Titles and Abstracts (in alphabetical order)

A new perspective on distance functions via nonlinear spectral theory

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We characterize consider the functional $J(u)=\|\nabla u\|_\infty$ defined on all functions $u\in W^{1,\infty}_0(\Omega)$ and show that one can characterize the distance function to the domain boundary as nonlinear eigenfunction of the subdifferential operator of J. This enables us to show that the distance function can be computed by rescaling the solution of the gradient flow of functional J. Furthermore, we are able to compute explicit solutions of the gradient flow for regular domains whose level sets move parallelly to the domain boundary and thus resemble the fast marching algorithm. In one space dimension we can characterize all eigenfunctions as well as all extreme points of the unit ball of the energy. Despite being formulated in the continuum, all our results carry over to finite weighted graphs which enables us to compute also nonlocal distance functions on unstructured graphs.

Optimal low-rank tensor recovery

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The problem of tensor recovery from a few linear measurements arise in a variety of applications in machine learning and signal processing. We present an efficient non-convex optimization approach for tensor recovery. Only O(nr^2log^2n) Gaussian measurements are sufficient for our algorithm to exactly recover tensors of size n-by-n-by-n and Tucker rank (r,r,r). Our approach has an optimal sampling complexity in n, and existing approaches usually need measurements in the order of n^{1.5} or n^2 in n.

Bayesian inference in high dimensional inverse problems

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Abstract: Inverse problems play a key role in modern image/signal processing methods. However, since they are generally ill-conditioned or ill-posed due to lack of observations, their solutions may have significant intrinsic uncertainty. Analysing and quantifying this uncertainty is very challenging, particularly in high-dimensional problems and problems with non-smooth objective functions (e.g. sparsity-promoting priors). In this talk, under the Bayesian inference framework, I will present a series of strategies to visualise this uncertainty, e.g. highest posterior density credible regions, and local credible intervals (cf. error bars) for individual pixels and superpixels. I will also talk about Bayesian evidence calculation, which is capable of managing e.g. model selection in inverse problems. Our methods support non-smooth priors for inverse problems and can be scaled to high-dimensional settings.

Fourier Masked Phase Retrieval: Mask Design, Blind Recovery, and Sparsity Modeling

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Phase retrieval plays an important role in vast industrial and scientific applications, which is essentially quadratic inverse problem mathematically. In this talk, we will mainly discuss how to design mask to guarantee unique recovery, build fast convergent splitting algorithm for blind ptychography imaging, and further improve the quality of reconstructed images driven by the sparse prior. This is a joint work with Stefano Marchesini, Pablo Enfedaquez in Lawrence Berkeley Lab, Yifei Lou in UT Dallas, Michael K. Ng in HKU, and Tieyong Zeng in CUHK.

Joint Image Reconstruction and Motion Estimation in Spatiotemporal Medical Imaging

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Spatiotemporal medical imaging is critical in clinic applications, such as tomographic imaging of the heart or lungs. As an example in PET-CT cardiac imaging, when data is acquired over a relatively long period of time (often in the range of minutes), the unknown motion of the organs leads to severe degradation in image quality. On the other hand, in order to reduce the radiation or conduct fast scanning, the low-dose or sparse sampling is often required. Hence, the image reconstruction with high spatiotemporal resolution becomes particularly important and very challenging in spatiotemporal sparse medical imaging. We proposed a new variational model for joint image reconstruction and motion estimation applicable to spatiotemporal sparse medical imaging, e.g. cardiovascular and pulmonary, which is investigated along a general framework that we present with shape theory. This model consists of two parts, one that conducts modified image reconstruction in a static setting and the other that estimates the motion by sequentially indirect image registration. The latter is a new concept termed by us, which is a key problem in spatiotemporal image reconstruction, for which we generalize the large deformation diffeomorphic metric mapping framework into the sequentially indirect registration setting. We also derived the equivalent first-order hyperbolic equation constrained optimal control formulation. The proposed model is compared theoretically against alternative approaches (optical flow based model and diffeomorphic motion models), and we demonstrate that the proposed model has desirable properties in terms of the optimal solution. We further show that the optimal solution of the time-discretized version is consistent with that of the time-continuous one. The proposed model is general, which can be used to several spatiotemporal sparse medical imaging, such as cone beam CT, PET-CT, SPECT-CT, and MRI, etc.

Boundary correspondence of planar domains based on optimal mass transport

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Domain parameterization is the process of setting up a map from a parametric domain to a computational domain. It is a fundamental problem in Computer Aided Geometric Design and Isogemetric Analysis. A prerequisite for domain parameterization is that a correspondence between the boundary of the parametric domain and that of the computational domain should be established. Currently, such correspondence is generally provided manually by users, which is very cumbersome and subjects to trial and error. In this talk, we propose an automatic approach to compute a correspondence between the boundaries of a unit square and a planar domain based on the theory of optimal mass transport (OMT). Given the boundary representation of a planar domain, the problem becomes to select four corner points on the boundary such that the difference between the curvature measure of the boundary of the planar domain and that of the unit square is minimized. We formulate the problem into an optimization problem, the objective function of which includes the transport cost between two curvature measures and the length differences of the opposite edges of the planar domain. Minimizing the objective function is equivalent to maximizing the similarity between the unit square and the computational domain. We develop an efficient algorithm to solve the optimization problem by combining Sinkhorn's algorithm with the L-BFGS method. Numerous examples show that our approach can produce satisfactory boundary correspondence results which are comparable to manually selected ones.

Reconstruction of High Dimensional Data via Weighted Norm Minimization Methods

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In this talk, we consider the reconstruction conditions for the exact reconstruction of data with structures in the noiseless setting and approximation in the noisy case from incomplete information. The structure includes sparsity, the context when some prior information on the support of the signals is available. Moreover, we consider the optimality or sharpness of these sufficient conditions.

Integration Strategy for Data Analysis

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Abstract: As the technologies advance, large data are rapidly generated, and the problem of information integration and modeling is becoming possible so as to solve complicated problems. The machine learning methods that have emerged in the past decades integrated different types of information for inferences and decision making. In this talk I'll review some of the techniques and results.

CHEBYSHEV-TYPE CUBATURE FORMULAS ON REGULAR DOMAINS

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In this talk, I will present the strict Chebyshev-type cubature formula (CF) (i.e., equal weighted CF) for doubling weights on the unit sphere equipped with the usual surface Lebesgue measure and geodesic distance. Our main interest is on the minimal number of nodes required in a strict Chebyshev-type CF. Precisely, given a normalized doubling weight on unit sphere, we will establish the sharp asymptotical estimates of the minimal number of distinct nodes which admits a strict Chebyshev-type CF. If, in addition, the weight function is essentially bounded, the nodes involved can be configured well- separately in some sense. The proofs of these results rely on constructing new convex partitions of the unit sphere that are regular with respect to the weight. The weighted results on the unit sphere also allow us to establish similar results on strict Chebyshev- type CFs on the unit ball and the standard simplex. This is a joint work with Professor Feng DAI.

A new model for phase retrieval

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In this talk, we introduce a new perturbed amplitude-based model for phase retrieval problem and propose an algorithm which named as Perturbed Amplitude Flow (PAF) for solving it. We prove that PAF can recover cx (|c| = 1) under O(n) Gaussian random measurements (optimal order of measurements). Unlike several existing O(n) algorithms that can be theoretically proven to recover only real signals, our algorithm works for both real and complex signals. Starting with a designed initial point, our PAF algorithm or the incremental version of PAF iteratively converges to the true solution at a linear rate.

Gibbs Phenomenon of Wavelets, Framelets and Quasi-projection Approximation

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A large class of data in applications often consists of piecewise smooth functions/signals. It is well known that the standard Fourier series approximation suffers the unpleasant ringing effect near discontinuity. This is termed as the Gibbs phenomenon and refers to the phenomenon that the nth Fourier partial sums overshoot a target function at jump discontinuities in such a way that such overshoots do not die out as n goes to infinity. A lot of effort has been given to overcome the Gibbs phenomenon for Fourier series and many other approximation schemes. Wavelets and framelets are known to be the mainstream multiscale sparse representation systems with many applications in data science. In this talk we study the Gibbs phenomenon of framelet/wavelet expansions and their associated quasi-projection approximation schemes at an arbitrary point. We show that the Gibbs phenomenon appears at all points for every tight or dual framelet having at least two vanishing moments and for quasi-projection approximation operators having at least three accuracy/approximation orders. This well explains the ringing effect of most wavelet approximation in applications. We shall also address how to avoid the Gibbs phenomenon for wavelets/framelets and quasi-projection approximation. This talk is based on [B. Han, Gibbs phenomenon of framelet expansions and quasi-projection approximation, Journal of Fourier Analysis and Applications, published online].

Phase retrieval from the norms of affine transformations

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In this talk, we consider the generalized affine phase retrieval which aims to recover a signal from the norms of several affine transformations. We first present some necessary and sufficient conditions for it to have generalized affine phase retrieval property. Then we focus on minimal measurement number for generalized affine phase retrieval and establish several tight results. Those results show we can reduce the measurement number dramatically by raising the rank of measurement matrices. It highlights a notable difference between generalized affine phase retrieval and other phase retrieval.

Lipschitz Learning for Signal Recovery

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Abstract: We consider the recovery of signals from their observations, which are samples of a transform of the signals rather than the signals themselves, by using machine learning (ML). We will develop a theoretical framework to characterize the signals that can be robustly recovered from their observations by an ML algorithm, and establish a Lipschitz condition on signals and observations that is both necessary and sufficient for the existence of a robust recovery. We will compare the Lipschitz condition with the well-known restricted isometry property of the sparse recovery of compressive sensing, and show the former is more general and less restrictive. For linear observations, our work also suggests an ML method in which the output space is reduced to the lowest possible dimension.

Compressive Sensing for cut improvement and local graph clustering

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We show how one can phrase the cut improvement for graphs as a sparse recovery problem, whence one can use algorithms originally developed for use in compressive sensing (such as {\tt Subspace Pursuit} or {\tt CoSaMP}) to solve it. We show that this approach to cut improvement is fast, both in theory and practice and moreover enjoys statistical guarantees of success when applied to graphs drawn from probabilistic models such as the Stochastic Block Model. Using this new cut improvement approach, which we call {\tt Cluster Pursuit}, as an algorithmic primitive we then propose new methods for local clustering and semi-supervised clustering, which enjoy similar guarantees of success and speed. Finally, we verify the promise of our approach with extensive numerical benchmarking.

Restricted Linearized Augmented Lagrangian Method for Euler's Elastica Model

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Euler's elastica model has been extensively studied and widely applied to image processing tasks. Due to the high nonlinearity and nonconvexity of the involved curvature term, conventional algorithms suffer from slow convergence and high computational cost. In recent years, various fast algorithms have been proposed in the literature, among which, the augmented Lagrangian based ones are very popular in the community. However, parameter tuning might be very challenging for these methods. In this talk, a simple cutting-off strategy is introduced into the augmented Lagrangian formulation for minimizing the Euler's elastica energy, which leads to easier parameter tuning and faster convergence. The cutting-off strategy is based on an observation of inconsistency inside the augmented Lagrangian formulation. When the weighting parameter of the curvature term goes to zero, the energy functional boils down to the ROF model. So, a natural requirement is that its augmented Lagrangian based algorithms should also approach the augmented Lagrangian based algorithms formulated directly for solving the ROF model from the very beginning. Unfortunately, this is not the case for certain existing augmented Lagrangian formulations for minimizing the Euler's elastica model. The proposed cutting-off strategy helps to decouple the tricky dependence between the auxiliary splitting variables, so as to remove the observed inconsistency. Numerical experiments suggest that the proposed algorithm enjoys easier parameter-tuning, much faster convergence and even higher quality of image restorations

One-Bit Compressed Sensing with Projected Subgradient Methods

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In this talk, I shall investigate one-bit compressed sensing by projected subgradient method and some convergence results were established. Furthermore, the corresponding stochastic projected subgradient method was also provided with convergence guarantee.

Hybrid regularized cone-beam reconstruction for axially symmetric object tomography

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We investigate the tomographic reconstruction for axially symmetric object from a single radiograph formed by cone-beam X-rays. Almost all of the reconstruction methods at present in high-energy ash radiography are based on the assumption that the cone beam can be treated as a lot of fan beams located at parallel planes perpendicular to the symmetric axis, so that the density of the whole object can be recovered layer by layer. Considering the relationship among different layers, we study the fully cone-beam reconstruction to solve the resulting ambiguity effect between material interfaces. Unlike those conventional discretized schemes of total variation, a new scheme which yields sharp edges and has better isotropy is introduced into our reconstruction model. Furthermore, since the object density consists of continually changing parts and jumps, a high-order regularization term is considered. Finally, the hybrid regularization model is solved by alternating proximal gradient method. Density reconstruction results are presented for simulated radiographs, which show that the proposed method has better performance on the preservation of edge locations.

Dictionary learning with block total least squares update

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Algorithms for learning a dictionary under which a data in a given set has sparse expansions typically alternate between sparse coding and dictionary update stages. Methods for dictionary update aim to minimize expansion error by updating dictionary vectors and expansion coefficients given patterns of non-zero coefficients obtained in the sparse coding stage. We propose a block total least squares (BLOTLESS) algorithm for dictionary update. BLOTLESS updates a block of dictionary elements and the corresponding sparse coefficients simultaneously. In the error free case, three necessary conditions for exact recovery are identified. Lower bounds on the number of training data are established so that the necessary conditions hold with high probability. Numerical simulations show that the bounds well approximate the number of training data needed for exact dictionary recovery. Numerical experiments further demonstrate several benefits of dictionary learning with BLOTLESS update compared with state-of-the-art algorithms especially when the amount of training data is small.

Semidefinite Relaxations for MIMO Detection: Tightness, Tighterness, and Beyond

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Multiple-input multi-output (MIMO) detection is a fundamental problem in modern digital communications. Semidefinite relaxation (SDR) based algorithms are a popular class of approaches to solving the problem because the algorithms have a polynomial-time worst-case complexity and generally can achieve a good detection error rate performance. In this talk, we shall first develop two new SDRs for MIMO detection and show their tightness under an easily checkable condition. This result answers an open question posed by So in 2010. Then, we shall briefly talk about the tighterness relationship between some existing SDRs for the MIMO detection problem in the literature. Finally, if time is allowed, we shall also talk about a branch-and-bound algorithm (based on the newly derived SDR) for globally solving the MIMO detection problem (and a more general class of nonconvex complex quadratic problems).

Neural network based on differential equation

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Deep network has become an efficient model in many machine learning tasks. Deep learning combines the underlying features to form more abstract high-level features to discover the distributed feature representation of data, but lacks general guidance on network structure design. In previous work, the depth network corresponds to the numerical format for solving ordinary differential equations. For example, the forward propagation of ResNet can be approximated to the Euler forward difference format. Based on this, a new neural network can be proposed according to the numerical format of the differential equation, while making the forward propagation of the neural network interpretable. The application of neural networks in solving linear equations is further explored.

Training low-bit neural networks

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We discuss the problem of training neural networks with low-bit weights. This is motivated by applications that are trained on memory constrained platforms. Our approach is based on stochastic Markov gradient descent (SMGD) and utilizes only low-bit weight vectors at every step of the training process. We prove theoretical error bounds for SMGD and also show that the approach performs well numerically. This is joint work with Jon Ashbrock.

The inverse problem for wave equations based on optimal transportation theory and deep learning

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The wave-based inverse problems aiming at geological imaging is often accompanied by nonlinearity, significant ill-posedness, and high computational cost. It usually uses the iterative method based on gradient descent to solve the corresponding optimization problem and is easy to fall into local minimums. Therefore, improving the convexity of the objective function of the optimization problem, avoiding the local minimization, and improving the efficiency of the large-scale inversion are the key issues in the study of the inverse problem of the wave equation.

First, with the aid of optimal transport theory, we propose a new data transformation method, improve the stability and convexity of the inverse problem, and expand the convergence radius of the inverse problem. At the same time, we also study the noise in the data and the inaccuracy of the measurement to the disturbance of the optimal transport metric, and systematically propose a fast and stable solution. Second, convolutional neural networks are also used to improve the performance and accuracy of the algorithm further. The network architecture we use is modified from the deep class aware model. This model does not use a fully connected layer, so fewer training samples are needed in the training step, and less memory and lower arithmetic complexity are required in the inference step. We use only a small amount of representative data during the training of the network, and the trained model can be used to extract the main features from the high-dimensional intermediate results automatically. This approach provides a novel platform for data-driven inversion/imaging methods.

Gradient Descent Method on the sphere with Sparsity Constrains

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Motivated by the recent work on one-bit compressed sensing, and sparse principal component analysis, we investigate the problem of minimizing a general continuously differentiable function defined on the unit sphere subject to sparsity constraints. Our goal is to study necessary optimality conditions for problem and to develop algorithms that find points satisfying these conditions for general choices of cost functions.

Accelerated Dual Optimization to Images Segmentation

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With a dual optimization approach, we developed several preconditioned and over-relaxed alternating direction method of multipliers (ADMM) for computer-based image segmentation. By the proposed novel and efficient preconditioners, we get certain accelerations with the over-relaxation variants of ADMM. Preconditioned and over-relaxed Douglas-Rachford splitting methods are also considered. Various novel preconditioners and block preconditioner are developed for the corresponding algorithms with convergence guarantee. Our framework can handle both two phases or multi-phases segmentation problems with appropriate block preconditioners. This is a joint work with Prof. Xuecheng Tai and Prof. Jing Yuan.

Model Meets Deep Learning: Model-driven Deep Learning Approach

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Traditional deep learning methods rely on black-box deep neural networks by training on a large scale training dataset. We propose “model-driven deep learning” approach, which combines the merits of traditional models and deep neural networks. On the one hand, we can build novel explainable network architectures, i.e., model-driven deep networks, based on mathematical models built upon domain knowledge. One the other hand, these model-driven deep networks can benefit to learning more powerful mathematical models and their hyper-parameters. In this talk, I will show some of our research progresses on model-driven deep learning approach, including statistical MRF-driven deep network, ADMM-Net for compression-sensing MRI, neural diffusion distance, variational hyper-Adam for network training, etc. We will demonstrate their effectiveness in image processing, medical image analysis and deep neural network optimization.

Convex shape prior for image segmentation problem

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For many applications, we need to use techniques to represent convex shapes and objects. In this work, we use level set method to represent shapes and find a necessary and sufficient condition on the level set function to guarantee the convexity of the represented shapes. We take image segmentation as an example to apply our techniques. Efficient numerical algorithm is developed to solve the variational model. In order to improve the performance of segmentation for complex images, we also incorporate landmarks into the model. One option is to specify points that the object boundary must contain. Another option is to specify points that the foreground (the object) and the background must contain. Numerical experiments on different images validate the efficiency of the proposed models and algorithms. We want to emphasis that the proposed technique could be used for general shape optimization with convex shapes. For other applications, the numerical algorithms need to be extended and modified. This talk is based on joint works with S. Luo, S. Yan, J. Liu, Yang Wang and H. Huang.

Some new results on sparsity-constrained information processing

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Sparse recovery aims at recovering high-dimensional sparse signals from a small number of linear samples, which has recently received much attention in electrical engineering, computer science, applied mathematics, etc. This talk will discuss some recent progress on sparse recovery algorithms, including (1) a lower bound on the number of iterations for exact sparse recovery via orthogonal matching pursuit and (2) approximate sparse pattern recovery. This talk will also introduce a novel preconditioning method for sparsity-constrained problem and its application in ghost imaging.

Scattering Transform and Stylometry Analysis in Arts

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With the rapid advancement in data analysis and machine learning, stylometry analysis in arts has gained considerable interest in recent years. A fundamental topic of research in stylometry is the detection of art forgery. But unlike many other machine learning applications, we typically face the challenge of not having enough data. In this talk I'll discuss how scattering transform can be applied to stylometry analysis, and demonstrate its effectiveness on Van Gogh paintings as well as another data set.

Fast Cadzow's algorithm and a New Variant

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Cadzow's algorithm has a wide range of applications, such as in time series denoising and forecasting, Dirac pulses reconstruction, and seismic data denoising and reconstruction. This algorithm was developed by J. A. Cadzow in 1988 for signal enhancement. A key ingredient in the algorithm is the low rank property of a structured matrix. We will first show how a subspace projection technique can be utilized to speed up the algorithm significantly. However, when applying Cadzow's algorithm (including the fast version) to signal denoising, it is often the case that the best MSE is achieved at the first iteration and then the MSE increases. To settle this issue, a new variant of the Cadzow's algorithm is developed which can achieve the decrement of the MSE as the algorithm iterates.

Signal-Dependent Performance Analysis of Orthogonal Matching Pursuit for Exact Sparse Recovery

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Exact recovery of K-sparse signals $\x\in \mathbb{R}^{n}$ from linear measurements $\y=\A\x$, where $\A\in \mathbb{R}^{m\times n}$ is a sensing matrix, arises from many applications. The orthogonal matching pursuit (OMP) algorithm is a widely used algorithm for reconstructing the $\x$ based on $\y$ and $\A$ due to its excellent recovery performance and high efficiency. A fundamental question in the performance analysis of OMP is the characterizations of the probability that it can exactly recover $\x$ for random matrix $\A$ and the minimal m to guarantee a satisfactory recovery performance. Although in many practical applications, in addition to the sparsity, $\x$ usually also has some additional properties (for example, the nonzero entries of $\x$ independently and identically follow the Gaussian distribution, and $\x$ has exponential decaying property), as far as we know, none of existing analysis uses these properties to answer the above question. In this talk, we first show that the prior distribution information of $\x$ can be used to provide an upper bound on $\|\x\|_1^2/\|\x\|_2^2$. Then, we explore this upper bound to develop a better lower bound on the probability of exact recovery with OMP in K iterations. Furthermore, we develop a lower bound on m to guarantee that the exact recovery probability of K iterations of OMP is not lower than a given probability. We further show that, if K is sufficiently small compared with n, when K approaches infinity, $m \approx 2K\ln(n)$, $m \approx K$ and $m \approx 1.6K\ln(n)$ are enough to ensure that OMP has a satisfactory recovery performance for recovering any K-sparse $\x$, K-sparse $\x$ with exponential decaying property and K-sparse $\x$ whose nonzero entries independently and identically follow the Gaussian distribution, respectively. This significantly improves Tropp {\em{et. al.}}'s result which requires $m\approx4K\ln(n/\delta)$.

On Nonconvex Regularized Models for Image Restoration Problems

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Variational methods with regularization techniques have become an important kind of methods image restoration. The convex total variation (TV) regularization, although achieved great successes, suffers from a contrast reduction effect. Recently nonconvex regularization techniques become popular. In this talk, I will mainly present two parts. The first one is a motivation of using nonconvex regularizations and a general truncated regularization framework. The second is a lower bound theory for nonconvex regularized models, which shows the good edge recovery property.

Reconstruction from convolution random sampling in local shift invariant spaces

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In this talk, we consider the problem of reconstructing functions in local multiply generated shift invariant spaces from convolution random samples. The sampling set is randomly chosen with one kind of probability distribution over a bounded cube and the sampled values are the convolution of the original function on sampling set. We obtain an explicit reconstruction formula. This reconstruction formula succeeds with overwhelming probability when the sampling size is sufficiently large.

Subset selection via interlacing families

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Subset selection refers to the challenge of extracting a sub-matrix from a matrix that has some distinguished property. It is one of the central problems in numerical linear algebra community and computer science community. In this talk, we propose a deterministic polynomial-time greedy selection algorithm for the subset selection problems. The main technology for proving our result is the interlacing families of polynomials which is developed by Marcus, Spielman and Srivastava. This is a joint work with Prof. Zhiqiang Xu at Chinese Academy of Sciences.

The recovery of sparse signals from phaseless measurements

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Compressed sensing shows that one can employ L1 minimization to recover k-sparse signals from O(klog(n/k)) random linear measurements. In many applied areas, it is hard to obtain the phase information. Naturally, one is interested in the performance of L1 minimization for recovering sparse signals from phaseless measurements. The aim of this talk is to show that one can employ L1 minimization to recover k-sparse real or complex signals from O(klog(n/k)) random phaseless measurements. This is joint work with V. Voroninski and Yu Xia.

The minimizers of the p-frame potential

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The p-frame potential is a family of potential functions which defined on the set of all collections of N unit-norm vectors in dimension d. Finding the minimizers of the p-frame potential is an interesting problem with long history. Few is known when $0<p<2$, even for the special case $N=d+1$. In this talk, we show how to find the minimizers for any $0<p<2$ when $N=d+1$. Our main idea is to connect this problem to another optimization problem. Our result confirms a conjecture posed by Chen, Gonzales, Goodman, Kang and Okoudjou.

On the Fourier transform and Smoothness Measurement of Graph Signals

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The definition of graph Fourier transform is a fundamental issue in graph signal processing. Conventional graph Fourier transform is defined through the eigenvectors of the graph Laplacian matrix, which minimize the l2 norm signal variation. In this paper, we discuss a generalized definition of graph Fourier transform based on nonnegative and homogeneous measurements for the smoothness of signal. We will construct the Fourier transform under l1 norm and discuss what measurements can produce the same Fourier transforms.

Deformable Image Registration Algorithms Based on Some Novel Variational Frameworks

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Deformable image registration is a widely used technique in the field of computer vision and medical image processing. Basically, the task of deformable image registration is to find the displacement field between the moving image and the fixed image. Many variational models are proposed for deformable image registration, under the assumption that the displacement field is continuous and smooth. However, displacement fields may be discontinuous, especially for medical images with intensity inhomogeneity, pathological tissues, or heavy noises. In the mathematical theory of elastoplasticity, when the displacement fields are possibly discontinuous, a suitable framework for describing the displacement fields is the space of functions of bounded deformation (BD). Inspired by this, we propose some novel deformable registration models, called the BD and BGD (bounded generalized deformation) models, which allow discontinuities of displacement fields in images. The BD and BGD models are formulated in variational frameworks by supposing the displacement fields to be functions of BD or BGD. The existence of solutions of these models is proven. Numerical experiments on 2D images show that the BD and BGD models outperform the classical demons model, the log-domain diffeomorphic demons model, and the state-of-the-art vectorial total variation model. Numerical experiments on two public 3D databases show that the target registration error of the BD model is competitive compared with more than ten other models. This is joint work with Ziwei Nie, Chen Li and Hairong Liu.

Recent progress on equiangular line

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Equiangular lines are the sets of lines such that for each pair of lines forms the same angle. To determine the maximum size of equiangular lines is one of the classical problems in discrete geometry area. In this talk, I will present our new progress on these topics, such as the solution of Lemmens-Seidel Conjecture which is the estimate of the upper bounds for equiangular lines with angle 1/5. This is the joint work with Cao, Koolen and Lin.

High-Performance Dual Optimization Theory and Algorithms to Medical Image Analysis

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Many problems of medical image analysis are challenging due to the associated complex optimization formulations and constraints, extremely big image data being processed, poor imaging quality, missing data etc. On the other hand, it is highly desired to process and analyze the acquired imaging data, for example segmentation and registration etc., in an automated and efficient numerical way, which motivated vast active studies during the last 30 years, in a rather broad sense. This talk targets to present an overview of modern dual optimization theory, which delivers an advanced unified framework of mathematical analysis and high-performance numerical schemes along with a wide spectrum of applications. We focus on the optimization problems arising from the most interesting topics: segmentation and registration, and present both analysis and high-performance numerical solutions in a unified manner in terms of dual optimization.

Semi-implicit Back propagation

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Neural network has attracted great attention for a long time and many researchers are devoted to improve the effectiveness of neural network training algorithms. Though stochastic gradient descent (SGD) and other explicit gradient-based methods are widely adopted, there are still many challenges such as gradient vanishing and small step sizes, which leads to slow convergence and instability of SGD algorithms. Motivated by error back propagation (BP) and proximal methods, we propose a semi-implicit back propagation method for neural network training. Similar to BP, the difference on the neurons are propagated in a backward fashion and the parameters are updated with proximal mapping. The implicit update for both hidden neurons and parameters allows to choose large step size in the training algorithm. Finally, we also show that any fixed point of convergent sequences produced by this algorithm is a stationary point of the objective loss function. The experiments on both MNIST and CIFAR-10 demonstrate that the proposed semi-implicit BP algorithm leads to better performance in terms of both loss decreasing and training/validation accuracy, compared to SGD and a similar algorithm ProxBP.

Iterative deep scatter correction (IDSC) using a DNN based high-fidelity measurement model for CT imaging

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X-ray scatter is a major cause of image quality degradation in dimensional CT. The corresponding artifacts which appear as cupping or dark streaks in the CT reconstruction may impair a metrological assessment. Therefore, an appropriate scatter correction is crucial. Recently, a deep scatter estimation (DSE) method was developed to correct for scatter in real-time. The method uses a deep convolutional neural network which is trained to reproduce the output of Monte Carlo simulations using only the acquired projection data of a calibration phantom as input. Once trained, DSE can be applied in real-time. The method requires the calibration phantom's shape, positioning, even orientation should be same as the test object. We present a novel iterative deep scatter correction (IDSC) method using a deep neural network based general high-fidelity CT measurement model which is capable of incorporating the scatter and noise correlations that are exhibited in CT measurement data. In contrast to the DSE method, our method is very robust and depends only slightly on the type of calibration phantom used. It has no assumptions on exact size or positioning of the calibration phantom. The present study demonstrates the potential of the proposed approach using simulations and measurements. In both cases the IDSE yields highly accurate scatter correction that clearly outperforms the DSE method, as it is in use today.