with several important differences. In particular, the proposed algorithm does not need a separate training phase, as the dictionaries are learned directly from the image to be scaled-up. Furthermore, the high-resolution dictionary is learned differently, by forcing its alignment with the low-resolution one. We show the benefit these modifications bring in terms of simplicity of the overall algorithm, and its output quality.

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MS45
Block Stein Sparse Denoising and Deconvolution

In this work, we propose fast image denoising and deconvolution algorithms that use adaptive block thresholding in sparse representation domain. Our main theoretical result investigates the minimax rates of Stein block thresholding in any dimension d over the so-called decomposition spaces. These smoothness spaces cover the classical case of Besov spaces for which wavelets are known to provide a sparse representation, as well as smoothness spaces corresponding to the second generation curvelet-type construction. We shows that block estimator can achieve the optimal minimax rate, or is at least nearly minimax (up to a log factor) in the least favorable situation. The choice of the threshold parameter is theoretically discussed and its optimal value is stated for the white Gaussian noise. We provide simple, fast and easy to implement algorithms. We also report a comprehensive simulation study to support our theoretical findings. The practical performance of our block Stein denoising and deconvolution algorithms compares very favorably to state-of-the art algorithms on a large set of test images.

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MS45
3D Sparse Representations and Inverse Problems

In this paper, we show that using a few three dimensional sparse transforms with atoms of different morphologies, including the wavelets and two types of curvelets, we can design simple algorithms based on iterative thresholdings that solve many restoration and inverse problems such as denoising, morphological component separation, inpainting, de-interlacing or inverse Fourier/Radon transform with relatively few projections.

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MS45
Image Modeling and Enhancement via Structured Sparse Model Selection

Joint work with Guillermo Sapiro and Stéphane Mallat

An image representation framework based on structured sparse model selection is introduced in this work. The corresponding modeling dictionary is comprised of a family of learned orthogonal bases. For an image patch, a model is first selected from this dictionary through linear approximation in a best basis, and the signal estimation is then calculated with the selected model. The model selection leads to a guaranteed near optimal denoising estimator. The degree of freedom in the model selection is equal to the number of the bases, typically about 10 for natural images, and is significantly lower than with traditional overcomplete dictionary approaches, stabilizing the representation. For an image patch of size $\sqrt{N} \times \sqrt{N}$, the computational complexity of the proposed framework is $O(N^2)$, typically 2 to 3 orders of magnitude faster than estimation in an overcomplete dictionary. The orthogonal bases are adapted to the image of interest and are computed with a simple and fast procedure. State-of-the-art results are shown in image denoising, deblurring, and inpainting. Demo website: http://www.cmap.polytechnique.fr/ yu/research/SSMS/demo.html

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MS46

Numerical Analysis of View Dependent Derivatives in Computed Tomography

A number of CT reconstruction formulas depend on a common derivative with respect to source position. In fan-beam or helical CT, the derivative can be viewed as the difference quotient of measurements made along parallel lines and an accurate numerical implementation is critical to the resolution of the reconstruction. We review some of the proposed methods to implement the derivative and present their corresponding error terms in a common framework for fan-beam CT.

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MS46

Analytic and Optimization-based Image Reconstruction in Cone-beam CT

CT hardware, algorithms, and applications have experienced tremendous advances in the last two decades. In the presentation, I will focus on discussing recently developed analytic and optimization-based algorithms for image reconstruction in cone-beam CT and their potential implications for CT applications. Emphasis will be placed on the discussion of differences between analytic and optimization-based algorithms and their implications for practical applications. Examples will be used to illustrate and clarify a number of issues, such as the relationship between the Nyquist sampling theorem and compressive sensing approach, which seem to be confusing. The mathematic exactness of an algorithm can be an irrelevant metric for meaningfully evaluating the algorithms practical utility in its practical applications. Discussion will thus be given as to how the performance evaluation of an algorithm can be meaningfully carried out.

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MS46

Band-Restricted Estimation of Noise Variance in Filtered Backprojection Reconstructions from Repeated CT Scans

We introduce a new estimator for noise variance in tomographic images reconstructed using algorithms of the filtered backprojection type. The new estimator operates on data acquired from repeated scans of the object under examination, is unbiased, and is shown to have significantly lower variance than the conventional unbiased estimator for many scenarios of practical interest. We provide an extensive theoretical analysis of this estimator and present preliminary results with real x-ray computed tomography data.

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MS46

Motion Compensation in Computed Tomography

Clinical applications of computed tomography (CT) often deal with motion-contaminated data. Examples are cardiac or respiratory patient motion. We discuss motion-compensated reconstruction with 3D cone beam CT. Currently there is a well-established theoretical foundation for exact 3D reconstruction of motionless phantoms, based on work of Katsevich, Zou, Pan, Noo, Pack, Wang, Chen, and others. However, when motion is introduced, the exactness breaks down. When motion is present we need to balance exactness with stability to motion. There are known techniques to handle motion with approximate reconstruction, based on work of Kachelriess, Taguchi, Schechter, and others; however these approaches disregard increasing cone angle and not suitable for fully 3D reconstruction. In this talk we propose an approach that combines elements of exact reconstruction with motion-gated reconstruction, and show evaluation results.

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MS47

From Observable Space to Parametric Space (and Back): Interpretation of earth formation structure from Electro-Magnetic Measurements by Anisotropic Diffusion Maps

Given empirical data generated by a non-linear transformation of some physical parameters we introduce an algorithm that can map newly observed data points back into the invariant parameters space. Moreover, the algorithm can map a new sample from the parameters space to the observable space. The key idea is the use of the anisotropic diffusion kernel on reference points from the observed data to approximate a Laplacian on the inaccessible independent parameters space. We demonstrate our method in Logging While Drilling (LWD), to interpret formation structure from Electro-Magnetic Measurements.

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MS47

Foundations of Multi-Manifold Modeling Algorithms

We present several methods for multi-manifold data modeling, i.e., modeling data by mixtures of manifolds (possibly intersecting). We first concentrate on the special but useful case of hybrid linear modeling, where the underlying manifolds are affine or linear subspaces. We emphasize various theoretical results supporting the performance of such algorithms as well as practical choices guided by it. This is part of joint works with E. Arias-Castro, G. Chen, A. Szlam, Y. Wang, T. Whitehouse and T. Zhang

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MS47

Multiple Scales in High-dimensional Noisy Data Sets and Images

We introduce multiscale geometric methods for studying the geometry of noisy point clouds in high-dimensions, which may model data sets in a variety of applications. These methods allow to estimate in a robust fashion the intrinsic dimensionality of the data, to generate automatically dictionaries for the data, and manipulate the data for tasks such as denoising and modeling in a way that respects the intrinsic geometry of the data.

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MS47

Image De-Noising on the Manifold of Patches: A Spectral Approach

Inspired by the work of Lee and Mumford, who showed experimentally that 3x3 patches of natural images organize themselves around nonlinear low dimensional manifolds, we propose to construct basis functions to efficiently parametrize the manifolds of image patches. In this work, we describe how we can remove the noise from an image by iteratively reconstructing and denoising the set of patches. This approach outperforms the most successful denoising techniques.

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MS48

Reconstruction of the Orientation Distribution Function in Q-Ball Imaging within Constant Solid Angle

Q-ball imaging is a high-angular-resolution diffusion imaging technique which has been proven successful in resolving multiple intravoxel fiber orientations. The standard computation of the orientation distribution function (ODF, the probability of diffusion in a given direction) neglects the change in the volume element along each direction. A new technique is proposed here that, by considering the solid angle factor, results in a dimensionless and normalized ODF expression computed from single or multiple q-shells.

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MS48

Diffusion Propagator Imaging: Going Beyond Single Shell HARDI

Many recent single-shell high angular resolution diffusion imaging (HARDI) reconstruction techniques have been introduced to reconstruct orientation distribution functions (ODF) that only capture angular information contained in the diffusion process of water molecules. By also considering the radial part of the diffusion signal, the reconstruction of the ensemble average diffusion propagator (EAP) of water molecules can provide much richer information about complex tissue microstructure than the ODF. In this talk, I will present recent techniques to reconstruct the EAP from multiple shell q-space acquisitions, one of which is named diffusion propagator imaging (DPI). The DPI solution is analytical and linear because it is based on a 3D spherical Laplace equation modeling of the diffusion signal. We validate DPI with simulations, ex vivo phantoms and also illustrate it on an in vivo human brain dataset. This opens perspectives in q-space acquisition schemes and lead to new ways to study white matter anomalies and properties with the diffusion propagator.

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MS48

Recent Advances in Estimation and Processing of High Angular Resolution Diffusion Images

High angular resolution diffusion imaging (HARDI) has become an important magnetic resonance technique for in vivo imaging. The first part of this talk focuses on estimating the diffusion orientation distribution function (ODF) from raw HARDI signals. We will present an estimation method that naturally constrains the estimated ODF to be a proper probability density function and regularizes this estimate using spatial information. By making use of the spherical harmonic representation, we pose the ODF estimation problem as a convex optimization problem and propose a coordinate descent method that converges to the minimizer of the proposed cost function. In the second part of this talk, we will present a Riemannian framework to carry out computations on an ODF field. The proposed framework does not require that the ODFs be represented by any fixed parameterization, such as a mixture of von Mises-Fisher distributions or a spherical harmonic expansion. Instead, we use a non-parametric representation of the ODF, and exploit the fact that under the square-root re-parameterization, the space of ODFs forms a Riemannian manifold, namely the unit Hilbert sphere. Specifically, we use Riemannian operations to perform various geometric data processing algorithms, such as interpolation, convolution and linear and nonlinear filtering.

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MS48

Regularization of Orientation Distribution Functions in Diffusion MRI

Orientation Distribution Functions (ODF) are very important in Diffusion Magnetic Resonance Imaging (Diffusion MRI). They can be used as probability density functions (PDF) when applied to statistical fiber tracking of brain tissues. There has been a lot of work on calculation, characterization and regularization of ODFs. To prepare ODFs for fiber tracking, it is best to incorporate global information in regularization. However, since there are many voxels involved in 3D regularization, and for each voxel there are several directional data, which makes the global regularization a 4D problem, and it is almost impossible to finish the regularization within a bearable time. There is no fast algorithms yet published for global 3D regularization of ODFs. We will introduce a new model of global regularization using total variation and wavelet transform. The novelty of our work is that we will implement a fast and robust method in the calculation of the global model. With the help of the fast numerical method, it is now viable for us to work on global regularization ODF calculation, which will provide much better ODF results and improve the accuracy of brain fiber tractography, in both single fiber direction cases and multiple fiber direction cases.

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MS49

Blind Motion Deblurring Using Multiple Images

We propose a novel method for automatically recovering a high-quality clear image from multiple blurred images. We avoid the bottleneck of previous methods which required multiple blurred image frames to be accurately aligned during pre-processing. Here instead, by exploring the sparsity of the motion blur kernel and the clear image under certain domains, we propose an alternative approach to simultaneously identify the blur kernels of given blurred images and restore a clear image.

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MS49

Flicker Stabilization in Image Sequences

Flicker is an artefact appearing in old films or in some videos, which is characterized by intensity changes from a frame to another. Some of these contrast changes are not global and may be localized only on a part of the image. In this talk, we will introduce a new method to stabilize flicker in films. Local contrast changes are performed in order to equalize the grey level distribution of an image patch with the grey level distributions of all its corresponding patches in the previous and following frames. The correspondences of a patch are computed thanks to a similarity measure that is built to be robust to contrast changes.

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MS49

Fast Dejittering for Digital Video Images Using Local Non-smooth and Non-convex Functionals

We propose several very fast algorithms to restore jittered digital video frames (their rows are shifted) in one iteration. The restored row shifts minimize non-smooth and possibly non-convex local criteria applied on the second-order differences between consecutive rows. We introduce specific error measures to assess the quality of dejittering. Our algorithms are designed for gray-value, color and noisy frames. They outperform by far the existing algorithms both in quality and speed.

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MS49

Restoration of Home Movies

Home movies are short films, usually produced by amateurs, which have high cultural and historical value. The home movie archive of the Catholic University of Uruguay has a large collection of movies, some in traditional film support and others in Umatic tapes. We explored the specificities of each material and the best way to restore them while preserving its original content. In the talk we will present the obtained results.

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MS50

An Approach of Feature Detection and Fusion in Facial Recognition

Currently, most facial recognition algorithms work under controlled environments. In real applications, a trade-off exists between efficiency and accuracy. We proposed an approach that performs fusion on the face area and facial components (eyes, nose, and mouth). These components are also compared to the respective features of other faces. The proposed approach has yielded promising results that demonstrate the benefits of fusion technology. High-resolution images are quickly processed to detect and recognize slightly-angled faces accurately.

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MS50

Automated Sea Mine Detection, Classification, and Fusion in Sonar Data

The Office of Naval Research (ONR) has sustained significant research in automated sea-mine detection and classification (D/C). This paper presents an overview of automated D/C processing for high-resolution side-looking sonar imagery including: normalization of sonar imagery, D/C algorithms, and Algorithm Fusion (combining multiple D/C algorithms). Results from recent exercises are given. Finally the paper presents current technical approaches regarding ONR's new focus on buried-mine D/C, exploiting multi-spectral and multi-aspect data from broadband synthetic aperture sonars.

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MS50

Metric Learning for Semi-supervised Clustering of Object Representations

Practical image processing systems require matching of objects among many cameras. Once foreground subtraction has been applied and object representations have been derived we perform semi-supervised clustering given a set of pairwise constraints provided by the user aided by metric learning approaches. Distance metric on the manifold of Symmetric Positive Definite matrices is represented as an L2 distance in a vector space and a Mahalanobis-type distance metric is learnt in the new space in order to improve the performance of semi supervised clustering. We will present results in clustering people appearances from single and multiple camera views.

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MS50

Adaptive Detection of Objects in Hyperdimensional Images via Domain-reducing Mappings

Adaptive object detectors whiten image backgrounds and then match-filter. When the number of degrees of freedom is large (e.g., hyperdimensional case), there may be insufficient data for estimating background statistics. We present optimal and near-optimal mappings for projecting hyperdimensional images into reduced domains and detecting objects of interest therein. The inverse problem: backprojecting the adaptive weights into the original domain, is also discussed, as this is of practical importance to ill-posed problems (e.g., tomography applications).

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MS51

Global Weak Solutions for Some Nonlinear Diffusions

A family of nonlinear nonlocal diffusions is analyzed which interpolates between a Perona-Malik type equation and regular linear diffusion via the use of fractional derivatives. Solvability, global existence of strong and of a kind of weak solutions as well as transition from non-trivial nonlinear to trivial diffusive behavior will be analyzed and numerically demonstrated.

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MS51

Multiphase Scale Segmentation

Variational approaches to image segmentation has been widely studied, specially since Mumford-Shah functional was proposed. Various extensions have been studied including multiphase segmentation. This talk will focus on multiphase segmentation using size of the objects in the image.

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MS51
On the Construction of Topology-preserving Deformation Fields

In this paper, we investigate a new method to enforce topology preservation on two-dimensional deformation fields. The method is composed of two steps: - the first one consists in correcting the gradient vector fields of the deformation at the discrete level, in order to fulfill a set of conditions ensuring topology preservation in the continuous domain after bilinear interpolation. This part, although related to prior works by Karacali and Davatzikos (Estimating Topology Preserving and Smooth Displacement Fields, B. Karacali and C. Davatzikos, IEEE Transactions on Medical Imaging, vol. 23(7), 2004), proposes a new approach based on interval analysis. - the second one aims to reconstruct the deformation, given its full set of discrete gradient vector fields. The problem is phrased as a functional minimization problem on a convex subset K of an Hilbert space V. Existence and uniqueness of the solution of the problem are established, and the use of Lagrange's multipliers allows to obtain the variational formulation of the problem on the Hilbert space V. Experimental results demonstrate the efficiency of the method. Comparisons and comments on the major differences between our model and the one introduced by Karacali and Davatzikos are also provided

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MS51
Global Minimization for Continuous Multiphase Partitioning Problems using a Dual Approach

This talk is devoted to the optimization problem of continuous multi- partitioning, or multi-labeling, which is based on a convex relaxation of the continuous Potts model. We prove that optimal solutions to this re- laxed problem is in fact integer valued and globally optimal to the Pott Rs model! In contrast to previous efforts, which are trying to tackle the optimal labeling problem in a direct manner, we first propose its novel dual model and then build up a corresponding duality-based approach. By this, the close connections between optimal labelings and geometrical clustering of spatial points are revealed. In order to deal with the highly nonsmooth dual problem, we suggest a smoothing method based on the log-sum exponential function and also indicate that such smoothing ap- proach formally gives rise to the novel smoothed primal-dual model and suggests labelings with maximum entropy. As shown in the numerical experiments, such smoothed method for the dual model produces an ex- pectation maximization like algorithm for the multi-labeling problem and yields better numerical results.

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MS52
Statistical and Computational Methods in Object Recognition

This course will cover existing algorithms and future challenges for object recognition with a focus on statistical models and computational issues. We will consider three main tasks in the area. The first involves classification of images containing a single object. The second involves the detection of objects from a particular class in large cluttered images. The third involves the challenge of labeling multiple interacting objects in an image. We will consider both generative and discriminative models, emphasizing their differences and similarities in terms of modeling, training and computation. Specific topics will include the notion of invariances, low-level features, intermediate representations, learning from weakly labeled data and part-based models.

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MS53
Frame Methodology for Dimension Reduction

Motivated by hyperspectral imaging problems, we construct a frame-based algorithm for dimension reduction and classification. The algorithm is formulated in terms of kernel methods, frame potential energy, and constraint-based optimal frames. The output of the algorithm is a data dependent frame. Sparse representation techniques ensure that this frame provides a frame element for each class to be identified to the exclusion of the other classes. The reduced dimension can be less than the number of classes to be analyzed.

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MS53
Processing and Compressing DTED and Hyperspectral Data

We have developed new algorithms for compressing and denoising DTED data, including multiple returns. We also have incorporated a new method for unmixing hyperspectral data using a recently developed algorithm of Arthur Szlam. We will discuss these techniques and give applications and ideas for future work.

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MS53

Full and Partial Pixel Methods for Spatial/spectral Pattern Analysis

Automated classification methods are typically full-pixel techniques that render hardened class labels at each site in an image. Often the labeling is made too soon in the overall decision process and the results are unreliable. In this study, a sub-pixel method constrained by full-pixel processes is applied to hyperspectral imagery resulting in "soft" class map layers for subsequent object recognition and terrain analysis. The context is terrain, urban, and shallow-water mapping.

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MS53

High-Dimensional Methods Applied to Summarizing, Indexing, and Search Full-Motion-Video

The pace at which full motion video is being collected, from persistent and mobile surveillance systems, is accelerating at such a fast pace that arent enough human eyeballs to monitor or analyze the volume of data. By taking advantage of a convergence of new analytics methods and advanced multi/many-core computing architectures this volume of video data can be reduced to a manageable set of high-compressed, content-based summarization and index tables that can facilitate the searching and analysis of the data for objects and events. This presentation describes the use of sparse representations to build a content based search engine for searching full motion EO and IR, and video data.

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MS54

Reconstruction of Thin Tubular Objects from Electromagnetic Scattering Data

We consider the inverse problem of reconstructing a collection of thin tubular objects from measurements of electromagnetic scattering data. In potential applications these objects could, e.g., be wires or tubes buried in the subsurface. Applying an asymptotic representation formula for the scattered field as the thickness of the scatterers tends to zero, we establish an asymptotic characterization of these scatterers in terms of the measurement data. This characterization is then implemented in a non-iterative reconstruction algorithm.

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MS54

Convex Source Support in Half-plane

We extend the concept of convex source support to the framework of inverse source problems for the Poisson equation in an insulated half-plane. The convex source support is, in essence, the smallest convex set that supports a source that produces the measured data. We modify a previously introduced method for reconstructing the convex source support in bounded domains to our unbounded setting. The resulting algorithm is also applied to the electrical impedance tomography.

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MS54

Backscattering in Electrical Impedance Tomography

Electrical impedance tomography is an imaging technique for recovering the admittance inside a body from boundary measurements of current and voltage. If the measurement probe is small, consists of two electrodes and can be moved along the boundary, the resulting data is of backscattering nature. We note that such measurements uniquely determine an insulating inclusion in constant background. Moreover, we present an algorithm for reconstructing the so-called convex backscattering support of a more general inhomogeneity.

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MS54

Detecting Anomalies in Electrical Impedance Tomography

The factorization method for electrical impedance tomography (EIT) is a successful method for the detection of anomalies, i.e. domains in which the conductivity is different from the background conductivity. However, it is a qualitative method, i.e. it doesn't provide the conductivity inside the anomalies. We present a new version of the factorization method for EIT and show that it leads to a method to compute this conductivity inside previously located anomalies.

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MS55

Variational Restoration of Images with Space-Variant Blur

We address the problem of space-variant image deblurring, where different parts of the image are blurred by different blur kernels. Assuming a region-wise space variant point spread function, we first solve the problem for the case of known blur kernels and known boundaries between the different blur regions in the image. We then generalize the method to the challenging case of unknown boundaries between the blur domains. Using variational and level set techniques, the image is processed globally. The space-variant deconvolution process is stabilized by a unified common regularizer, thus preserving discontinuities between the differently restored image regions. We address the cases of space-variant out-of-focus blur, and simultaneous motion estimation, blur segmentation and restoration.

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MS55

Mathematical and Computational Techniques for Inverse Problems with Poisson Data

In image processing, Poisson data arises when intensities are measured via counting processes, e.g., when a CCD camera is used and in positron emission tomography. The resulting Poisson maximum likelihood reconstruction problem presents both computational and mathematical challenges. For one, regularization is typically needed, which leads to theoretical questions in the realm of classical regularization theory and to the problems of regularization parameter and operator choice. Also, the resulting computational problem, being large-scale and nonnegatively constrained, is challenging and requires an efficient method. In this talk, we will present some results that we've obtained in our effort to address these disparate challenges.

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MS55

Image Restoration Using Nonlocal Mumford-Shah Regularizers

We introduce several color image restoration algorithms based on the Mumford-Shah model and nonlocal image information. The standard Ambrosio-Tortorelli and Shah models are defined to work in a small local neighborhood, which are sufficient to denoise smooth regions with sharp boundaries. However, textures are not local in nature and require semi-local/non-local information to be denoised efficiently. Inspired from recent works such as NL-means of Buades, Coll, Morel and NL-TV of Gilboa, Osher, we extend the standard models of Ambrosio-Tortorelli and Shah approximations to Mumford-Shah functionals to work with nonlocal information, for better restoration of fine structures and textures. We present several applications of the proposed nonlocal MS regularizers in image processing such as color image denoising, color image deblurring in the presence of Gaussian or impulse noise, and color image super-resolution. In the formulation of nonlocal variational models for the image deblurring with impulse noise, we propose an efficient preprocessing step for the computation of the weight function. In all the applications, the proposed nonlocal regularizers produce superior results over the local ones.

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MS55

Computational Approaches for Multi-Frame Blind Deconvolution

Multi-frame deconvolution (MFBD) requires using iterative methods to solve large scale, nonlinear optimization problems. In this talk we describe an efficient variable projection Gauss-Newton method to solve the MFBD problem. Tikhonov regularization is incorporated using an iterative Lanczos hybrid scheme, where regularization parameters are chosen automatically using a weighted generalized cross validation method, thus providing a nonlinear solver that requires very little input from the user. In addition, we consider approaches that incorporate nonnegativity constraints and preconditioning, which provide both additional prior information and help to improve computational efficiency.

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MS55

Space-Continuous Models and Algorithms for Image Deconvolution

To introduce to the thematic spectrum of the minisymposium, the talk will start with an overview over minimisation-based approaches to image deconvolution. Afterwards it will focus on variational models and present methods to accommodate the positivity constraint within such models. Firstly, this includes a reparametrisation approach in connection with a gradient descent technique. Reinterpretations then lead to differential-geometric models on one hand, and to interesting new fixed-point iterations on the other hand.

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MS56

Discrete Optimization via Graph Cuts for Nonrigid Registration

In this presentation, we formulate non-rigid image registration as a discrete labeling problem. Each pixel in the source image is assigned a displacement label (which is a vector) indicating which position in the floating image it is spatially corresponding to. A smoothness constraint based on the first derivative is used to penalize sharp changes in displacement labels across pixels. The whole system can be optimized by using the graph-cuts method via alpha-expansions. We compare 2D and 3D registration results of our method with two state-of-the-art approaches.

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MS56

Optimization Based Methods for Non-Rigid Image Registration

In my talk I will focus on numerical methods for non-rigid registration based on optimization. Starting from a variational formulation we discretize the registration problem and apply efficient Newton-type optimization methods such as Gauss-Newton or limited memory BFGS. Furthermore, I will demonstrate how to incorporate additional knowledge and requirements from applications such as landmarks or control of local volume changes by constraint optimization.

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MS56

Variational Registration with Free Form Deformations

Traditionally dense deformable registration and grid based (such as free form using b-splines) deformable registration are numerically solved using different approaches. Dense deformable registration problem is usually formulated as an iterative partial differential equation and efficiently solved using semi-implicit approaches. On the other hand, for free from deformable (FFD) registration problem explicit gradient-based approaches are used. In this talk, we outline a unified approach for solving these problems. We show that the grid based approaches can be interpreted as a dense deformable registration, where the interpolation kernel is built in the regularization constraint. Using this unified approach, we gain computational efficiency while not compromising the quality of the match and the deformation field. The empirical results show the promise of the proposed approach.

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MS56

FAIR: A Toolbox for Image Registration

Image registration is one of the challenging tasks in image processing and in particular in medical imaging. Roughly speaking, the problem is to automatically find correspondences between points in two different images. This talk provides a brief introduction to image registration and outlines a general framework, which is based on a variational approach. The talk also introduces the freely available software FAIR (Flexible Algorithms for Image Registration). Based on a variety of examples, it is demonstrated, why the software is useful and how it can be used.

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MS57

Sampling Over Infinite Unions: Towards Compressive Ultrasonic Imaging

Real-time cardiac ultrasound suffers from complexity due to high sampling rates. Our goal is to reduce this rate by exploiting the mathematical structure of ultrasound images, captured by a union of subspaces model. We develop extensions of compressed sensing (CS) to the general union model including continuous-time signals by combining CS ideas with traditional analog sampling theory, leading to a framework we coin Xampling (CS+sampling). We then apply Xampling to reduce the complexity of ultrasound imaging.

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MS57

Sampling, Reconstruction, and Recognition of Visual Signals Guided by Self-similarity

We present a non-parametric framework based on the notion of Kernel Regression which we generalize to adapt to local geometric characteristics of the given signal. These descriptors are exceedingly robust in capturing the underlying structure of multidimensional signals even in the presence of significant noise, missing data, and other disturbances. This framework is applicable to a wide variety of problems. Of particular interest in two and three dimensions are sampling and restoration. Of recent relevance to computer vision, are applications to object and action detection/recognition in images, and in video, respectively, from a single example.

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MS57

Optical Image Reconstruction from Binary Sensors

We propose an optical setup for the acquisition of image data using binary sensors, which is a special form of compressed sensing. We address the ill-posedness of the problem by imposing a penalty on the total variation of the solution. We derive the image reconstruction algorithm based on the minimization of a corresponding convex functional. We illustrate the feasibility of the approach with some concrete examples.

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MS57

'Rewiring' Filterbanks for Interpolation and Denoising: Theory and Applications

This article describes a series of new results outlining equivalences between certain "rewirings' of filterbank system block diagrams, and the corresponding actions of convolution, modulation, and downsampling operators. This gives rise to a general framework of reverse-order and convolution subband structures in filterbank transforms, which we show to be well suited to the analysis of filterbank coefficients arising from subsampled or multiplexed signals. These results thus provide a means to understand time-localized aliasing and modulation properties of such signals and their subband representations—notions that are notably absent from the global viewpoint afforded by Fourier analysis. The utility of filterbank rewirings is demonstrated by the closed-form analysis of signals subject to degradations such as missing data, spatially or temporally multiplexed data acquisition, or signal-dependent noise, such as are often encountered in practical signal processing applications.

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MS58

Differential Geometry of Curves for Large-Scale Multi-View Stereo and Applications to Biomedical Imaging

We will present a large-scale system for automatic 3D reconstruction of arbitrary curves and occluding surfaces from multiple views. The system is multi-threaded and scales up to thousands of images at high-definition, and handles complex scenes beyond the capabilities of other methods. The use of differential geometry for multiview matching and calibration are shown to be key for achieving robustness. Biomedical applications which may require fast, flexible, low-cost, and non-invasive photogrammetric solutions will be discussed.

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MS58

Comparing GPU Implementations of Bilateral and Anisotropic Diffusion Filters for 3D Biomedical Datasets

We compare the performance of hand-tuned CUDA implementations of bilateral and anisotropic diffusion filters for denoising 3D MRI datasets. Our tests sweep comparable parameters for the two filters and measure total runtime, memory bandwidth, computational throughput, and mean squared errors relative to a noiseless reference dataset. To assess the suitability of these implementations and parameter choices for an image processing pipeline, we also perform segmentation and calculate validation scores.

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MS58

Combining Imagery, Documents, Audio, and Video in a Multi-Domain Data Space

Technology has allowed for data collection from multiple domains, however the methods by which this data is scoured has not advanced in the same way. Data searches still rely on single-domain searches. This precludes the use of inter-domain linkages that are inherent in natural data. In this work, a set of multiple-domain subspaces are created such that a query of one type of data can directly recall data from all other domains

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MS58

Retinopathy Diagnosis from Ocular Fundus Image Analysis

Eye care can benefit from the use of ocular fundus images to diagnose pathologies. The analysis of these images requires automatic identification of normal and aberrant structures in human retina such as macula, vascular network, optic disc, hemorrhages, drusen, fovea, exudates, and microaneurysms. Our algorithms use Hough transform to locate the optic disk, which facilitates classification of microaneurysms. We also consider vascular network extraction and other structures by means of mathematical morphology.

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MS59

The Unreasonable Effectiveness of Bregman Iteration for L1 Type Opimization

Bregman iteration was introduced to TV based restoration a few years ago and improved the performance significantly. Later it was found that this same idea gave what appear to be state-of-the-art fast algorithms for L1 based optimization problems arising in compressive sensing and elsewhere. Not only has this method been around since 1967, but every new variant recently invented appears to be closely related to and indeed often a special case of known techniques. So why is it a so important now? The answer seems to be found in the nature of L1 itself. Errors cancel beautifully. I will discuss this here. This is joint work with Wotao Yin and many other collaborators.

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MS59

FPC_AS: A Fast Algorithm for Sparse Reconstruction Based on Shrinkage and Subspace Optimization

We describe a fast algorithm for sparse reconstruction. The algorithm is divided into two stages that are performed repeatedly. In the first stage, "shrinkage" yields an estimate of the subset of variables likely to be nonzero in an optimal solution. Subspace optimization are then used to recover the magnitude of the solution in the second phase. Our implementation of this method exhibits state-of-the-art performance both in terms of its speed and its ability to recover sparse signals.

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MS59

A Review and Recent Results of the Bregman Methods

We review four Bregman methods that arise in applications of imaging, compressed sensing, and other inverse problems. We explain their numerical properties and highlight their relationships with the augmented Lagrangian and alternating direction methods. Recent results on the Bregman methods are included. Applied to the ℓ_1-type regularization, the original Bregman method has an exact error cancellation property that leads to machine-precision solutions. In addition, we briefly show an exact penalty property of the linearized Bregman method. These properties explain the great preformance of the Bregman methods. The analysis and discussions broadly apply to polyhedral regularization functions such the (weighted) ℓ_1-norm, anisotropic total variation, piece-wise linear functions.

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MS59

An Efficient Tv-Minimization Algorithm with Application to Single-Pixel Camera

We propose and study the use of the classic Augmented Lagrangian Method in image reconstruction in compressive sensing. The subproblems involved are solved through a variable splitting and alternating minimization scheme. The resulting Matlab code, called TVAL3, is compared with several state-of-the-art codes on both synthetic data and real data measure by the Rice single-pixel camera.

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MS60

Challenges in Developing a DWI/DTI Pipeline

While diffusion MRI is already an established field, its potential clinical applications are still in a formative stage. One impediment to the implementation of diffusion MRI is the dearth of an established analysis framework to enable one to make valid statistical inferences and draw meaningful scientific conclusions, particularly from longitudinal and multi-center data. Some unresolved issues will be described whose resolution would help ensure that these studies will produce high-quality findings.

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MS60

Optimal Sampling Schemes for Diffusion MRI Acquisitions and Online Models Estimation

High angular resolution diffusion magnetic resonance imaging has been widely used in research. However, its clinical use remains hindered by its demand in acquisition time. New trends propose to reconstruct the diffusion model in real-time, thus providing more flexible protocols, which can be switched off or continued on demand. These techniques raise new challenges, we present recent advances in models estimation and acquisition design with respect to these considerations.

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MS60

A Finite Element Based Method for Quantification of Self-diffusion Process in White Matter Environment

Diffusion MRI (DMRI) is a biomedical imaging modality for non-invasive assessment of anatomy of white matter tracts in human brains. It offers local sensitivity of white matter tracts to orientations of water molecules diffusive motions. To simulate the DMRI process, we develop a higher-order finite element method for solving the diffusion PDE in a multi-compartment environment in this work, which provides more flexibility for geometry and material of different white tracts compartments than existing techniques.

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MS60

Shore in Action: Estimation of Microstructural Features from Magnetic Resonance (MR) Data

Analysis of diffusion-weighted MR data characterizes the microstructural features of materials or tissues. The Simple Harmonic Oscillator based Reconstruction and Estimation (SHORE) technique, which successfully represents a wide range of MR signal profiles, will be described. We will discuss how the SHORE framework can be utilized to quantify several characteristics of the specimen including its structural anisotropy, pore size distributions, and an apparent fractal dimension.

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MS61

A General Framework for a Class of First Order Primal-Dual Algorithms for TV Minimization

We generalize the primal-dual hybrid gradient (PDHG) algorithm proposed by Zhu and Chan, draw connections to similar methods and discuss convergence of several special cases and modifications. In particular, we point out a convergence result for a modified version of PDHG that has a similarly good empirical convergence rate for total variation (TV) minimization problems. Its convergence follows from interpreting it as an inexact Uzawa method discussed. We also prove a convergence result for PDHG applied to TV denoising with some restrictions on the PDHG step size parameters. It is shown how to interpret this special case as a projected averaged gradient method applied to the dual functional. We discuss the range of parameters for which the inexact Uzawa method and the projected averaged gradient method can be shown to converge. We also present some numerical comparisons of these algorithms applied to TV denoising, TV deblurring and constrained l1 minimization problems.

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MS61

Dynamic Network Flows and Nonlinear Discrete Total Variation Evolutions

We consider combinatorial minimization algorithms for solving some variational image processing problems. In particular, we consider energies involving Discrete Total Variations. Their minimizations yield a differential inclusion problem that can be efficiently solved via parametric maximum-flow. A maximum-principle follows. Links with first-order methods, Hamilton-Jacobi equations and conservations are described.

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MS61

Non-local Regularization of Inverse Problems

This article proposes a new framework to regularize linear inverse problems using a total variation prior on an adapted non-local graph. The non-local graph is optimized to match the structures of the image to recover. This allows a better reconstruction of geometric edges and textures present in natural images. A fast algorithm computes iteratively both the solution of the regularization process and the non-local graph adapted to this solution. The graph adaptation is particularly efficient to solve inverse problems with randomized measurements such as inpainting random pixels or compressive sensing recovery. Our non-local regularization gives state of the art results for this class of inverse problems. On more challenging problems such as image super-resolution, our method gives results comparable to translation invariant wavelet-based methods.

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MS61

Image Restoration by Tikhonov Regularization Based on Generalized Krylov Subspace Methods

We describe Tikhonov regularization of large linear discrete ill-posed problems with a regularization operator of general form and present an iterative scheme based on a generalized Krylov subspace method. This method simultaneously reduces both the matrix of the linear discrete ill-posed problem and the regularization operator. The reduced problem so obtained may be solved, e.g., with the aid of the singular value decomposition. Also, multiparameter Tikhonov regularization is discussed. Numerical results illustrate the promise of problem-oriented operator in image denoising and deblurring.

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MS62

Multiscale Geometry and Probability Measures on Plane Curves

We will construct some families of probability measures on equivalence classes of plane curves, where the equivalence relations depend on the local regularity of the curve at different scales. We will also discuss sampling from these distributions.

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MS62

Spectral Gromov-Wasserstein Distances for Shape Matching and the Role of Scale

We introduce a spectral notion of distance between shapes (closed Riemannian manifolds) and study its theoretical properties. We show that our distance satisfies the properties of a metric on the collection of isometry classes of Riemannian manifolds. Our construction is similar to the Gromov-Wasserstein distance, but rather than viewing shapes as metric spaces, we define our distance via the comparison of heat kernels. This is possible since the heat kernel characterizes the shape up to isometry. By establishing two different hierarchies of lower bounds, we relate our distance to previously proposed spectral invariants used for shape comparison, such as the spectrum of the Laplace-Beltrami operator and statistics of pair-wise diffusion distances. Lower bounds in these hierarchies provide increasing discriminative power at the expense of more involved computations.

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MS62

On the Localization Behavior of Graph Laplacian Eigenfunctions Over Dendrite Structures

We report our observation and analysis of the eigenvalue distribution of the Laplacian of graphs representing neuronal dendrite patterns, and the behavior of the corresponding eigenfunctions. In particular, we discuss a "phase transition' phenomenon occurring at the eigenvalue 4. The eigenfunctions corresponding to the eigenvalues below 4 are semi-global oscillations (like Fourier modes) over the dendrite arbors whereas those corresponding to the eigenvalues above 4 are localized (like wavelets) in branching regions.

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MS62

The Multiscale Flat Norm for Shape Signatures

In this talk, I will discuss the application of the New Multiscale Flat Norm to shapes. Computations are carried out using graph cut methods with 16 neighbors. As a result the minimizers computed are actually minimizers of an anisotropic energy that approximates the usual TV energy. Some details, involving a simple but cumbersome least squares calculation, yields slightly better weights than those which are obtained through the usual Crofton's Formula method.

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MS63

Numerical Methods for Optimal Mass Transport with Applications to Image Registration

Optimal mass transport refers to an optimization problem in which mass is optimally transported. In recent work, Benmou and Brenier have shown that although the original formulation is highly nonlinear and non-convex it is possible to reformulate the problem as a convex, PDE constrained optimization problem. In this talk we consider efficient numerical techniques for the solution of the resulting problem. We show that the formulation leads to a problem a-kin to nonlinear flow in porous media. We then discuss discretization and effective multigrid solution to the problem

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MS63

Gauss-Newton Optimization in the Large Deformation Diffeomorphic Metric Mapping

The Large Deformation Diffeomorphic Metric Mapping (LDDMM) can be considered among the pioneering paradigms for diffeomorphic registration in Computational Anatomy. Although LDDMM is embedded into a rigorous mathematical framework where anatomical variability can be properly studied, the huge computational complexity inherent to the use of the non-stationary parameterization of diffeomorphisms constitutes its important practical limitation. In order to alleviate the computational requirements of LDDMM, different variations focused on diffeomorphism characterization have been proposed in the literature. Much less attention has been paid to the optimization strategy in LDDMM, where classical gradient descent is often used. As shown in alternative non-rigid registration paradigms, the use of efficient second-order optimization techniques may improve the rate of convergence during optimization thus reducing time requirements in LDDMM with an affordable increase of the needed memory per iteration. In this talk, I will present a numerical implementation of Gauss-Newton's method for second-order optimization in LDDMM for both non-stationary and stationary parameterizations. The computations of the Gateaux derivatives of the corresponding objective functions are performed in the tangent bundle of the Riemannian manifold of diffeomorphisms. Two different approaches for the computation of the Gateaux derivatives associated to the stationary parameterization of diffeomorphisms lead to two different algorithms for Gauss-Newton stationary LDDMM. The three proposed Gauss-Newton LDDMM methods have been compared to their respective versions of gradient descent LDDMM using the non-rigid registration evaluation project (NIREP) databases. I will report the advantages of Gauss-Newton with respect to gradient descent optimization for the three methods. Finally, I will also show the advantages of performing optimization in the tangent bundle with respect to optimization in the space of squared integrable functions proposed in Dartel.

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MS63

Diffeomorphic Demons for Image Registration

In this talk, we will present the evolution of the demons' algorithm over a decade. Originally proposed by Thirion as an efficient procedure for non-linear registration, the algorithm was revisited several times to be recast in a sound minimization framework, in particular through Cachier's pair and smooth (PASHA) method. Additional modifications were performed bu Stefanescu to make it fully parallelizable and to include a non-stationnary adaptive regularization that could take into account pathologies (areas that do no correspond). Recently, Vercauteren adapted the efficient optimization procedure to work on a space of diffeomorphic transformations, which leads to the diffeomorphic demons. Our experiments show that the results are similar in terms of image similarity metric, but more regular and closer to the true transformation in controlled experiments, particularly in terms of Jacobian. Following the proposition of Arsigny to parameterize (some of) the diffeomorphism using one parameter subgroups, we will finally present the symmetric version and the statistical framework on diffeomorphisms that we could build on it results.

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MS63

Unbiased Nonlinear Image Registration

We present a novel unbiased nonlinear image registration technique. The unbiased framework generates theoretically and intuitively correct deformation maps, and is compatible with large-deformation models. We apply information theory to quantify the magnitude of deformations and examine the statistical distributions of Jacobian maps in the logarithmic space.

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MS64

SD-OCT Image Segmentation in Retinal Pathology Assessed with Adaptive Optics

Our lab uses adaptive optics ophthalmoscopy to image the cone mosaic in a variety of retinal pathology. Adaptive optics enables visualization of individual cone photoreceptors, so we can quantify the degree of degeneration. SD-OCT is a more prevalent imaging technology, and here we present data on extracting information from SD-OCT images in these clinical cases. Common metrics like layer thickness can be insensitive to dramatic cone disruption, so alternative image analysis tools are needed.

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MS64

Introduction to SDOCT imaging and Registeration Using Generalized Pseudo-Polar Fourier Grids

Fast and accurate estimation of the Fourier transform in polar coordinates has long been a major challenge for many image processing applications. To address this problem, it has been proposed to calculate the Fourier transform coefficients on the pseudo-polar coordinates. To acquire better image registration accuracy, we introduce the generalized pseudo-polar motion estimation framework that encompasses the classic pseudo-polar and related techniques. Experimental results on neonatal SDOCT images attest to the effectiveness of this method.

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MS64

Imaging Processing Techniques for Adaptive Optics Fourier Domain Optical Coherence Tomography

Adaptive optics Fourier domain optical coherence tomography (AO-FDOCT) is a relatively new retinal imaging technique that provides micron-level axial and lateral resolution in the live eye by dynamic correction of ocular aberrations. AO-FDOCT systems contain at least two imagers and require several parallel stages of real-time processing and control for efficient feature extraction, visualization, and manipulation. Post-processing algorithms, for example those for segmentation, registration, and Doppler phase retrieval, are used to enhance and discriminate signal from noise or to delineate tissue margins. Both established and new techniques will be discussed.

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MS64

Applications of Adaptive Optics - Ultra-high Resolution Optical Coherence Tomography for In Vivo Retinal Imaging and Visualization

Recent developments in adaptive optics - optical coherence tomography (AO-OCT) allow for real time ultra-high isotropic resolution imaging of the in-vivo retina, offering unprecedented insight into its volumetric microscopic and cellular structures. To achieve full potential of this technique for clinical ophthalmic applications novel image acquisition and visualization methods as well as data processing techniques has to be implemented. We will describe our AO-UHR-OCT system and techniques developed in our laboratory that allow its use for in-vivo clinical imaging.

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MS65

The Role of Similarity Measures in Face Recognition

A fundamental challenge in face recognition lies in determining which steps are important in the recognition of faces. Several studies have indicated the significance of certain steps in this regard, particularly preprocessing and feature extraction. Surprisingly, however, it has not been made clear whether the similarity measures play an important role in the recognition of faces. Here, we report experimental results which suggest that for face recognition the similarity measures are influential.

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MS65

Person Detection and Tracking for Large-scale Surveillance

Person detection and tracking for large sites is challenging due to a variety of reasons. The scenes can get crowded, and in such instances crowd segmentation techniques are needed to separate individuals. The large areas to be covered may require several non-overlapping cameras, and tracking between them requires person re-identification. For city-wide surveillance, cameras mounted on mobile platforms may be required. This talk is concerned with research that has been done in the areas of multi-camera person detection and tracking, crowd segmentation, person reidentification, and person detection for moving cameras.

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MS65

Understanding Crowded Visual Scenes

Most video surveillance/monitoring approaches assume the capability to reliably track individuals, thus failing in crowded environments where such tracking is difficult. We first model dense crowd scenes using Lagrangian particle dynamics to segment crowd flows and detect flow instabilities. Then, observing that pedestrian behavior in crowds results from collective behavioral patterns evolving from large numbers of individuals interacting among themselves and the scene geometry, we generate an algorithm for tracking an individual within the crowd.

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MS65

Dimensionality Reduction and Sparsity for Object Recognition

A large body of work has been performed recently exploring ideas in dimensionality reduction, sparse representations and compressed sensing. Some work has begun to merge machine learning and dimensionality reduction and sparsity, utilizing these ideas to improve image recognition performance. This talk will focus on usage and performance of geometric diffusion and sparse representations for pattern recognition in challenging imaging conditions.

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PP0

Use of Machine Vision for Online Estimation of Coal Fines on Conveyor Belts

Excessive fines in coal fed to power stations, metallurgical furnaces and other fixed or fluidized bed reactors can cause major problems by adversely affecting the flow of gas through the solid burden. In this industrial case study, the novel application of machine vision to monitor coal on conveyor feed systems is described. By making use of a modified adaptive thresholding algorithm, the fines content in the stratified coal could be estimated reliably.

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PP0

A Modified Piecewise Constant Mumford-Shah Model Based Simultaneous Segmentation and Registration

A new variational region based model for a simultaneous image segmentation and registration is proposed. The segmentation is obtained by minimizing a modified piecewise constant Mumford-Shah model and registration is assisted by the segmentation information and region intensity values. The numerical experiments of the proposed model are tested against synthetic data and simulated normal noisy human-brain magnetic resonance (MR) images. The preliminary experimental results show the effectiveness of the proposed model.

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PP0

Image Diffusion and Sharpening Via High-Order Sobolev Gradient Flows

We utilize Sobolev gradients for image diffusion and sharpening and show that reformulating the gradient flow for the heat equation energy functional under various Sobolev metrics yields well posed flows both forward and backward. This opens the door to applications such as image sharpening via reverse diffusion. We present several theoretical results in this direction as well as favourable comparisons to the Shock Filter with striking further improvements as the Sobolev order is increased.

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PP0

Improving Small Angle X-Ray Scattering for Modern Computing

Small angle X-ray scattering (SAXS) is a technique to find the structure of biological macromolecules. Imaging macromolecules via SAXS is an inverse problem. The difficulty is that the inverse problem associated with SAXS is ill-posed and ill-conditioned. Traditionally, many physical simplifications are made to work around this. The CSU SAXS group is proposing to strengthen SAXS with a new modeling approach and new computationl methods that do not impose these simplifications.

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PP0

3D Tensor Factorization for Video Restoration

We have applied blind source separation (BSS) techniques, such as independent component analysis and dependent component analysis, to video restoration, where the commonly used point spread function (PSF) information in blind or non-blind deconvolution is not required. However, these matrix factorization based BSS methods have limitations. For instance, image local spatial structure is not used, and constraints should be imposed for unique solutions. In this paper, we will investigate 3D tensor factorization for video restoration. It is expected that the quality of the restored image will be improved with simpler implementation due to its model-free and constraint-free nature.

The restored image can be further enhanced by formulating a second multi-channel image restoration problem via Gabor filtering, where 3D tensor factorization is applied again to achieve final enhancement.

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PP0

Synthetic Boundary Conditions and Preconditioning for Image Deblurring Problems

Given a blurred image and the corresponding blurring operator, we try to restore the original unblurred image. We do not use the classical periodic or Neumann boundary conditions. The boundary conditions we use are directly derived from the blurred images and we name it synthetic boundary conditions. The resulting deblurred images are better than those under classical assumptions. We have also developed an effective regularized DCT preconditioner to solve these difficult large-scale imaging problems.

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A Piecewise Smooth Region Based Simultaneous Image Segmentation and Non-Rigid Registration

The goal of the paper is to segment and register novel images simultaneously using a modified piecewise smooth Mumford-Shah technique and region intensity values. The segmentation is obtained by minimizing a modified piecewise smooth Mumford-Shah model. A non-rigid registration is assisted by the segmentation information and region intensity values. The numerical experiments against synthetic data and simulated normal noisy human-brain magnetic resonance (MR) images show the effectiveness of the presented model.

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Inverse Illumination Techniques for Automated Visual Inspection

Many industrial inspection tasks can be accomplished by comparing a test object with a master object. We review illumination techniques that aim to minimize the effort of defect detection by encoding knowledge about the master object into the process of image formation. Based on this idea we propose an illumination technique using a projector-camera system that directly displays differences between the two objects by projecting an inverse illumination mask of the master object.

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PP0

Shapes from Geometric Measures

In this work we show that shapes can be reconstructed from simple non asymptotic densities measured only along edge shapes. The particular density we study corresponds to the area of a disk centered on the boundary that is also inside the shape. It is easy to show uniqueness when these densities are known for all radii in a neighborhood of r = 0, but much less straightforward when we assume we know it for (almost) only one r ¿ 0. We present variations of uniqueness results for polygons and smooth curves under certain regularity conditions.

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A Fully Automated Approach to Segmentation and Registration of Medical Image Data for Pulmonary Diagnosis

Molecular imaging is an important tool in drug development but generates large amounts of data, demanding for fully automated analysis tools. We propose a novel fully-automated approach to the analysis of ventilation/perfusion SPECT data acquired in the context of pulmonary diseases. Particularly, we propose a modification of the Chan-Vese approach for a stable segmentation which then serves as a starting point in a spatial alignment process. Our results demonstrate the potential of the new approach.

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PP0

Texture - Noise Separation

It is a very ill-posed problem to recover a clean image from a noisy blurred image simply because deblurring and denoising processes are contradicting in that deblurring is sharpening process and denoising is smoothing process. In this model, we collect some a priori information about pure noise and pure texture by using different Sobolev spaces of negative differentiability, which will provide noticeably different behaviors, and incorporate them to distinguish noise from texture.

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PP0

A Variational Joint Framework for Deblurring, Denoising and Segmenting.

In this talk, we propose a variational joint framework for both restoration (deblurring and denoising) and segmentation of blurred and noisy images. We aim to solve, by an alternating framework, an extended modified Mumford-Shah functional. The segmentation stage based on the Active Contours Without Edges and solved using Sobolev Gradients and Additive Operator Splitting schemes, allows to partition the image domain into several subdomains. These subdomains are then used to parallelize the computations of the discretized PDE related to the restoration stage. Details of the numerical analysis as well as numerical experiments are provided.

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Direct Sparse Deblurring

We propose a deblurring algorithm that explicitly takes into account the sparse characteristics of natural images and does not entail solving a numerically ill-conditioned backward-diffusion. The key observation is that the sparse coefficients that encode a given image with respect to an over-complete basis are the same that encode a blurred version of the image with respect to a modified basis. Following an "analysis-by-synthesis' approach, an explicit generative model is used to compute a sparse representation of the blurred image, and the coefficients of which are used to combine elements of the original basis to yield a restored image. We compare our algorithm against the state of the art in deblurring algorithms.

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PP0

Comparing Regularized Cut to Normalized Cut

In comparing two segmentation algorithms approximating the Normalized Cut criterion, both returned reasonable segmentations for images with simple backgrounds. The two algorithms we considered are Hochbaums Normalized Cut approximation, which we have called Regularized Cut, and Shi and Maliks Normalized Cut algorithm. Regularized Cut can have more flexibility, since it requires some user interaction, and in practice, Regularized Cut runs faster than Normalized Cut.

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A Mechanical Bidomain Model of the Heart

When representing the electrical properties of the heart with the bidomain model, one distinguishes between the intracellular and extracellular spaces. We develop a bidomain model for the mechanical properties of the heart, accounting for the different mechanical properties inside and outside the cells. This is particularly relevant in cases where the intracellular and extracellular (e.g. Lorentz) forces are in opposition. Uses include analysis of displacement of current carrying tissue in MRI.

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Measuring Conductivity of Biological Tissue Using Magnetic Induction Tomography

Magnetic Induction Tomography is finding use as an experimental tool for mapping the conductivity of biological tissues. Our numerical approach is to obtain a Fourier expansion of the relevant stream functions relating the magnetic fields, eddy current density, and conductivity (resistivity). Thus, we are able to add noise to the system and determine the fidelity of the measured signal to the true conductivity map. We focus on representations of cardiac tissue.

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PP0

Efficient Implicit Smooothing of Contour Lines for

Image Reconstruction

The standard approach to image reconstruction typically produces noisy object boundaries. By contrast to explicit edge-field models, we propose to incorporate the smoothness of the contour lines in an implicit way by introducing an additional penalty term defined in the wavelet domain. We also derive an efficient stress-majorization algorithm to solve the associated optimization problem. Our technique produces visually pleasing reconstructions which are quantitatively better than those obtained without wavelet domain constraints.

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A Basis Pursuit Approach for Multi-Scale Am-Fm Reconstructions

Recently a new multi-scale amplitude-modulation frequency-modulation (AM-FM) demodulation method for image processing was introduced. The model function considers the sum of the product of the instantaneous amplitude (IA) times the cosine of L harmonics of the instantaneous phase (IP) as the independent variables. We propose to consider the L harmonics of the IP as the basis of an overcomplete dictionary within the Basis Pursuit framework.

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PP0

Denoising Using Decomposition

In an earlier work, the author proposed a new decorrelation term to be added to the decomposition model of Osher, Sole and Vese, with favourable results obtained. In the present work, the new term is used for the purpose of denoising textured images. Time permitting, other new extensions to decomposition models will also be discussed for texture denoising. Finally, some applications to real-world imaging will be shown.

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PP0

Data Fusion of Combined High Spatial Resolution X-Ray CT and High Temporal Resolution Electrical Impedance Tomography Imaging

CBCT is a high spatial resolution imaging system. It suffers from low temporal resolution and consequently from motion artefacts. EIT can generate images with high temporal resolution and poor spatial resolution. An EIT-CBCT modality has been investigated in this study. Motion information was extracted from EIT images. The motion data then has been implemented into CBCT reconstruction for compensating the motion. CT images with reduced motion artefacts could be observed by this dual modality.

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PP0

Spatio-Spectral Anomalous Change Detection in Hyperspectral Imagery

Given two images of the same scene, taken at different times and under different conditions, the aim of anomalous change detection is to distinguish the pervasive differences (due for instance to illumination or calibration effects) from the actual changes that have occurred in the scene. This poster will present an approach for combining local spatial context with the spectral properties of a pixel for the purpose of identifying anomalous changes in pairs of images.

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PP0

Graph Based Denoising Using Local Non-Parametric Image Graph Modifications: Variations and Applications

In this work, we describe experiments that explore the recent image denoising and segmentation methods of Asaki et al. in which minor modifications to the now classical local numerical methods produce good results in cases of low to medium noise. These modifications are based on constructions of subgraphs of the standard nearest-neighbor graph commonly used in numerical computations of gradients. We investigate the precise ways in which the new methods succeed and fail, explaining what we mean by success and failure. The central feature of the innovation is the non-parametric nature of the graph modifications.

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PP0

Convolution Equations and Digitization

The main goal of this paper is approximation of convolution equation on a straight line by a system of linear algebraic equations in a following way. First given convolution kernel one writes out discrete convolution kernel by direct digitization of continuous kernel, and then the discrete kernel will be cut off and periodically extended on a whole discrete line (so called cyclic convolution). It permits to solve the finite system of linear algebraic equations by using fast Fourier transform.

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PP0

Small Sample Histograms Variabilty

Small sample histograms have extreme variabilty as does small-sample-just-about-everything. However for uniform bin width histograms, extreme shape variability challenges their usefulness. Shape variability can be understood and controlled by first obtaining all possible shapes via partitioning the space of bin locations and width into shape level sets. The level sets allow method of moments and maximum likelihood procedures to be used to obtain representative small sample histograms. This builds on J. R. Thompson's 1978/1990 histogram maximum likelihood result.

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PP0

Variational Model for Depth from Motion Blur

A variational method for combined deblurring and depth estimation from a single still image degraded by spatially variant motion blur is presented. The blur is assumed to be caused by translatory camera motion. The variational method is based on minimising an energy functional with respect to the sharpened image and depth field simultaneously. Experiments on synthetic data confirm the viability of the approach.

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PP0

Block Estimation Methods in Exemplar-Based Image Restoration

Exemplar-based methods have recently been shown to give competitive performance in a variety of image restoration tasks, including denoising, inpainting, and super-resolution. One of the most important aspects of an exemplar-based method is the actual block estimation, for which a rather diverse range of algorithms has been applied. We present the results of an extensive set of experiments comparing a number of the leading algorithms within a common context.

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PP0

Hermite Polynomials in a Searching for Global Maximum Position

Analysis of multiextreme functions for maximum is based on the Hermite polynomials series of function symmetrized around objective (anknown) point. This method searches for a global maximum position and in recursive iterations allows to find all significant maxima.

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PP0

Logical "or" in Trajectory Recognition

Likelyhood function based on logical "OR" transforms a trajectory recognition (by measured 3D points) in the task of analysis of multi-extreme function of trajectory parameters where each real trajectory corresponds to big maximum at a background of small ones of noise and combinatorial nature.

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