# Optimization Methods in Computer Vision and Image Processing

Poster Session Abstracts
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**Learning to optimize multigrid PDE solvers**
Daniel Greenfeld, Weizmann Institute of Science

Constructing fast numerical solvers for partial differential equations (PDEs) is crucial for many scientific disciplines. A leading technique for solving large-scale PDEs is using multigrid methods. At the core of a multigrid solver is the prolongation matrix, which relates between different scales of the problem. This matrix is strongly problem-dependent, and its optimal construction is critical to the efficiency of the solver. In practice, however, devising multigrid algorithms for new problems often poses formidable challenges. In this paper we propose a framework for learning multigrid solvers. Our method learns a (single) mapping from discretized PDEs to prolongation operators for a broad class of 2D diffusion problems. We train a neural network once for the entire class of PDEs, using an efficient and unsupervised loss function. Our tests demonstrate improved convergence rates compared to the widely used Black-Box multigrid scheme, suggesting that our method successfully learned rules for constructing prolongation matrices.

**Sparse Multi-task Inverse Covariance Estimation for Connectivity Analysis in EEG Source Space**
Feng Liu, Harvard Medical School

Understanding how different brain areas interact to generate complex behavior is a primary goal of neuroscience research. One approach, functional connectivity analysis, aims to characterize the connectivity patterns within brain networks.
In this research, we address the problem of discriminative connectivity, i.e. determining the differences in network structure under different experimental conditions. We introduce a novel model called Sparse Multi-task Inverse Covariance Estimation (SMICE) which is capable of estimating a common connectivity network as well as discriminative networks across different tasks. We apply the method to EEG signals after solving the inverse problem of source localization, yielding networks defined on the cortical surface. We propose an efficient algorithm based on the Alternating Direction Method of Multipliers (ADMM) to solve SMICE. We apply our newly developed framework to find common and discriminative connectivity patterns for alpha-oscillations during the Sleep Onset Process (SOP) and during Rapid Eye Movement (REM) sleep. Even though both stages exhibit a similar alpha-oscillations, we show that the underlying networks are distinct.

**Exact Support Recovery with Coordinate-Projection Admissible Constraints**
Seyedahmad Mousavi, University of Maryland, Baltimore County

An attractive approach to tackle sparse optimization problems are greedy algorithms, for example, the most popular one, Orthogonal Matching Pursuit (OMP). Starting from zero, OMP picks an appropriate index in each step to add its corresponding column of the measurement matrix to the set of columns chosen before and then computes the orthogonal projection of the measurement vector onto this set as the new estimate. This method benefits from its simplicity of implementation and the low number of required computations.
A revised version of OMP that seeks for the sparsest nonnegative solution of an underdetermined linear system is also recently studied.

In general, assuming that a desired set $C$ contains zero (this assumption is reasonable in sparse optimization), the following generalized version of OMP manages to find a sparse feasible point $x$ for which $\|y-Ax\|_2$ is small (if existed). With this knowledge that a $k$-sparse vector of interest exists, I found an applicable convergence condition when $C$ is coordinate-projection admissible, that is, for a given $x \in C$ and $ J\subset {supp(x)}$, we have $(x_{J}, 0) \in C$. In other words, this condition imposes that in each step of the algorithm, a correct index is selected, and consequently the signal of interest is sought through the projection idea after at most $k$ steps. Trivial examples that inherit this property are the whole space and the nonnegative cone so my results not only recover these important cases obtained in the literature but also show the possibility of finding the correct support set for other interesting types of constraints by giving meaningful and useful convergence conditions that are indeed related to the standard RIP constants.

**SparsePPG: Towards Driver Monitoring Using Camera-Based Vital Signs Estimation in Near-Infrared**

Ewa Nowara, Rice University

Camera-based measurement of the heartbeat signal from minute temporal changes in the intensities of a person's skin is known as remote photoplethysmography (rPPG). Methods for rPPG have improved considerably in recent years, achieving sufficient accuracy to be used in clinical settings. Unfortunately, there are several challenges unique to the driver monitoring context that must be overcome for rPPG monitoring to be feasible in the car. First, there are drastic illumination changes on the driver's face, which significantly corrupts rPPG measurements. We argue that these variations are significantly reduced by narrow-bandwidth near-infrared (NIR) active illumination at 940 nm, with matching bandpass filter on the camera. Second, the amount of motion during driving is significant and false peaks due to motion have the potential to confound the rPPG signal. To address these challenges, we develop a novel rPPG signal tracking and denoising algorithm (SparsePPG) based on Robust Principal Components Analysis to leverage low-rankness of the rPPG signals and sparse frequency spectrum estimation to recover the quasiperiodic rPPG signals buried in noise. We demonstrate that our new method performs better than current state-of-the-art rPPG algorithms both in RGB and NIR video recordings. While driver vital signs monitoring using NIR cameras is promising, much work needs to be done to improve robustness to motion artifacts before it becomes practical.

**Determinantal Ideals in Multiview Geometry**

Andrew Pryhuber, University of Washington

The set of images of a common real-world point under a collection of cameras forms a quasi-projective variety. The closure of all such points is the multiview variety and its vanishing ideal is the multiview ideal of the camera configuration. We investigate the algebraic structure of the multiview ideal for both generic and non-generic arrangements of cameras and the potential implications for practitioners in computer vision.

**Joint registration and Bias field correction**

Afzal Rahman, University of Buner

How to connect image registration and bias field correction, and some experimental result which shows that a new image registration model using NGF and LC perform well under a strong bias field, fast and accurate in comparison with the existing models.

**Efficient Seismic Event Detection using Robust Principal Component Analysis**
Ningyu Sha, Michigan State University

There are many methods to detect seismic events based on the property of signal and noise. Signals received at different receivers are correlated, and they lie in a low dimensional space. Therefore, dimension reduction techniques are utilized to model signals. Robust Principle Component Analysis (RPCA) is one of them. Here we combine infimal convolution and fast iterative soft-thresholding algorithm (FISTA) to obtain a new algorithm with 3x-20x faster than existing ones. We also used different nonconvex penalties to improve the performance.

**Probabilistic relaxation approach to loopy beleief propagation**
Billy Braithwaite, University of Jyväskylä

A (computationally) cheap probabilistic relaxation approach for solving MAP estimation in loopy belief propagation is presented. By evaluating the semblance (or coherency) by non-local estimations, the approach gives a fresh way for evaluating data costs and neighborhoods in a generalized graph setting. Applications in image restoration is presented.