Minerva Conference on Computational Challenges in Large Scale Image Analysis

16-18 February 2015

Program:

	Monday, Feb 16	Tuesday, Feb 17	Wednesday, Feb 18
Morning	09:00 Yair Weiss	09:00 Daniel Cremers	09:00 Stefan Roth
	09:45 Kristian Kersting	09:45 Bogdan Savchynskyy	09:45 David Jacobs
	10:30 Coffee Break	10:30 Coffee Break	10:30 Coffee Break
	11:00 Shai Shalev-Shwartz	11:00 Yaron Lipman	11:00 Fred Hamprecht
	11:45 Alexander Kolesnikov	11:45 Jan Lellmann	11:45 Gabriele Steidl
	12:30 Lunch Break		12:30 Lunch Break
Afternoon	14:30 Shai Avidan	Afternoon: Trip to Jerusalem	14:00 Christoph Lampert
	15:15 Boaz Nadler		14:45 Michael Hirsch
	15:30 Coffee Break		15:30 Coffee Break
Evening	16:30 Poster Session		16:00 Open time for discussions
	18:30 Conference Dinner		18:00 Conference Dinner

Titles and Abstracts:

Yair Weiss: Learning Optical Flow

In recent years "pure learning" methods that have very little built-in knowledge about images have achieved state-of-the-art performance in image restoration tasks (e.g. denoising, deblurring) and outperfomed many hand designed approaches.. I will present work-in-progress that asks whether a similar approach can also work for optical flow. Our preliminary results suggest that "pure learning" methods yield high quality energy functions (arguably better than handcrafted ones) but optimizing these energy functions still requires image specific knowledge.

Joint work with Dan Rosenbaum.

Kristian Kersting: Relational Linear Programming

In this talk I shall present relational linear programming, a simple framework for combing linear programs (LPs) and logic programs.
A relational linear program (RLP) is a declarative LP template defining the objective and the constraints through the logical concepts of objects, relations, and quantified variables. This allows one to express the LP objective and constraints relationally for a varying number of individuals and relations among them without enumerating them.
Together with a logical knowledge base, effectively a logical program consisting of logical facts and rules, it induces a ground LP. This ground LP is solved using lifted linear programming. That is, symmetries within the ground LP are employed to reduce its dimensionality, if possible, and the reduced program is solved using any off-the-shelf LP solver. In contrast to mainstream LP template languages such as AMPL, which features a mixture of declarative and imperative programming styles, RLP's relational nature allows a more intuitive representation of optimization problems, in particular over relational domains. I shall illustrate this empirically by experiments on approximate inference in Markov logic networks using LP relaxations, on solving Markov decision processes, and on collective inference using LP support vector machines.

Joint work with Martin Mladenov and Pavel Tokmakov and based on previous joint works together with Babak Ahmadi, Martin Grohe and Aziz Erkal Selman.

Shai Shalev-Shwartz: On the Computational Complexity of Deep Learning

It is well-known that deep networks are computationally hard to train. On the other hand, in practice, modern day deep networks are trained efficiently using SGD and a variety of tricks that include different activation functions (e.g. ReLU), over-specification (i.e., train networks which are larger than needed), and regularization. I will revisit the computational complexity of training deep networks from a modern perspective, providing both positive and negative results, some of them yield new provably efficient and practical algorithms for training certain types of neural networks. Joint work with Roi Livni and Ohad Shamir.

Alexander Kolesnikov: Gaussian processes for assessing the quality of training data for large-scale image segmentation

In this work we present a learning method for the semantic image segmentation task in which some amount of segmentation masks in a training data may have poor quality. This is a realistic scenario that occurs, for example, when one uses Amazon Mechanical Turk to annotate training images or automatic tools to facilitate segmentation process. We propose a learning method that automatically determines the quality of segmentation masks in the training data and incorporates this in the training procedure. At the heart of our approach lie Gaussian processes (GP). Their probabilistic nature allows us to obtain and treat the quality of segmentation masks in a principled way. The power of GPs comes with a computational expense: in general, the time complexity of the training scales cubically with a number of training objects.
We, however, exploit the special case of GP with low-rank kernel matrix and present the learning algorithm with the time complexity scales linearly with a number of images and does not depend on a number of semantic classes. Empiri cal experiments on contemporary datasets with tens of thousands of images demonstrate the usefulness of our approach.

Shai Avidan: FAsT-Match: Fast Affine Template Matching

Fast-Match is a fast algorithm for approximate template matching under 2D affine transformations that minimizes the Sum-of-Absolute-Differences (SAD) error measure. There is a huge number of transformations to consider but we prove that they can be sampled using a density that depends on the smoothness of the image. For each potential transformation, we approximate the SAD error using a sublinear algorithm that randomly examines only a small number of pixels. We further accelerate the algorithm using a branch-and-bound scheme. As images are known to be piecewise smooth, the result is a practical affine template matching algorithm with approximation guarantees, that takes a few seconds to run on a standard machine. We perform several experiments on three different datasets, and report very good results. To the best of our knowledge, this is the first template matching algorithm which is guaranteed to handle arbitrary 2D affine transformations.

Joint work with: Simon Korman, Daniel Reichman and Gilad Tsur

Boaz Nadler: Edge Detection on a computational budget: a sub-linear approach

Edge Detection is an important task in image analysis. Various applications require real-time detection of long edges in large noisy images. Motivated by such settings, in this talk we'll address the following question: How well can one detect long edges under severe computational constraints that allow only a fraction of all image pixels to be processed?

We present fundamental lower bounds on edge detection in this setup, a sublinear algorithm for long edge detection and a theoretical analysis of the inevitable tradeoff between its detection performance and the allowed computational budget. The competitive performance of our algorithm will beillustrated on both simulated and real images.

Joint work with Inbal Horev, Meirav Galun, Ronen Basri (Weizmann)and Ery Arias-Castro (UCSD).

Daniel Cremers: Convex Relaxation Methods for Computer Vision

Numerous problems in computer vision and image analysis can be solved by variational methods and partial differential equations. Yet, many traditional approaches correspond to non-convex energies giving rise to suboptimal solutions and often strong dependency on appropriate initialization. In my presentation, I will show how problems like image segmentation, multiple view reconstruction, optical flow estimation and 3D shape matching can be tackled by means of convex relaxation methods. Subsequently, I will introduce methods of convexification which allow to efficiently compute globally optimal or near-optimal solutions. The arising convex problems can be solved by means of provably convergent primal-dual algorithms. They are easily parallelized on GPUs providing high-quality solutions in acceptable runtimes.

This is joint work with Kalin Kolev, Martin Oswald, Evgeny Strekalovskiy, Thomas Windheuser, Thomas Pock, Bastian Goldlücke, Jan Lellmann and Antonin Chambolle.

Bogdan Savchynskyy: Global MAP-Optimality by Shrinking the Combinatorial Search Area with Convex Relaxation.

We consider energy minimization for undirected graphical models, also known as the MAP-inference problem for Markov random fields. Although combinatorial methods, which return a provably optimal integral solution of the problem, made a significant progress in the past decade, they are still typically unable to cope with large-scale datasets. On the other hand, large scale datasets are often defined on sparse graphs and convex relaxation methods, such as linear programming relaxations then provide good approximations to integral solutions.
We propose a novel method of combining combinatorial and convex programming techniques to obtain a global solution of the initial combinatorial problem. Based on the information obtained from the solution of the convex relaxation, our method confines application of the combinatorial solver to a small fraction of the initial graphical model, which allows to optimally solve much larger problems.
We demonstrate the efficacy of our approach on a computer vision energy minimization benchmark.

Yaron Lipman: Bounded Distortion Mappings in Geometry and Image Processing

In this talk we will introduce a special type of simplicial mappings of two and three dimensional meshes called Bounded Distortion Mappings and explore their theoretical properties and applications in geometry and image processing.

Jan Lellmann: Variational models with finite and infinite label spaces

In this talk we consider energy minimization problems where the goal is to identify a function that maps from some domain into a non-convex set (the "label space"). An important class is the case where the label space is finite, and the problem essentially becomes a partitioning problem. Such problems naturally occur in the context of image segmentation, 3D reconstruction, detection and recognition, and many other problems in image processing and computer vision. In order to solve them, we solve a convex relaxation instead, and show that the solution of the relaxed problem approximated the actual solution within a certain bound of the energy. We also extend these relaxation methods to problems where the data lives on a manifold, such as angular, directional, or orientation data. By taking the manifold structure into account we can construct solutions that are more accurate than the ones obtained with the naive labeling approach and avoid discretization artifacts

Stefan Roth "Scaling Image Restoration to Large Images"

Many state-of-the-art image restoration approaches do not scale well to larger images, such as megapixel images common in the consumer segment. Computationally expensive optimization is often the culprit. While efficient alternatives exist, they have not reached the same level of image quality. In this work we aim to develop an effective approach to image restoration that offers both computational efficiency and high restoration quality. I will introduce shrinkage fields, a random field-based architecture that combines the image model and the optimization algorithm in a single unit. The underlying shrinkage operation bears connections to wavelet approaches, but is used here in a random field context. Computational efficiency is achieved by construction through the use of convolution and DFT as the core computational components; high restoration quality is attained through loss-based training of all model parameters and the use of a cascade architecture. Unlike heavily engineered solutions, our learning approach can be adapted easily to different trade-offs between efficiency and image quality. Moreover, our discriminative framework is directly descended from principled, but inefficient generative models. Our method leads to state-of-the-art restoration results with high levels of computational efficiency, and significant speedup potential through inherent parallelism.

David Jacobs: Part Detection and Species Identification

Species identification is an interesting example of fine-grained classification, in which an object must be assigned to one of a large number of very similar classes. It is also a problem with many practical applications that evokes great interest in the general public. I will describe a series of work that we have done aimed at using automatic recognition in field guides for species identification in a variety of domains.

One of the core technical problems in fine-grained classification is the identification of the parts of animals. This allows us to make meaningful comparisons between objects from similar animals. I will first describe our work on part detection using a non-parametric model of part configurations called a consensus of exemplars. We have applied this to the detection of fiducial points on human faces, and to the detection of animal parts. Then I will explain how these parts

can be used for fine-grained classification of animal species. We experiment with this approach using dog breeds as a model problem. The resulting system is displayed in our iphone app Dogsnap, which uses visual classification to determine the breed of dog in a photograph. Similar ideas have also been used to develop Birdsnap, which also uses species distribution data to provide a practical field guide to birds. Finally, I will describe our earlier work developing Leafsnap, the first mobile app for identifying plant species using automatic visual recognition. Leafsnap has been downloaded by over a million users and has been used in many classrooms and in biodiversity studies.
This work has been done in collaboration with many people at Columbia University and the Smithsonian Institution National Museum of Natural History.

Fred Hamprecht: The asymmetric cut, and efficient inference for the multiway cut

The asymmetric cut is a segmentation model that takes into account both boundary and region label evidence. Unlike the multiway cut, it allows active boundaries also between same-label regions, in keeping with requirements from natural image partitioning. I will illustrate the usefulness of the model in connectomics, a difficult segmentation problem from the neurosciences. Finally, I will discuss the currently fastest heuristic approximation for the NP-hard multiway cut / correlation clustering problem.

Joint work with Thorben Kroeger, Thorsten Beier, Joerg Kappes, Niko Krasowski, Anna Kreshuk, Ullrich Koethe.

Gabriele Steidl: Second Order Differences of Cyclic Data and Applications in Variational Denoising

In many image and signal processing applications, as interferometric synthetic aperture radar (SAR), electroencephalogram (EEG) data analysis, ground based astronomy, and color image restoration in HSV or LCh spaces the data has its range on the one-dimensional sphere. Although the minimization of total variation (TV) regularized functionals is among the most popular methods for edge-preserving image restoration such methods were only very recently applied to cyclic structures. However, as for Euclidean data, TV regularized variational methods suffer from the so called staircasing effect. This effect can be avoided by involving higher order derivatives into the functional.
This is the first paper which uses higher order differences of cyclic data in regularization terms of energy functionals for image restoration. We update the cyclic variational TV approach by our new cyclic second order differences. To minimize the corresponding functional we apply a cyclic proximal point method which was recently successfully proposed for Hadamard manifolds. Choosing appropriate cycles this algorithm can be implemented in an efficient way. The main steps require the evaluation of proximal mappings of our cyclic differences for which we provide analytical expressions. Under certain conditions we prove the convergence of our algorithm. Various numerical examples with artificial as well as real-world data demonstrate the advantageous performance of our algorithm.
Joint work with R. Bergmann, F. Laus (University of Kaiserslautern), and A. Weinmann (University of Munich).

Christoph Lampert: Classifier Adaptation at Prediction Time

In the era of "big data" and a large commercial interest in computer vision, it is only a matter of time until we will buy commercial object recognition systems in pre-trained form instead of training them ourselves. This, however, poses a problem of domain adaptation: the data distribution in which a customer plans to use the system will almost certainly differ from the data distribution that the vendor used during training. Two relevant effects are a change of the class ratios and the fact that the image sequences that needs to be classified in real applications are typically not i.i.d. In my talk I will introduce simple probabilistic technique that can adapt the object recognition system to the test time distribution without having to change the underlying pre-trained classifiers. I will also introduce a framework for creating realistically distributed image sequences that offer a way to benchmark such adaptive recognition systems. Our results show that the above "problem" of domain adaptation can actually be a blessing in disguise: with proper adaptation the error rates on realistic image sequences are typically lower than on standard i.i.d. test. sets.

Michael Hirsch: Imaging the Invisible Universe - Tracing Dark Matter

Cosmology aims at the understanding of the universe and its evolution through scientific observation and experiment and hence addresses one of the most profound questions of human mankind. With the establishment of robotic telescopes and wide sky surveys cosmology already now faces the challenge of evaluating vast amount of data. Several projects will image large fractions of the sky in the next decade; for example the Dark Energy Survey will culminate in a catalogue of 300 million objects extracted from peta-bytes of observational data, while the Large Synoptic Survey Telescope is designed to image the entire observable Southern sky every few nights for 10 years. The importance of automatic data evaluation and image analysis tools for the success of these surveys is undisputed.

In this talk I will give a brief overview of the computational challenges related to weak gravitational lensing, one of the most promising methods to trace dark matter, a yet unknown kind of matter whose existence is nonetheless widely accepted within the scientific community. A peculiar property of dark matter is that it cannot be seen with telescopes, yet it accounts for most of the matter in the Universe. This fact renders dark matter one of the greatest mysteries in modern cosmology.