Mini Workshop on Bayesian Inverse Problems and Imaging

May 26, 2017

601 Pao Yue-Kong Library

Institute of Natural Sciences, Shanghai Jiao Tong University

Contents

1 General Information

Introduction

This one-day mini-workshop aims at bring together researchers on Bayesian inverse problems and imaging. The topics include Bayesian and varaitional models, numerical algorithms and application in diverse medical imaging. The mini-workshop is supported by Institute of Natural Sciences and School of Mathematical Sciences.

Date

May 26, 2017

Venue

601 Pao Yue-Kong Library

Organizers

- Jinglai Li, Shanghai Jiao Tong University
- Xiaoqun Zhang, Shanghai Jiao Tong University

2 Schedule

2017-05-26

Time	Speaker	Title
09:00 - 09:40	Tan Bui-Thanh	Towards Large-Scale Computational Science and Engineering with Quantifiable Uncertainty
09:40 - 10:20	Matthias J. Ehrhardt	Faster PET Reconstruction with a Stochastic Primal-Dual Hybrid Gradient Method
10:20 - 10:40		Coffee Break
10:40 - 11:20	Xiaoqun Zhang	A primal-dual fixed-point algorithmic framework for minimization of two-block, three-block to multi-block convex separable functions in Imaging sciences
11:20 - 12:00	Lukas F. Lang	Optical Flow on Evolving Sphere-Like Surfaces
12:00 - 13:30		Lunch Break
13:30 - 14:10	Heikki Haario	Parameter uncertainty of chaotic systems
14:10 - 14:50	Jinglai Li	Learning with orthogonal polynomials: an elastic net approach revisited

14:50 - 15:30	Joana Sarah Grah	Learning Filter Functions in Regularisers by Minimising Quotients
15:30 - 15:50		Coffee Break
15:50 - 16:30	Veronica Corona	Joint reconstruction and segmentation from undersampled MRI data
16:30 - 17:10	Tatiana Bubba	A nonsmooth regularization approach based on
17:10 - 17:50	Jae Kyu Choi	PET-MRI Joint Reconstruction by Joint Sparsity Based Tight Frame Regularization

3 Abstract

3.1 2017-05-26

3.1.1 Towards Large-Scale Computational Science and Engineering with Quantifiable Uncertainty (Tan Bui-Thanh)

Tan Bui-Thanh, The University of Texas at Austin
2017-05-26 09:00 - 09:40

We present our recent efforts towards uncertainty quantification for large-scale computational sciences and engineering. The talk has three parts.

In the first part we present a systematic FEM-based discretization of function-space Markov chain Monte Carlo (MCMC) methods to obtrain dimension-independent MCMC methods. This class of MCMC methods are important for PDE-constrained Bayesian inverse problems because they ensure the convergence of the computation as the mesh is refined.

In the second part, we present several particle methods to compute (approximate) posterior samples without the need for a Markov chain. We present theory,computational experiments, and comparisons among the methods.

In the last part, we present dimension-reduction techniques to reduce the data, the parameter, and the state for large-scale data-driven inverse problems in high dimensional parameter spaces.

Numerical results for several inverse problems, including inverse electromagnetic scattering and seismici nversions, will be discussed.

3.1.2 Faster PET Reconstruction with a Stochastic Primal-Dual Hybrid Gradient Method (Matthias J. Ehrhardt)

Matthias J. Ehrhardt, Cambridge University
2017-05-26 09:40 - 10:20

In this talk we revisit the problem of PET reconstruction with non-smooth and convex priors. As the data fidelity term in PET is the Poisson likelihood there are not many algorithms that can solve this problem. A very popular choice to solve this problem is the Primal-Dual Hybrid Gradient method proposed by Chambolle and Pock. The system matrix for clinical PET scanners is very large and cannot be stored in the memory of most computers and thus an expensive algorithm to compute matrix vector products has to be employed. In this talk we extend the Primal-Dual Hybrid Gradient method to the subset setting (like in ART, Kaczmarz or OSEM). By choosing subsets randomly we can prove that the algorithm is convergent for all sensible random subset selections. Examples based on synthetic and real data show that it is much faster (in terms of actual time) than the standard Primal-Dual Hybrid Gradient method.

3.1.3 A primal-dual fixed-point algorithmic framework for minimization of two-block, three-block to multi-block convex separable functions in Imaging sciences (Xiaoqun Zhang)

Xiaoqun Zhang, Shanghai Jiao Tong University
2017-05-26 10:40 - 11:20

Many problems arising in arising in signal processing and imaging science can be formulated as minimization of multi-block convex separable functions. We start with the problem of two −block minimization that involves a smooth function with Lipschitz continuous gradient and a linear composite nonsmooth function, and then extend to three-block minimization with one additional non-smooth function. We propose a primal-dual fixed-point (PDFP) framework to solve the above class of problems. The proposed algorithm for three-block problems is a fully splitting symmetric scheme, only involving explicit gradient and linear operators without inner iteration, when the nonsmooth functions can be easily solved via their proximity operators, such as L1 type regularization. We study the convergence of the proposed algorithm. We then extend PDFP to solve two kinds of separable multi-block minimization problems and illustrate how practical and fully decoupled schemes can be derived, especially for parallel implementation of large scale problems. The connections and comparisons to ADMM are also present. Finally, some experiments on image restoration and sparse approximation are provided to illustrate the performance of several schemes derived by the PDFP algorithm.

3.1.4 Optical Flow on Evolving Sphere-Like Surfaces (Lukas F. Lang)

Lukas F. Lang, Cambridge University
2017-05-26 11:20 - 12:00

We consider optical flow on evolving surfaces which can be parametrised from the 2-sphere. Our main motivation is to estimate cell motion in time-lapse volumetric microscopy images depicting fluorescently labelled cells of a live zebrafish embryo.

We exploit the fact that the recorded cells float on the surface of the embryo and allow for the extraction of an image sequence together with a sphere-like surface. We solve the resulting variational problem by means of a Galerkin method based on compactly supported vectorial basis functions and present numerical results.

3.1.5 Parameter uncertainty of chaotic systems (Heikki Haario)

Heikki Haario, LUT, Lappeenranta University of Technology
2017-05-26 13:30 - 14:10

The challenge of estimating parameters in chaotic systems is related to the fact that a fixed model parameter does not correspond to a unique long-time model integration, but to a set of quite different solutions as obtained by setting, e.g., slightly different initial values or solver settings. But while all such trajectories are different, they approximate the same underlying attractor. We show how this idea can be used to create a well-defined statistical likelihood that enables model identification even in the chaotic regime where other methods fail. The approach is verified with various chaotic ODE and PDE systems, together with an extension to SDE.

3.1.6 Learning with orthogonal polynomials: an elastic net approach revisited (Jinglai Li)

Jinglai Li, Shanghai Jiao Tong University
2017-05-26 14:10 - 14:50

We study leaning problems with orthogonal polynomial basis where we want to learn the underlying function from a finite nunber of data points. We propose an learning algorithm that can impose both smoothness and sparsity assumptions on the underlying function. The proposed algorithm can be interpreted as a modified elastic net approach. With numerical examples, we illustrate that the algorithm has competitive performance against existing ones.

3.1.7 Learning Filter Functions in Regularisers by Minimising Quotients (Joana Sarah Grah)

Joana Sarah Grah, Cambridge University
2017-05-26 14:50 - 15:30

Learning approaches have recently become very popular in the field of inverse problems and a large variety of methods has been established. However, most learning approaches only aim at fitting parametrised models to favourable training data whilst ignoring misfit training data completely. In contrast to that, we present a learning framework for parametrised regularisation functions based on quotient minimisation, where we allow for both fit- and misfit-training data in the numerator and denominator, respectively. We present results resembling behaviour of well-established derivative-based sparse regularisers like total variation or higher-order total variation in one-dimension. Moreover, we introduce novel families of non-derivative-based regularisers. This is accomplished by learning favourable scales and geometric properties while at the same time avoiding unfavourable ones.

3.1.8 Joint reconstruction and segmentation from undersampled MRI data (Veronica Corona)

Veronica Corona, Cambridge University
2017-05-26 15:50 - 16:30

Magnetic resonance imaging (MRI) is widely used in medical and non-medical applications. It often deals with fast acquisition techniques and incomplete measurements, posing challenges in the reconstruction and further analysis of the data. One common imaging task is segmentation, which is typically posterior to acquisition. However, it has been shown for different imaging techniques (x-rays, SPECT, PET) that solving both problems simultaneously can improve performances. We propose a method to jointly reconstruct and segment undersampled data from MRI. We derive a variational model that consists of a total variation regularised reconstruction from undersampled k-space and a Chan-Vese based segmentation. We develop an algorithm based on a splitting approach that solves efficiently the two minimisation subproblems. We present our method and its performance for synthetic and real data.

3.1.9 A nonsmooth regularization approach based on (Tatiana Bubba)

Tatiana Bubba, University fo Helsinki
2017-05-26 16:30 - 17:10

Region-of-interest tomography (ROI CT) is among the "hot topics" in the feld of X-ray to-mographic imaging, due to its potential to lower exposure to X-ray radiation and reduce the scanning time. This is particularly appealing for a wide range of biomedical application, such as contrast-enhanced cardiac imaging or positioning of intracranial stents. However, the truncation of projection measurements results in a severe ill-posedness, and the presence of noise compromises the stability of traditional CT reconstruction algorithms. In order to obtain stable reconstructions, we introduce a nonsmooth convex optimization approach based on shearlets, a recent multiscale method especially designed to sparsely approximate images with edges. For the solution of this problem, we analyze the very recently proposed variable metric inexact line-search algorithm (VMILA), a proximal-gradient method that enables the inexact computation of the proximal point defining the descent direction. By using both Poisson noisy simulated data and real data from fan-beam CT geometry, we evaluate the reconstruction performance of our approach and we compare it with the same framework with total variation (TV) as regularization term. In particular, we investigate which technique is more effective in recovering the desired features of the image and avoids unwanted artifacts. The results show that for real data the texture is reconstructed more accurately with the proposed nonsmooth shearlet-based approach, compared to the TV-based approach, without biasing the image towards a piecewise constant image model. Also, the proposed approach reveals to be insensitive to the location and the size of the ROI.

3.1.10 PET-MRI Joint Reconstruction by Joint Sparsity Based Tight Frame Regularization (Jae Kyu Choi)

Jae Kyu Choi, *Shanghai Jiao Tong University*
2017-05-26 17:10 - 17:50

Recent technical advances lead to the coupling of PET and MRI scanners, enabling to acquire functional and anatomical data simultaneously. In this talk, we present a tight frame (wavelet frame and data driven tight frame) based PET-MRI joint reconstruction model which exploits the structural similarity between two modalities. To exploit the structural similarity, our model inflicts the joint sparsity of tight frame coefficients. Our model adopts the balanced approach in the tight frame based image restoration to further take the different sparsity of different modality images into account. A proximal alternating minimization algorithm is proposed to solve the nonconvex and nondifferentiable model, and the global convergence is presented based on the Kurdyka-Lojasiewicz property.