Optimization in Image Processing
Workshop Program

Monday, June 27

9:30-10:20 Joachim Weickert, Saarland University

Title: "FSI Schemes: Fast Semi-Iterative Methods for Diffusive or Variational Image Analysis Problems"

Abstract: Many problems in image processing and computer vision require the efficient numerical solution of evolutions of diffusion type or variational models. In this talk we discuss a class of novel solvers for such tasks, so-called Fast Semi-Iterative (FSI) schemes. They are designed for a broad range of applications, while being easy to implement and well-suited for parallel computing. For the derivation of our algorithms, we establish a recursion relation that connects box filters at three different scales with an explicit scheme for 1D homogeneous diffusion filtering. Generalising this result allows us to accelarate explicit schemes for arbitrary diffusion processes as well as classical iterative solvers for linear or nonlinear systems of equations with symmetric positive definite system matrices. Moreover, our FSI schemes are capable of incorporating additional side-constraints. We show that they avoid the main drawbacks of recent Fast Explicit Diffusion (FED) schemes (Grewenig et al. 2010) and Fast Jacobi solvers (Weickert et al. 2016), and that they have an interesting connection to the Heavy Ball method in optimisation (Polyak 1964). We demonstrate the benefits of our schemes with image processing applications ranging from anisotropic diffusion inpainting to nonsmooth regularisation.

10:20-10:50am Break

10:50-11:40am Patrick Louis Combettes, Université Pierre et Marie Curie

Title: "Block-Iterative Asynchronous Variational Image Recovery"

Abstract: Block-iterative algorithms have been extensively used in image recovery problems formulated as convex feasibility problems. However block-iterative processing in more general convex optimization formulations found in image recovery remains an open problem. We propose a new class of proximal splitting problems that can be implemented in a block iterative fashion and, in addition, permit asynchronous implementations. Image recovery applications are discussed.

Based on joint work with J. Eckstein

11:40am-12:30pm Isao Yamada, Tokyo Institute of Technology

Title: "Spicing up Convex Optimization for Certain Inverse Problems"

Abstract: Many inverse problems in signal processing, such as signal denoising, deconvolution, signal interpolation, image restoration, have been cooked successfully with a unified recipe, the so-called proximal splitting algorithms for large scale convex optimization problems. The proximal splitting algorithms can iteratively approximate a solution, among

possibly many other solutions, of the minimization of the superposition of multiple smooth and/or nonsmooth convex functions. In this talk, we introduce two mathematical spices which further enhance the applicability of the proximal splitting algorithms. The first spice, the hybrid steepest descent method, evolves the proximal splitting algorithms by adding an advanced feature of the hierarchical optimization. The method allows to select a most desirable one, from the set of possibly infinite solutions, by minimizing another convex function over the solution set.

The second spice, the algebraic phase unwrapping, is a finite-step algorithm to compute continuous arguments of complex polynomials. Indeed, certain convex optimizations in spline function spaces, followed by the algebraic phase unwrapping, blazes a trail to the two-dimensional phase unwrapping which has been a long-standing bottleneck in various inverse problems.

12:30-2:30pm Lunch

2:30-3:20pm Fiorella Sgallari, University of Bologna

Title: "Majorization-Minimization for Nonconvex Optimization"

Abstract: A real captured image may be distorted by many expected or unexpected factors among which blur and random noise are typical and often unavoidable examples. Hence, image deblurring and denoising are fundamental tasks in the field of image processing and a plethora of approaches have been proposed throughout the last few decades. Several image restoration approaches such as nonlinear-diffusion partial differential equations based methods and variational approaches, succeeded in obtaining good quality edge preserving restorations, especially for noise removal.

Variational formulations are in general obtained by minimizing a functional which is the sum of a data fidelity term and a regularization term, based on a regularization operator chosen to yield a computed solution with some known desired features. A scalar parameter balances the influence of the fidelity and regularization terms on the computed solution in a suitable manner.
Many different proposed functionals are convex thus relying on the robust convex optimization theory. However, it has been shown that non-convex formulations hold the potential for higher quality results, at the cost of more challenging numerical solutions.

The idea of constructing and then optimizing convex functionals containing non-convex (sparsity-promoting) regularization terms, referred to as Convex-NonConvex (CNC) strategy is quite new. The attractiveness of such CNC approach resides in its ability to promote sparsity more strongly than is possible by using convex regularization while at the same time maintaining the convexity of the optimization problem, so that well-known reliable convex minimization approaches can be used to compute the (unique) solution.

A challenging approach is to provide numerical efficient solutions also for nonconvex nonsmooth functionals. At this aim, we will discuss an efficient optimization algorithm based on a majorization-minimization (MM) strategy. The MM algorithms are based on the principle of successively minimizing upper bounds of the objective function. Each upper bound, or surrogate function, constructed according to the CNC strategy, is locally tight at the current estimate, and each minimization step decreases the value of the objective functional. Analysis of convergence of the proposed approach are provided. Our

experiments show that our method is competitive with the state of the art for the solution of nonconvex minimization problem.

Joint work with Alessandro Lanza, Serena Morigi and Ivan Selesnick.

3:20-3:50pm Break

3:50-4:40pm Shoham Sabach, Israel Institute of Technology

Title: "A Framework for Globally Convergent Methods in Nonsmooth and Nonconvex Problems"

Abstract: Large scale nonsmooth and nonconvex optimization models arise in various data science paradigms. They induce many highly challenging mathematical and computational issues. In this talk, we outline a fairly general theoretical framework to derive globally convergent schemes. We then show how this framework can be successfully applied and adapted to design and analyze novel algorithms for various classes of nonsmooth and nonconvex models, by exploiting friendly structures and data information of the problem at hands. Numerical results will illustrate our findings.

Tuesday, June 28

9:30-10:20am Antonin Chambolle, CMAP, Ecole Polytechnique

Title: "Acceleration of alternating minimisations"

Abstract: I will discuss the possibility to accelerate (in the FISTA/Nesterov way) deterministic alternating minimisations or descent schemes, with as an application parallel algorithms for minimising the total variation.

10:20-10:50am Break

10:50-11:40am Mario Figueiredo, Instituto Superior Tecnico

Title: "ADMM in Image Restoration and Related Problems: Some History and Recent Advances"

Abstract: The alternating direction method of multipliers (ADMM) is an optimization tool of choice for several imaging inverse problems, namely due its flexibility, modularity, and efficiency. In this talk, I will begin by reviewing our earlier work on using ADMM to deal with classical problems such as deconvolution, inpainting, compressive imaging, and how we have exploited its flexibility to deal with different noise models, including Poissonian and multiplicative, as well as with several types regularizers (TV, frame-based analysis, synthesis, or combinations thereof). I will then describe more recent work on the use of ADMM for other problems, namely blind deconvolution and image segmentation, as well as very recent work where ADMM is used with plug-in learned denoisers to achieve state-of-the-art results in class-specific image deconvolution. Finally, on the theoretical front, I will describe very recent work on dealing with the infamous problem of adjusting the penalty parameter of ADMM.

11:40AM-12:30PM KE CHEN, UNIVERSITY OF LIVERPOOL

Title: "Image Restoration and Registration Based on Total Fractional-Order Variation Regularization"

Abstract: Regularization is one essential component for both restoration and registration models. In this talk, we propose and analyse a fractional-order derivative based nonlocal regulariser, which can reduce the staircase effect of the total variation based model and yet outperform the currently popular high order regularization models. Two applications are considered here: the blind deconvolution problem and the non-rigid image registration problem. Numerical experiments show that the proposed models can produce highly competitive results.

Joint work with Dr Jianping Zhang and Dr Bryan Williams, University of Liverpool Liverpool, UK.

12:30-2:30pm Lunch

2:30pm Discussions

WEDNESDAY, JUNE 29

9:30-10:20AM ALFRED HERO, UNIVERSITY OF MICHIGAN

Title: "Continuum relaxations for discrete optimization"

Abstract: Many applications in imaging are formulated as solutions to a discrete optimization problem over a database of images. Examples include image indexing by computing spanning graphs over the database, representing intrinsic geometry by computing minimal paths between image pairs, and image search and retrieval by computing nearest neighbor matches to a query. Sometimes solutions to the discrete optimization problem can be approximated by the solution to a continuous optimization problem over a continuous domain, e.g., integrals and differential equations. This can lead to continuum relaxations for such discrete optimization problems.

10:20-10:50am Break

10:50-11:40AM WOTAO YIN, UCLA

Title: "Coordinate Update Algorithms for Computational Imaging and Machine Learning"

Abstract: This talk focuses on a class of algorithms, called coordinate update algorithms, which are useful at solving large-sized problems involving linear and nonlinear mappings, and smooth and nonsmooth functions. They decompose a problem to simple subproblems, where each subproblem updates one, or a small block of, variables each time. They have found applications throughout signal/imaging processing, differential equations, and machine learning. We abstract many problems to the fixed-point problem $x^{k+1}=Tx^k$. This talk discusses the favorable structures of the operator T that enable highly efficient coordinate update iterations. It can be carried out in sequential, parallel, or async-parallel

fashions. We introduce new scalable coordinate-update algorithms to many problems involving coupling constraints Ax=b, composite nonsmooth functions f(Ax), and large-scale data. We will present a software package and its numerical examples. This is joint work with Zhimin Peng and Tianyu Wu (UCLA), Yangyang Xu (IMA), and Ming Yan (MSU).

11:40am-12:30pm Mila Nikolova, Ecole Normale Superieure Cachan

Title: "Limits on noise removal using log-likelihood and regularization"

Abstract: Many imaging tasks are defined as the solution of a compound optimization problem where a data term is based on the log-likelihood and a prior model on the sought-after object is incorporated in a regularization term.

We will show that in general the obtained solution deviates from both the noise and the image models. Thus the residual does not follow the noise model and noise features remain in the solution. We emphasize that following the precise noise model via the log-likelihood function does not entail (good) noise removal in the optimal solution. These facts will be exemplified in the context of different noises and priors. Furthermore, useful tools for inverse modelling are thus exhibited. We will give a flavor of the rich possibilities offered by inverse modeling.

12:30-2:30pm Lunch

2:30-3:20pm Martin Benning, University of Cambridge

Title: "Nonlinear spectral decompositions and the inverse scale space method"

Abstract: This talk deals with applications and a deeper analysis of a novel type of spectral decomposition based on the inverse scale space method. We are going to present several of its applications in image processing, ranging from (automated) image fusion to artistic image manipulations and tone mapping. The second part of the talk will address theoretical issues of the spectral decomposition method, respectively the underlying inverse scale space method. In particular are we going to address the question under which conditions a sum of generalised singular vectors can be recovered via this method.

3:20-3:50pm Break

3:50-4:40pm Ronald Lok Ming Lui, The Chinese University of Hong Kong

Title: "TEMPO: Feature-endowed Teichmuller extremal mappings of point cloud for shape classification"

In recent decades, the use of 3D point clouds has been widespread in computer industry. The development of techniques in analyzing point clouds is increasingly important. In particular, mapping of point clouds has been a challenging problem. In this talk, I will introduce a discrete analogue of the Teichmuller extremal mappings, which guarantees uniform conformality distortions, on point cloud surfaces. Based on the discrete analogue, we develop a novel method called TEMPO for computing Teichmuller extremal mappings between feature-endowed point clouds. Using our proposed method, the Teichmuller metric can be computed for evaluating the dissimilarity of point clouds. Consequently, our algorithm enables accurate recognition and classification of point clouds. Experimental results will be demonstrated to show the effectiveness of our proposed method.

Thursday, June 30

9:30-10:20 Jin Keun Seo, Yonsei University

Title: "Mathematical methods for biomedical impedance imaging"

Abstract: Recent bioimpedance imaging studies including EIT, MREIT and EPT combine advanced knowledge and techniques from a wide range of fields including bioelectro-magnetism, partial differential equations, scientific computing, and MR physics. Their mathematical models are expressed as nonlinear inverse problems involving time-harmonic Maxwell's equations with electrical tissue properties being described by frequency-dependent conductivity and permittivity. Solving the inverse problems with practical significance requires deep knowledge on underlying physical mechanisms, image reconstruction algorithms, uncertainties in modeling, and practical limitations associated with the measurement sensitivity, specificity, noise, data acquisition time, and so on. My talk will focus on these limitations with reviewing a number of issues in electrical tissue property imaging modalities.

10:20-10:50am Break

10:50-11:40am Gabriele Steidl, Kaiserslautern University of Technology

Title: "Iterative Multiplicative Filters for Data Labeling"

Abstract: We propose a new iterative multiplicative filtering method for label assignment matrices which can be used for the supervised partitioning of data. Starting with a row-normalized matrix containing the averaged distances between the prior data and the observed ones the method assigns in a very efficient way labels to the data which are unique under mild assumptions. From another point of view each iteration step can be understood as finding the weighted barycenters of the previous iterates with respect to the Kullback-Leibler distance on the probability simplex. We prove the convergence of our method. Numerical examples show that the proposed simple and fast algorithm leads to very good results. In particular we apply the method for the partitioning of manifold-valued images.

This is joint work with Ronny Bergmann, Jan Henrik Fitschen, and Johannes Persch

11:40am-12:30pm Raymond Chan, The Chinese University of Hong Kong

Title: "Point-spread function reconstruction in ground-based astronomy"

Abstract: Because of atmospheric turbulence, images of objects in outer space acquired via ground-based telescopes are usually blurry. One way to estimate the blurring kernel or point spread function (PSF) is to make use of the aberration of wavefronts received at the telescope, i.e., the phase. However only the low-resolution wavefront gradients can be collected by wavefront sensors. In this talk, I will discuss how to use regularization methods to reconstruct high-resolution phase gradients and then use them to recover the phase and the PSF in high accuracy.