ORAL PRESENTATIONS

Single shot high dynamic range imaging using an hyperprior Bayesian estimator

Andrés Almansa
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Abstract

Building high dynamic range (HDR) images by combining photographs captured with different exposure times present several drawbacks, such as the need for global alignment and motion estimation in order to avoid ghosting artifacts. The concept of spatially varying pixel exposures (SVE) proposed by Nayar et al. enables to capture in only one shot a very large range of exposures while avoiding these limitations. In this presentation, we propose a novel approach to generate HDR images from a single shot acquired with spatially varying pixel exposures. The proposed method makes use of the assumption stating that the distribution of patches in an image is well represented by a Gaussian Mixture Model. Drawing on a precise modeling of the camera acquisition noise, we extend the piecewise linear estimation (PLE) strategy developed by Yu et al. for image restoration. The proposed method permits to reconstruct an irradiance image by simultaneously estimating saturated and under-exposed pixels and denoising existing ones, showing significant improvements over existing approaches.

Time permitting we shall address some of the weaknesses of the PLE approach, such as the reliance on a fixed number of models to describe all image patches. In contrast, local model estimation has proven very powerful for image denoising, but it becomes seriously ill-posed for other inverse problems such as interpolation of random missing pixels, zooming, or single-shot HDR imaging.

In this talk, we present ongoing work on a new framework for image restoration that combines these two powerful approaches: Bayesian restoration and a continuous, local characterization of image patch priors. By making use of a prior on the model parameters, we overcome the ill-posedness of the local estimation and obtain state-of-the-art results in problems such as interpolation, denoising, zooming and single-shot HDR imaging. Experiments conducted on synthetic and real data show the effectiveness of the proposed approach.

Joint work with: Cecilia Aguerrebere, Julie Delon, Yann Gousseau & Pablo Musé.

Related Publication: http://perso.telecom-paristech.fr/~gousseau/single_shot_hdr/

Preconditioned Douglas-Rachford algorithms for the solution of variational imaging problems

Kristian Bredies
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Abstract

We present a preconditioned version of the Douglas-Rachford (DR) splitting method for the solution of convex-concave saddle-point problems which often arise in variational imaging. The method enables to replace the solution of a linear system in each iteration step in the cor- responding DR iteration by approximate solvers without the need to control the error. This iteration is shown to converge in Hilbert space under minimal assumptions on the preconditioner and for any step- size. Moreover, ergodic sequences associated with the iteration admit a convergence rate in terms of restricted primal-dual gaps.

The methods are applied to non-smooth and convex variational imaging problems. We discuss denoising and deconvolution with and discrepancy and total variation (TV) as well as total generalized variation (TGV) penalty. Preconditioners which are specific to these problems are presented, the results of numerical experiments are shown and the benefits of the respective preconditioned iterations is discussed.

This is a joint work with Hongpeng Sun.

On a new non-local fractional order variation model with applications to

modeling deformation of image registration

Ke Chen

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Abstract

In this talk, a new framework of modeling nonlocal deformation in image registration is presented. The well-known total variation regulariser is widely used in two related image problems, restoration and registration, due to its excellent edge preserving property. Its weakness of stair-casing and no contrast preservation have been improved by (among others) high order regularizers such as the total generalised variation and the mean curvature. While the latter type does overcome the weakness of the total variation, it introduces additional difficulties or weakness to restoration models: i) the convexity is always true and so the related theories are incomplete; ii) it is a challenge to develop fast algorithms for high order models; iii) when used for image registration, high order regularizers can lead to non-diffeomorphic (i.e. non-physical) mapping if the dissimilarity between the reference and the template images is large. There was a lot of recent developments in fractional order differential equations, although less has been applied to image modeling. Among the relatively few papers applied to image restoration and registration there is a common observation that fractional derivatives based regularizers offer quality solutions, as good as from high order models (based on integer derivatives). However almost neither analysis nor comparison was done with this type of new regularizers.

The first part of this talk will introduce the fractional order derivatives and then the total fractional-order variation. We then give some analytical results on this new variation, which can be shown to be convex in suitable function spaces. The second part of this talk will present our model based on the analysed fractional order regulariser, the derived fractional Euler-Lagrange equation and its solution method. Different from image restoration models, data fidelity term is always non-convex for image registration models. To make use of the convexity of the regularizers, we propose an iterative scheme where each iteration involves the solution of a convex model. Numerical experiments show that the new registration not only produces accurate and smooth solutions but also allows for a large rigid alignment, and the evaluations of the new model demonstrate substantial improvements in accuracy and robustness over the conventional image registration approaches.

This is joint work with Jianping Zhang.

Smoothing quadratic regularization methods for box constrained non-Lipschitz optimization in image restoration

Xiao-Jun Chen

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Abstract

We propose a smoothing quadratic regularization (SQR) method for solving box constrained optimization problems with a non-Lipschitz regularization term that includes the norm ($0 < p < 1$) of the gradient of the underlying image in the problem as a special case. At each iteration of the SQR algorithm, a new iterate is generated by solving a strongly convex quadratic problem with box constraints. We prove that any cluster point of scaled first order stationary points with satisfies a first order necessary condition for a local minimizer as goes to 0, and the worst-case iteration complexity of the SQR algorithm for finding an scaled first order stationary point is . Numerical examples are given to show good performance of the SQR algorithm for image restoration.

A calculus of variations-elliptic solver approach to the numerical solution of an Eikonal system

Roland Glowinski

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Abstract

Motivated by the mathematics of ***origami***, B. Dacorogna and his collaborators have investigated the properties of the solutions

of ***Eikonal systems*** of the following type:

$$\nabla \mathbf{u}(x) \in O(d), a.e. \text{ on } \Omega, \qquad \text{(ES)}$$

completed by boundary conditions. In (ES):

- Ω is a bounded domain of $\mathbf{R}^d$ (with $d \geq 2$).
- $O(d)$ is the multiplicative group of the $d \times d$ orthogonal matrices.
- $\mathbf{u}$ is a vector-valued function belonging to the space $(W^{1,\infty}(\Omega))^d$.

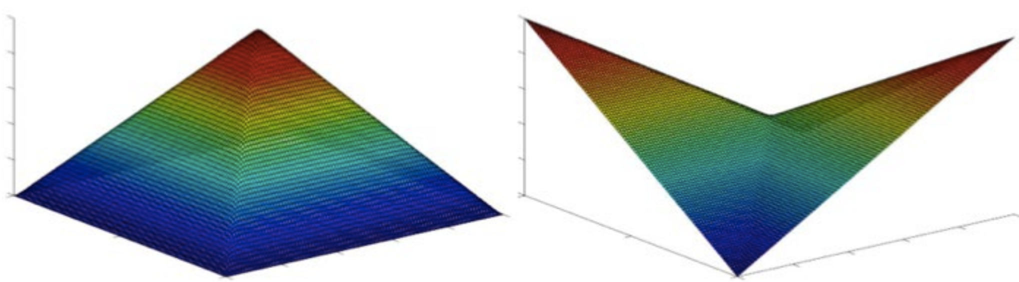
In order to solve (ES) numerically, we advocate a method combining penalty and elliptic regularization, reducing the solution of (ES) to that of a non-convex, quartic nonlinear, and bi- harmonic problem from Calculus of Variations, well-suited to low-order mixed finite element approximations. To solve the above variational problem, we associate with its optimality system an initial value problem ideally suited to time-discretization by operator-splitting.

Various test problems for d = 2, where (ES) is associated with Dirichlet boundary conditions, show that the methodology under consideration is robust and accurate; its modularity makes it easy to implement.

Simpler variants of the methodology discussed here have been successfully applied to the solution of seismic inversion problems modelled by the scalar Eikonal equation.

On the figure below, we have visualized the graphs of the two components of the approximate solution of a particular (ES) problem, where $\Omega = (0,1)^2$.

This is a joint work with Xiting Niu.



Graphs of the two components of the solution of a particular (ES) problem

ADMM-like methods for three-block separable convex programming: from variational inequality perspective

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Abstract

When the alternating direction method of multipliers (ADMM) is extended directly to a three-block separable convex minimization model, it was recently shown that the convergence is not guaranteed. This fact urges to develop efficient algorithms that can preserve completely the numerical advantages of the direct extension of ADMM but with guaranteed convergence. In this talk, we give some ADMM-like methods for three-block separable convex programming in an unified framework. It includes the method which corrects the output of the direct extension of ADMM slightly via a simple correction step, and the method without correction in the sense of customized PPA. The analysis is conducted in the variational inequality context. We show the contraction property, prove the global convergence and establish the worst-case convergence rate measured by the iteration complexity.

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20110091110004. This is joint work with Xiaoming Yuan (Department of Mathematics, Hong Kong Baptist University, Hong Kong, China. This author was supported by the General Research Fund from Hong Kong Research Grants Council: 203613. Email: xmyuan@hkbu.edu.hk).

Keywords. Convex optimization, Alternating direction method of multipliers, Variational inequal- ities, Splitting methods, Contraction, Convergence rate.

Robust principal component pursuit via inexact alternating minimization on matrix manifolds

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Abstract

Robust principal component pursuit (RPCP) refers to a decomposition of a data matrix into a low-rank component and a sparse component. In this work, instead of invoking a convex-relaxation model based on the nuclear norm and the l1-norm as is typically done in this context, RPCP is solved by considering a least-squares problem subject to rank and cardinality constraints. An inexact alternating minimization scheme, with guaranteed global convergence, is employed to solve the resulting constrained minimization problem. In particular, the low-rank matrix subproblem is resolved inexactly by a tailored Riemannian optimization technique, which favorably avoids singular value decompositions in full dimension. For the overall method, a corresponding q-linear convergence theory is established. The numerical experiments show that the newly proposed method compares competitively with a popular convex-relaxation based approach.

Methods for accelerating x-ray tomographic reconstruction

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Abstract

In addition to multi-CPU clusters, GPU and DSP, FPGA (field-programmable gate array) is another hardware accelerating approach. High-level synthesis tools from C to FPGA can optimize the implementation under the performance, power, and cost constraints, and enable energy-efficient accelerator-rich architecture. In previous work, we used FPGA for the simultaneous image reconstruction and segmentation with Mumford-shah regularization for XCT under -convergence, and achieved 31X speed-up and 622X energy efficiency compared to CPU implementation. However, FGPA was only used to accelerate the computation of forward and backward projections. Because of the limited memory on chip, recently, we propose asynchronous parallel Kaczmarz (ART) and RAMLA methods with diminishing relaxations. Preliminary results demonstrate better early reconstruction images with both methods. This asynchronous parallel approach fits well with the architecture of FPGA and reduces the communication cost, and is applicable to other parallel architectures in general (e.g. multi-core CPUs). In this talk, we also discuss more general asynchronous parallel data-block and image-block iterative methods with regularization, and approaches to establish their convergence from theoretical perspective.

This is a joint work with Jason Cong, Yijin Guan, Peng Li, Guojie Luo, Peter Maass, Thomas Page, Li Shen, Pei Wang, Peng Zhang, Wentai Zhang.

Introduction on mathematical medicine and some applications to accurate operations

De-Xing Kong
Zhejiang University, CHINA

Abstract

In this talk we introduce the theory and method of mathematical medicine and some applications to clinical medicine. In the living donor liver transplant carried out at Puri Indah Hospital conducted in cooperation with the liver transplant team of First Aliated Hospital, Zhejiang University, Doctors used the software named Digital Liver and Surgical Navigation developed by

our team. Our software rapidly provided an exact and detailed preoperative assessment with dissection information on liver by 2D/3D visualization and a complete and exact geometric structure of the liver and the inner blood vessels by 3D registration, which provides detailed dissection information of living donor liver transplant. Based on these, Docotors could perform simulative surgery and accurately measured the volume of the whole liver, the volumes of the left/right liver after simulative surgery, the diameters of sections of blood vessls and other important quantitative information. These successful living donor liver transplant show that our theory and software is efficient and worthy of confidence.

High-genus surface registration and its applications to medical imaging

Ronald Lui

Department of Mathematics, The Chinese University of Hong Kong

Abstract

We present a method to obtain the geometric registration between high-genus surfaces ($g \geq 1$). The high-genus topology of the surfaces poses great challenges for surface registration. Conventional approaches partition surfaces into simply-connected patches and registration is done by a patch-by- patch manner. Consistent cuts are required, which are difficult to obtain and prone to error. This talk presents a method to handle the registration problem for high-genus surfaces without introducing consistent cuts. The key idea is to formulate the problem on the universal covering spaces of the surfaces and registration is obtained using quasi-conformal approaches. Both constrained registration and curvature-matching registration will be considered. In the second part of the talk, some applications of the registration algorithm to medical imaging will be presented.

This is a joint work with Ka Chun Lam and Chengfeng Wen.

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Proximal heterogeneous block input-output method and application to blind pdiffraction imaging

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Abstract

We propose a general alternating minimization algorithm for nonconvex optimization problems with separable structure and nonconvex coupling between blocks of variables. To fix our ideas, we apply the methodology to the problem of blind ptychographic imaging. Compared to other schemes in the literature, our approach di↵ers in two ways: (i) it is posed within a clear mathematical framework with practically verifiable assumptions, and (ii) under the given assumptions, it is provably convergent to critical points. A numerical comparison of our proposed algorithm with the current state-of-the-art on simulated and experimental data validates our approach and points toward directions for further improvement.

This is joint work with Shoham Sabach, Matthew Tam and Robert Hesse.

Keywords: Alternating minimization, deconvolution, Kurdyka-Lojasiewicz, nonconvex-nonsmooth minimization, ptychography.

Stochastic Quasi-Newton Methods for Nonconvex Stochastic Optimization

Shi-Qian Ma

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Abstract

In this talk we study stochastic quasi-Newton methods for nonconvex stochastic optimization, where we assume that only stochastic information of the gradients of the objective function is available via a stochastic first-order oracle (SFO). Firstly, we propose a general framework of stochastic quasi-Newton methods for solving nonconvex stochastic optimization. The proposed framework extends the classic quasi-Newton methods working in deterministic settings to stochastic settings, and we prove its almost sure convergence to stationary points. Secondly, we propose a general framework for a class of randomized stochastic quasi-Newton methods, in which the number of iterations conducted by the algorithm is a random variable. The worst-case SFO-calls complexities of this class of methods are analyzed. Thirdly, we present two specific methods that fall into this framework, namely stochastic damped-BFGS method and stochastic cyclic Barzilai-Borwein method. Finally, we report numerical results to demonstrate the efficiency of the proposed methods.

Fast Transform Learning

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Abstract

Dictionary learning is a matrix factorization problem. It aims at finding a dictionary of atoms that best represents an image or a class of images according to a given objective, usually sparsely. It has led to many state-of-the-art algorithms in image processing. In practice, all algorithms performing dictionary learning iteratively estimate the dictionary and a sparse representation of the images using this dictionary. However, the numerical complexity of dictionary learning restricts its use to atoms with a small support since the computations using the constructed dictionaries require too much resources to be deployed for large scale applications. In order to alleviate these issues, this paper introduces a new strategy to learn dictionaries composed of atoms obtained by translating the composition of K convolutions with S-sparse kernels of known support. The dictionary update step associated with this strategy is a non-convex optimization problem. The purpose of the present paper is to study this non-convex problem. We first reformulate the problem to reduce the number of its irrelevant stationary points. A Gauss-Seidel type algorithm, referred to as Alternative Least Square Algorithm, is introduced for its resolution. The search space of the considered optimization problem is of dimension KS, which is typically smaller than the size of the target atom and is much smaller than the size of the image. Moreover, the complexity of the algorithm is linear with respect to the size of the image, allowing larger atoms to be learned (as opposed to small patches). The conducted experiments show that, when K is large (say $K = 10$), we are able to approximate with a very good accuracy many atoms such as wavelets, curvelets, sinc functions or cosines.

This is joint work with O. Chabiron, J.Y. Tourneret and N. Dobigeon

Optimization of image sharpness metrics based on phase coherence and application to blind deblurring

Lionel Moisan
Université Paris Descartes, FRANCE

Abstract

In a high-quality image, the presence of sharp edges together with smooth areas strongly constrains the phase of the Fourier Transform of the image. This property has been recently exploited to build sharpness metrics based on phase coherence, some of them leading to explicit but rather uncommon formulas. In this talk, we shall present recent results concerning these metrics and see how they can be embedded in an optimization scheme for blind deblurring tasks.

This is a joint work with Arthur Leclaire (Université Paris Descartes)

Reference: A. Leclaire, L. Moisan, “No-reference image quality assessment and blind deblurring with sharpness metrics exploiting Fourier phase information”, to appear in *Journal of mathematical Imaging and Vision*.

Optical Imaging Through Atmospheric Turbulence in Remote Sensing

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Abstract

Hyperspectral, Light Detection and Ranging (LiDAR), and Polarimet- ric imaging are the pervasive optical imaging modalities in remote sensing. Here, we primarily consider the blurring e↲ ects of atmospheric turbulence (AT) on hyperspectral images (HSI). We show how to construct an optimal preconditioner, and provide numerical methods for estimating the multiple wavelength-dependent PSFs using Mo↲ at function models and spectral data from isolated (guide) stars. This is followed by joint deblurring and feature extraction using the multiple PSFs in order to spectrally analyze the image objects. In addition,

fused HSI-LiDAR data is considered and we develop and test methods for deblurring and analyzing compressive spectro-polarimetric snapshot images through AT for astronomy and space situational analysis.

This is joint work with Paul Pauca and James Nagy.

Total variation regularisation as a discrete gradient flow

Carola-Bibiane Schönlieb

University of Cambridge

Abstract

In this talk we are interested in the numerical solution of nonlinear diffusion equations that appear in image processing applications by employing a discrete gradient flow approach. In particular, we consider equations that arise as steepest descent evolutions for total variation (and related) regularization for image de-noising, de-convolution and inpainting. Taylored discrete gradient approaches are discussed for their application to large-scale image data and are compared with other state of the art methods for total variation minimisation such as explicit Euler, lagged-diffusivity and the Chambolle-Pock method. We will show that the discrete gradient approach offers guaranteed energy decrease in every step, and could be particularly interesting for large-scale data as it can be designed such that its computation can be reduced to the solution of a sequence of one-dimensional problems.

This is joint work with Volker Grimm, Robert MacLachlan, David McLaren, and Reinout Quispel.

1-Bit Compressive Sensing

Li-Xin Shen

Department of Mathematics, Syracuse University

Abstract

We introduce an optimization model for reconstruction of sparse signals from noisy 1-bit measurements. The model is derived based on maximum a posterior. The data fidelity term of the objective function of the model uses the one-sided function to impose the consistency restriction of the one-bit compressive sensing problem. Unlike existing algorithms, our proposed model does not require prior knowledge for noise level of the 1-bit measurements. A fixed-point proximity algorithm is developed for this model and the convergence analysis of the algorithm is provided. The numerical results show that the proposed model is suitable for reconstruction of sparse signals from noisy 1-bit measurements.

Disparity and Optical Flow Partitioning Using Extended Potts Priors

Gabriele Steidl

University of Kaiserslautern, Germany

Abstract

This paper addresses the problems of disparity and optical flow partitioning based on the brightness invariance assumption. We investigate new variational approaches to these problems with Potts priors and possibly box constraints. For the optical flow partitioning, our model includes vector-valued data and an adapted Potts regularizer. Using the notion of asymptotically level stable functions we prove the existence of global minimizers of our functionals. We propose a modified alternating direction method of multipliers. This iterative algorithm requires the computation of global minimizers of classical univariate Potts problems which can be done efficiently by dynamic programming. We prove that the algorithm converges both for the constrained and unconstrained problems. Numerical examples demonstrate the very good performance of our partitioning method.

This is joint work with X. Cai (University of Cambridge), Mila Nikolova (CMLA, ENS Cachan), J. H. Fitschen (University of Kaiserslautern) and M. Storath (EPFL Lausanne).

SaCoseg: Object Cosegmentation by Shape Conformability

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Abstract
In this paper an object cosegmentation method based on shape conformability is proposed. Different from the previous object cosegmentation methods which are based on the region feature similarity of the common objects in image set, our proposed SaCoseg cosegmentation algorithm focuses on the shape consistence of the foreground objects in image set. The SaCoseg algorithm assumes there exists a common object with a specific shape in image set and the shapes of the correctly segmented objects are topologically similar. Then the common shape pattern in image set can be automatically mined and regarded as the shape prior of those hard images segmented unsatisfactorily. The SaCoseg algorithm mainly consists of four steps: 1) the initial Grabcut segmentation; 2)the shape mapping by CPD registration; 3)the common shape pattern discovery by AP clustering; 4)the refinement by Grabcut with common shape constraint. To testify our proposed algorithm and establish a benchmark for future work, we built the CoShape dataset to evaluate the shape based cosegmentation. The experiments on CoShape dataset and the comparison with some related cosegmentation algorithms demonstrate the good performance of the proposed SaCoseg algorithm.

Soothing methods for nonsmooth optimization: a guided detour

Marc Teboulle
School of Mathematical Sciences Tel Aviv University

Abstract
Many applied models arising in signal and image recovery, machine learning and other fields share nonsmoothness. Smoothing is a well known approach to tackle nonsmooth optimization problems via adequate algorithms applied to their smoothed counterparts. Within this approach the resulting schemes only provide an -optimal solution to the *approximated* smoothed problem, which regretfully also depends on a smoothing parameter, but do not find an -optimal solution to the original nonsmooth problem. The question is, whether it is possible to do something better.

In this talk we describe some approaches and new analytical tools, highlighting the ways which allows us to address the aforementioned drawback, with a particular focus on the design, analysis and potential applications of smoothing methods that can efficiently solve the *original nonsmooth* problem via first order algorithms.

Computing geodesics in shape spaces: why, when and how ?

Alain Trouvé
CMLA, ENS Cachan, FRANCE

Abstract
Shape spaces have emerged as new kind of infinite dimensional riemannian manifolds that are challenging both mathematicians and computer scientists. In particular, bridging the gap between formal pictures to rigorous statements and actual algorithms has driven intensive joint efforts in the last decade. We will discuss in this talk the emerging picture around the central question, that underlies several important optimization problems, of geodesics existence and computation in such spaces.

Fixed-point proximity algorithms for solving non-convex non-smooth optimization problems arising from signal and image processing

Yue-Sheng Xu
Sun Yat-sen University, China

Abstract

We shall present fixed-point proximity algorithms for solving a class of non-convex non-smooth optimization problem which come from signal and image processing recently. Convergence of the algorithms will be considered and numerical examples will be discussed.

High-order Compressive Sensing: A Target and Background Separation Tensor Approach

Zong-Ben Xu

Xi'an Jiaotong University

Abstract

Various applications, e.g., video surveillance, hyper-spectral image processing and dynamic MR image reconstruction, can be cost as a high-order compressive sensing (h_{rd}CS) problem in which the to-be-processed signals are of high-order tensors with target and background separation form. As highlighted in the 2nd order case (namely, the Low Rank Decomposition of Matrices), Sparsity measure has been central in modeling and solving such h_{rd}CS problems. The existing approaches to measure the sparsity of a tensor are through unfolding the tensor into different matrix forms and then using the matrix sparsity. Such matriacization methodologies fail to exploit the global sparse structure and effectively eliminate the spatio-temporal redundancy of the tensor. In this talk we introduce an rational sparsity measure for any high-order tensors in terms of the number of fundamental Kronecker basis. The introduced measure unifies the sparsity adopted extensively in the 1st order case (namely, the number of nonzero components of a vector) and the 2nd order case (namely, the rank of a matrix), and also well characterizes the global sparse structure of a high-order tensor. With the new sparsity measure, we define a h_{rd}CS model based on the target and background separation framework. Unlike the existing models, we model the target and background tensors respectively with their essential priors like sparsity, smoothness and similarities. The well known alternating direction method of multipliers (ADMM) is then employed to solve the h_{rd}CS model. To lay the theoretical foundation, we stablish an recovery theory of the h_{rd}CS based on tensor RIP, prove a convergence result of ADMM, and provide extensive simulated and real world experiments with video surveillance and hyper-spectral image reconstruction which support the superiority of the h_{rd}CS model over the existing state-of-the-art methods.

Authentication of Van Gogh paintings with geometric tight frames

Yuan Yao

Peking University, CHINA

Abstract

Vincent Van Gogh is perhaps the modern artist who has been forged most frequently and as time goes on, there are more heated debates over the authenticity of Van Gogh’s work than that of any other artists of the period. We approach the problem of authenticating genuine van Gogh paintings from forgeries based on feature extraction with geometric tight frames and statistical machine learning. Our dataset is provided by van Gogh museum and Kröller-Muller museum consisting both original Van Gogh’s work and some mimics by the contemporary. We found that a small set of features account for an accurate authentication so that van Gogh paintings are highly concentrated towards some center point while forgeries are spread out as outliers. Numerical results show that our method can achieve 86.08% classification accuracy under leave-one-out cross-validation on this dataset. With only 5 selected features, our method can give 88.61% identification accuracy. These features mainly describe tail distributions of the frame coefficients along certain orientations, providing us discriminative features for van Gogh paintings and reflecting a highly consistent style in van Gogh's brushstroke movements, where many forgeries demonstrate a more diverse spread in these features.

This is a joint work with Haixia Liu (HKUST&CUHK) and Raymond Chan (CUHK).

High-Performance Dual Optimization Methods with Applications to Medical Image Analysis

Jing Yuan

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Department, Western University, Canada

Abstract

Many problems of medical image analysis are challenging due to the associated complex optimization formulations and constraints, extremely big image data volumes to be processed, poor imaging quality, missing data etc. On the other hand, it is highly desired in clinical practices to process and analyze the acquired imaging data, for example segmentation and registration, in an automated and efficient numerical way, which motivated vast active studies during the last 30 years, in a rather broad sense, to deliver advanced mathematical analysis and develop high-performance numerical schemes. This talk targets to present an overview of the convex/dual optimization approaches, one most successful optimization framework of image processing developed recently, to a wide spectrum of applications in medical image analysis. It focuses on the optimization problems arising from two most interesting topics: medical image segmentation and registration, and presents both analysis and algorithmic solutions in a unified manner in terms of dual optimization.

Block-wise Alternating Direction Method of Multipliers for Multiple-block Convex Programming and Beyond

Xiao-Ming Yuan

Hong Kong Baptist Univ, Hong Kong, China

Abstract

The alternating direction method of multipliers (ADMM) is a benchmark for solving a linearly constrained convex minimization model with a two-block separable objective function; and it has been shown that its direct extension to a multiple-block case where the objective function is the sum of more than two functions is not necessarily convergent. For the multiple-block case, a natural idea is to artificially group the objective functions and the corresponding variables as two groups and then apply the original ADMM directly —- the block-wise ADMM is accordingly named because each of the resulting ADMM subproblems may involve more than one function in its objective. Such a subproblem of the block-wise ADMM may not be easy as it may require minimizing more than one function with coupled variables simultaneously. We discuss how to further decompose the block-wise ADMM's subproblems and obtain easier subproblems so that the properties of each function in the objective can be individually and thus effectively used, while the convergence can still be ensured. Extensions to the block-wise versions of the generalized ADMM and the ADMM with Gaussian back substitution will also be discussed.

Dynamic SPECT reconstruction from few projections: a sparsity enforced matrix factorization approach

Xiao-Qun Zhang

Shanghai Tongji University, China

Abstract

The reconstruction of dynamic images from few projection data is a challenging problem, especially when noise is present and when the dynamic images vary fast. In this paper, we propose a variational model, sparsity enforced matrix factorization (SEMF), based on low rank matrix factorization of unknown images and enforced sparsity constraints for both representing coefficients and bases. The proposed model is solved via an alternating iterative scheme, for which each sub-problem is convex and involves efficient alternating direction method of multiplier (ADMM). The convergence of the overall alternating scheme for the nonconvex problem relies upon recently studied Kurdyka-ojasiewicz property. Finally our proof-of-concept simulation on 2D dynamic images shows the advantage of the proposed method compared to conventional methods.

A Variational Model for Shape from Shading Using Mean Curvature

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Abstract

Shape from shading is a classic and fundamental problem in image processing. It aims to reconstruct a 3D scene from a given 2D irradiance image, which is a highly ill-posed problem. In this work, we will address a variational model that employs mean curvature of image surface as the regularizer and discuss some features of this model. Due to the specific features of the regularizer, the model is able to successfully restore smooth parts as well as parts with sharp transitions of objects reconstructed in the 3D scene. We will discuss how the model can be minimized by using augmented Lagrangian methods. Numerical experiments will be presented to validate the model.

This is joint work with Any Yip (Department of Mathematics, Hong Kong Baptist University, Hong Kong. E-mail: mhyipa@hkbu.edu.hk.)

POSTER PRESENTATIONS

Variational image segmentation via a two-stage method

Hui-Bin Chang
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Abstract

We present a novel discrete Mumford-Shah model for the simultaneous bias correction and image segmentation(SBCIS) for images with intensity inhomogeneity. The model is based on the assumption that an image can be approximated by a product of true intensities and a bias field. Unlike the existing methods, where the true intensities are represented as a linear combination of characteristic functions of segmentation regions, we employ L0 gradient minimization to enforce a piecewise constant solution. We introduce a new neighbor term into the Mumford-Shah model to allow the true intensity of a pixel to be influenced by its immediate neighborhood. A two-stage segmentation method is applied to the proposed Mumford-Shah model. In the first stage, both the true intensities and bias field are obtained while the segmentation is done using the K-means clustering method in the second stage. Comparisons with the two-stage Mumford- Shah model show the advantages of our method in its ability in segmenting images with intensity inhomogeneity.

This work is collaborated with Dr. Yuping Duan in Neural & Biomedical Technology Department, Institute for Infocomm Research, A*Star, Singapore.

Domain Decomposition Methods For Total Variation Minimization

Hui-Bin Chang

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Abstract

In this paper, overlapping domain decomposition methods (DDMs) are used for solving the Rudin-Osher-Fatemi (ROF) model in image restoration. It is known that this problem is nonlinear and the minimization functional is non-strictly convex and non-differentiable. There- fore, it is difficult to analyze the convergence rate for this problem. In this work, we use the dual formulation of the ROF model in connection with proper subspace correction. With this approach, we overcome the problems caused by the non-strict-convexity and non-differentiability of the ROF model. However, the dual problem has a global constraint for the dual variable which is difficult to handle for subspace correction methods. We propose a stable unit decomposition, which allows us to construct the successive subspace correction method (SSC) and parallel subspace correction method (PSC) based domain decomposition. Numerical experiments are supplied to demonstrate the efficiency of our proposed methods.

This is joint work with Xue-Cheng Tai (Department of Mathematics, University of Bergen, Bergen, Norway tai@math.uib.no) and Dan-Ping Yang (Department of Mathematics, East China Normal University, China dpyang@math.ecnu.edu.cn).

A preconditioned primal-dual fixed point algorithm for convex separable minimization with applications to image restoration

Jian-Guo Huang

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Abstract

In the area of image science, many problems or models involve minimization of a sum of two convex separable functions. In this talk, we intend to develop a general algorithmic framework for solving such a problem from the point of view of fixed point algorithms based on proximity operators. Motivated from proximal forward-backward splitting (PFBS) and fixed point algorithms based on the proximity operator for image denoising, we design a primal-dual fixed point algorithm based on proximity operator (for [0, 1]) and obtain a scheme with close form for each iteration. We establish the convergence of the proposed algorithm, and under some stronger assumptions, we can further prove the global linear conver- gence of the proposed algorithm. We illustrate the efficiency of through some numerical examples on image supper-resolution and computerized tomographic reconstruction. Finally, we are going to show our recent work on how to precondition the previous algorithm.

This is a joint work with Peijun Chen and Xiaoqun Zhang.

Half-Quadratic Algorithm for Problems with Applications to TV- Image Restoration and Compressive Sensing

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Abstract

In this poster, we present our work on minimization model. We consider the minimization problem with . The problem has been studied extensively in image restoration and compressive sensing. We first extend the half-quadratic technique from -norm to -norm with $0 < p < 2$. Based on this, we develop a half-quadratic algorithm to solve the problem. We prove that our algorithm is indeed a majorize-minimize algorithm. From that we derive some convergence results of our algorithm, e.g. the objective function value is monotonic decreasing and convergent. We apply our algorithm to TV- image restoration and compressive sensing in magnetic resonance (MR) imaging applications. The numerical results show that our algorithm is fast and ecient in restoring blurred images that are corrupted by impulse noise, and also in reconstructing MR images from very few *k*-space data.

Interpolation and Denoising of High-Dimensional Seismic Data by Learning Tight Frame

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Abstract

Sparse transforms play an important role in seismic signal processing at the time of solving problems associated prestack noise attenuation and data reconstruction. Analytic basis sparse transforms (so-called implicit dictionaries) such as Fourier, Radon and curvelet transforms, are widely used for representation of seismic data. There are situations, however, where the complexity of the data requires adaptive sparse transforms that are found via learning methods. In other words, the idea is to estimate an optimal representation of data in terms of basis functions that are derived from the data. We present an extension of previous data-driven tight frame (DDTF) method for noise suppression and interpolation of high-dimensional seismic data. Rather than choosing a model beforehand (for example, a family of lines, parabolas, or curvelets) to fit the data, the DDTF derives the model from the data itself in an optimum manner. With the tight frame assumption, DDTF significantly reduces the computation time for training dictionary, which makes it available for high- dimensional data processing. Raw data is first divided into small blocks to form training sets, and then the DDTF is used for the training sets. The DDTF is typically embodied as an explicit dictionary and a sparsity-promoting training algorithm is employed to obtain an optimized tight frame representation to the observed data. The computational time and redundancy is controlled by block overlap. Numerical results show that the proposed methodology is capable of recovering three-dimensional and five-dimensional prestack seismic data under different signal-to-noise ratio (SNR) scenarios. Subtle features tend to be better preserved in the DDTF method in comparison with traditional Fourier and wavelet based methods, and the state-of-the- art curvelet and block matching based methods.

This is joint work with Shiwei Yu, Xiaoqun Zhang and Mauricio Sacchi.

Image restoration based on the divergence free field and the surface fitting strategy

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Abstract

In this report, we propose a new two-step model for image restoration problem. By using the fact that the isophote line in the image must be a constant, then the tangential vector field satisfies the incompressibility condition in fluid mechanics. So we first recover a smoothed and divergence-free tangential vector field as the first step model. Then in the second-step model we consider to reconstruct the restored image from corresponding normals. Here We use the linearized alternating direction method of multipliers (LADMM) to solve the proposed model. Some numerical results illustrate the improvements of proposed model.

This is joint work with Yu-Hong Dai (Academy of Mathematics and Systems Science, Chinese Academy of Sciences, Beijing 100190, China).

A Variational Histogram Equalization Method for Image Contrast Enhancement

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Abstract

In this presentation, I will introduce a variational approach for histogram equalization, which contains an energy functional to determine a local transformation such that the histogram can be redistributed locally, and the brightness of the trans- formed image can be preserved. In order to minimize the differences among the local transformation at the nearby pixel locations, the spatial regularization of the transformation is also incorporated in the functional for the equalization process.

Randomized Structural Sparsity via Constrained Block Subsampling for Better Discriminative Voxel Identification

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Abstract
In this paper, we focus on the sparse regularization based voxel selection for functional Magnetic Resonance Imaging (fMRI, for short) brain data. The main diculty lies in the extremely high dimensional voxel space and very few training samples, easily resulting in unstable feature selection results for many traditional multivariate feature selection methods. In order to deal with the difficulty, stability selection based on the common sparsity models have recently received great attention, especially due to its finite sample control for certain error rates of false discoveries and transparent principle for choosing a proper amount of regularization. However, it fails to consider some prior or data-driven estimated incoherent structural information of these features and be likely to lead to large false negative rates in order to keep small false positive rate. Correspondingly, we propose a new variant of stability selection named Randomized Structural Sparsity, which incorporates the idea of structural sparsity, and its advantages over the common stability selection is the better control of false negatives, yet keeping the control of false positives. Numerical experiments verify this point.

CGIHT: Conjugate Gradient Iterative Hard Thresholding

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Abstract
We propose a new hard thresholding algorithm, CGIHT, that balances the low per iteration complexity of NIHT with the fast asymptotic convergence rate of ALPS and HTP. In particular, CGIHT reduces to NIHT when the support set has changed in the prior iteration, and corresponds to HTP once the final the support set converged to remains fixed. In intermediate exploratory iterations, CGIHT corresponds to an efficient implementation of restarted nonlinear conjugate gradient on the restricted support set, though with an unrestricted search direction which allows the support set to change under hard thresholding to the nearest k sparse solution. If the sensing matrix A has suitably bounded restricted isometry then CGIHT is guaranteed to recover a sparse vector within a multiple of the minimum residual obtainable at the specified sparsity level. Moreover, empirical testing shows CGIHT to be able to recovery synthetic signals of high complexity and in less time than other hard thresholding algorithms.

This is joint work with Jeff Blanchard (Grinnell College) and Jared Tanner (University of Oxford).

High-order Total Variation Regularization Approach for Axially Symmetric Object Tomography from a Single Radiograph

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Abstract
We consider Abel transform based density reconstruction for axially symmetric objects from a single radiograph by fan-beam x-rays. All contemporary methods assume that the density is piecewise constant or linear. This is quite a restrictive approximation. Our proposed model is based on high-order total variation regularization. Its main advantage is to reduce the staircase effect and enable the recovery of smoothly varying regions. We compare our model with other potential regularization techniques, like TV, TGV, LLT. The numerical tests show that the proposed model has advantages on staircasing reduction,

density level preservation, CPU time cost and SNR value improvement.

This is joint work with Raymond H. Chan (Department of Mathematics, The Chinese University of Hong Kong rchan@math.cuhk.edu.hk), Haixia Liang (Mathematics and Physics Teaching Centre, Xi'an Jiaotong-Liverpool University haixia.liang@xjtlu.edu.cn), Mila Nikolova (Centre de Mathematiques et de Leurs Applications, CNRS, ENS de Cachan, France nikolova@cmla.ens-cachan.fr) and Xue-Cheng Tai (University of Bergen, Norway. tai@mi.uib.no)

Primal-Dual Algorithms for Total Variation Based Image Restoration under Poisson Noise

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Abstract

We consider the problem of restoring images corrupted by Poisson noise. Under the framework of maximum a posteriori estimator, the problem can be converted into a minimization problem where the objective function is composed of a Kullback-Leibler (KL)-divergence term for the Poisson noise and a total variation (TV) regularization term. Due to the logarithm function in the KL-divergence term, the non-differentiability of TV term and the positivity constraint on the images, it is not easy to design stable and efficiency algorithm for the problem. Recently, many researchers proposed to solve the problem by Alternating Direction Method of Multipliers (ADMM). Since the approach introduces some auxiliary variables and requires the solution of some linear systems, the iterative procedure can be complicated. Here we formulate the problem as two new constrained minimax problems and solved them by Chambolle-Pock's first order primal-dual approach. The convergence of our approach is guaranteed by their theory. Comparing with ADMM approaches, our approach requires about half of the auxiliary variables and is matrix-inversion free. Numerical results show that our proposed algorithms are efficient and outperform the ADMM approach.

Robust Asymmetric Nonnegative Matrix Factorization

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Abstract

The problems that involve separation of grouped outliers and low rank part in a given data matrix have attracted a great attention in recent years in image analysis such as background modeling and face recognition. In this paper, we introduce a new formulation called linf-norm based robust asymmetric nonnegative matrix factorization (RANMF) for the grouped outliers and low nonnegative rank separation problems. The main advantage of linf-norm in RANMF is that we can control denseness of the low nonnegative rank factor matrices. However, we also need to control distinguishability of the column vectors in the low nonnegative rank factor matrices for stable basis. For this, we impose asymmetric constrains, i.e., denseness condition on the coefficient factor matrix only. As a byproduct, we can obtain a well-conditioned basis factor matrix. One of the advantages of the RANMF model, compared to the nuclear norm based low rank enforcing models, is that it is not sensitive to the nonnegative rank constraint parameter due to the proposed soft regularization method. This has a significant practical implication since the rank or nonnegative rank is difficult to compute and many existing methods are sensitive to the estimated rank. Numerical results show that the proposed RANMF outperforms the state-of-the-art robust principal component analysis (PCA) and other robust NMF models in many image analysis applications.

An Efficient Primal-Dual Hybrid Gradient Descent Method for Total Variation-Based Image Processing

Ming-Qiang Zhu

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Abstract

We propose a simple yet efficient algorithm for total variation (TV) minimizations with applications in the image processing realm. This descent-type algorithm alternates between the primal and dual formulations and exploit the information from both the primal and dual variables. It converges faster than some popular existing methods as demonstrated in our experiments. The method can be generalized to other L1-minimization problems.