Shape, Imaging and Optimization

General information:

Welcome to the 3rd Applied Mathematics Symposium in Münster:

Shape, Imaging and Optimization

Information on the schedule and the talks of the workshop is provided on the following pages. All talks take place in our seminar building (map A, no. 5) in room SRZ 19. Below we provide some information on the activities of the workshop.

We have a lunch break on Wednesday and Thursday from 12:30 p.m. until 2:00 p.m. During lunch there will be a poster-session in the main hall of the seminar building (map A, no. 5).

On Wednesday, for those who have signed up there is a guided city tour at 6:30 p.m. The meeting point is the "Domplatz" in Münster (see map B).

The conference dinner, if you signed up for it, takes place on Thursday at 6.30 p.m. in the A2 restaurant at Aasee Münster (see map C).

Wifi access is available. The password will be provided during the workshop. Alternatively, if you are part of the eduroam community, you may connect to the network "eduroam" as usual.

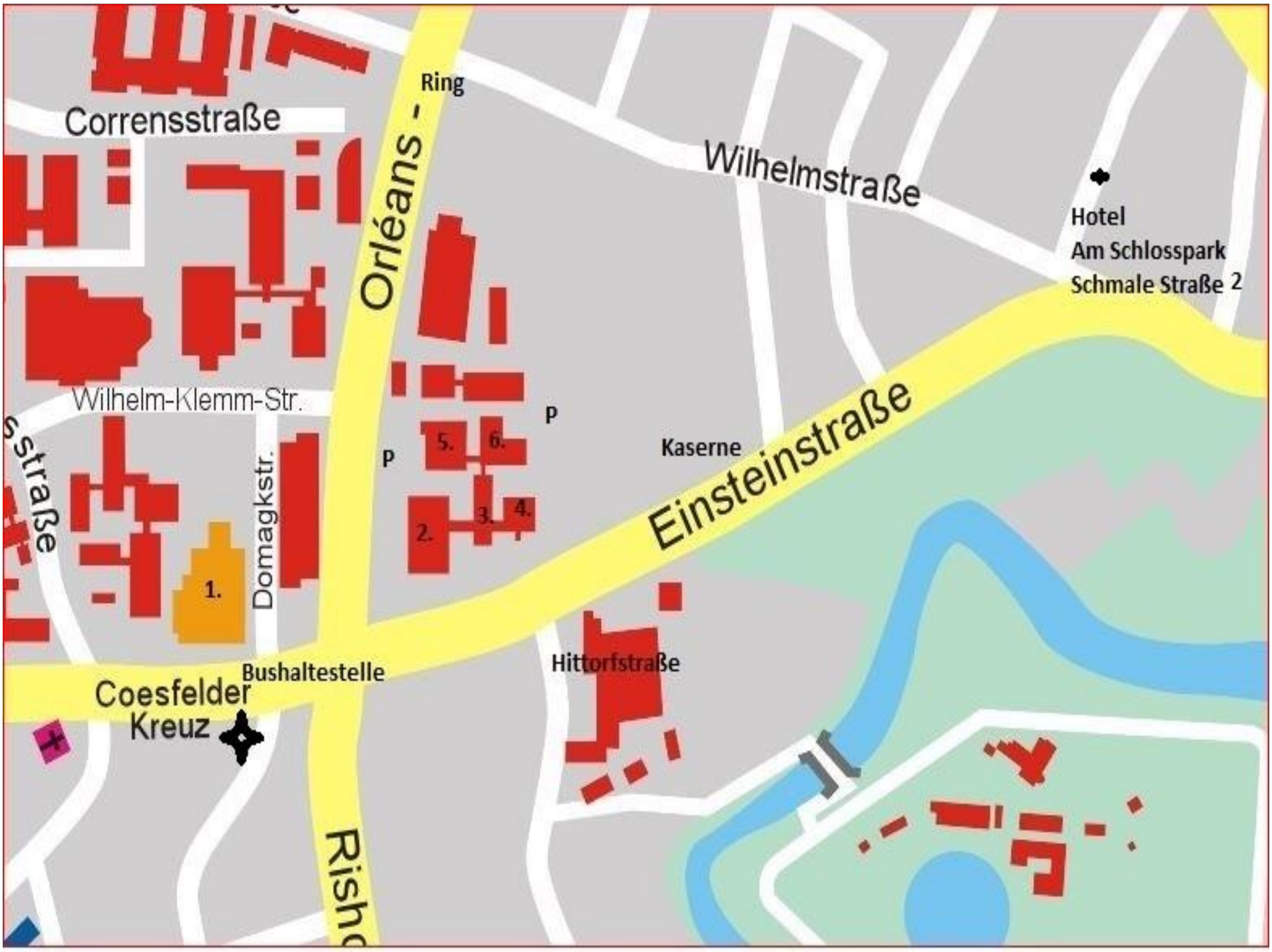
Information for speakers:

You may use your own notebook and pointer for your presentation or the ones provided in the lecture room.

Please make sure that everything works before your actual talk (e.g. during one of the coffee/lunch breaks before your session).

In case of questions, we are happy to assist you. You find contact persons at the registration desk during the breaks.

Map A: University of Münster

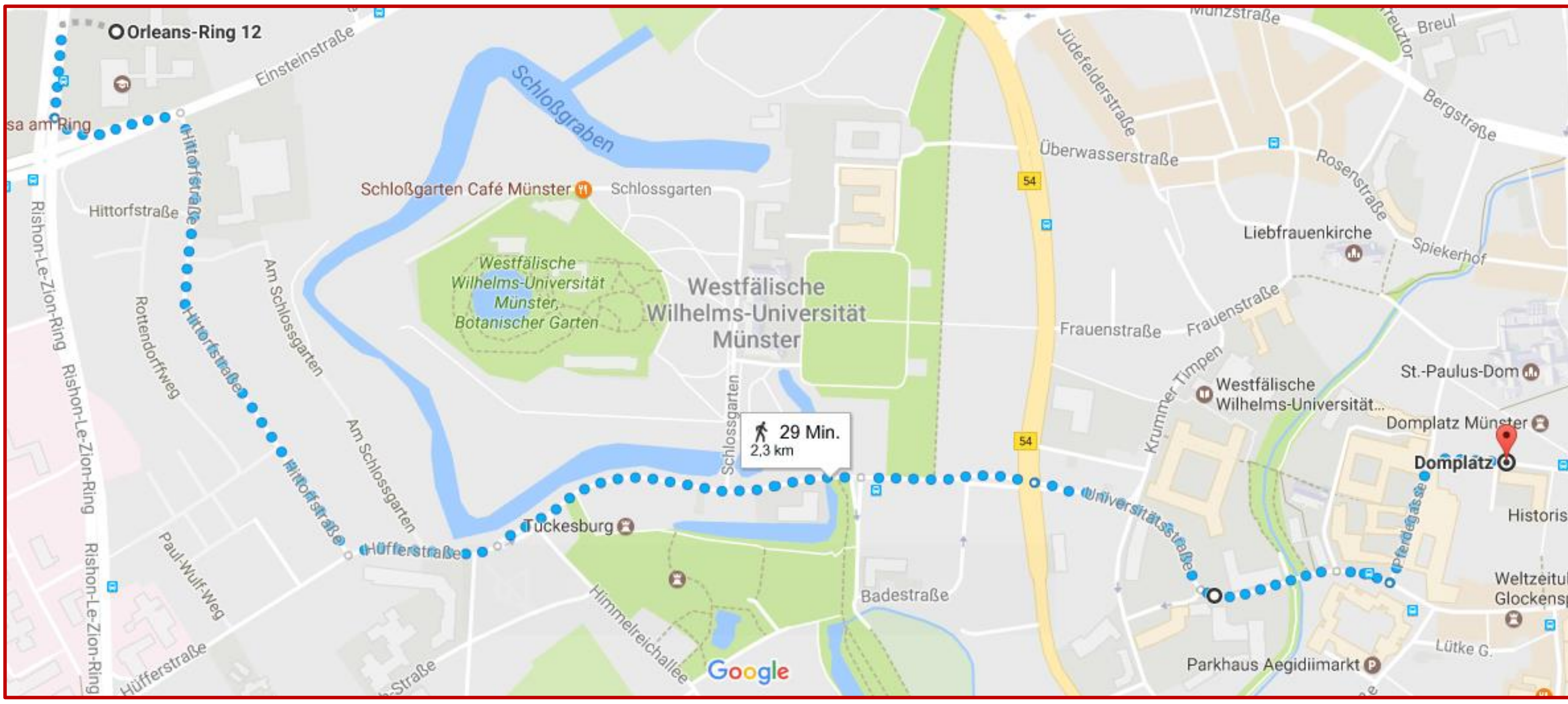


1. Mensa/canteen
2. Hörsaalgebäude / Lecture Hall — Einsteinstr. 64
3. Hochhaus Mathematik/Informatik / highrise Mathematics/ Informatics — Einsteinstr. 62
4. ZIV
5. Seminargebäude / seminar building — Orléansring 12
6. Angewandte Mathematik / Applied Mathematics — Orléansring 10

P- Parkplatz / parking

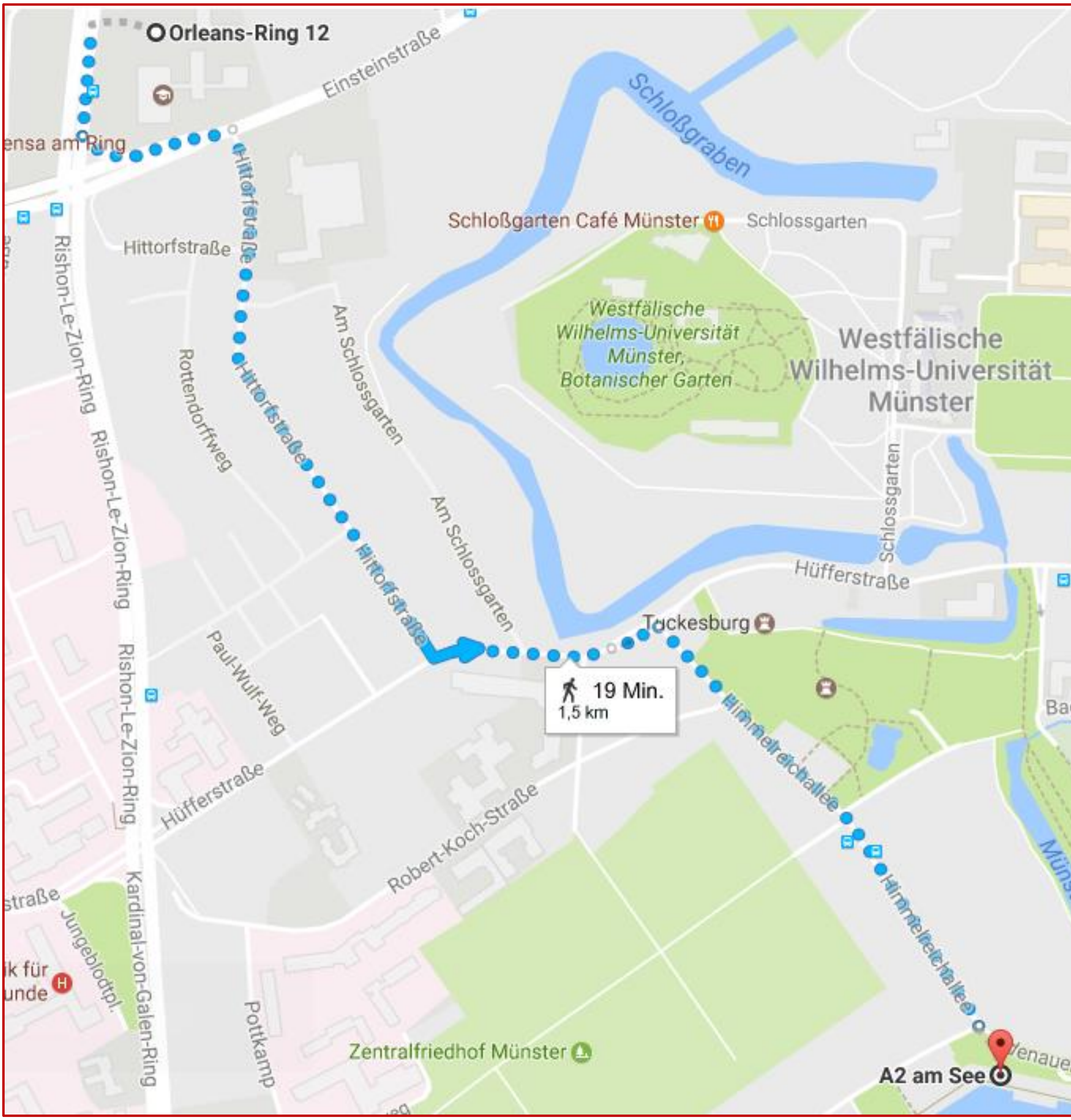
* Bushaltestelle Coesfelder Kreuz / bus stop Coesfelder Kreuz

Map B: City Tour



The meeting point for the city tour is in front of the entrance to the cathedral on the "Domplatz", 20 minutes walking distance from the seminar building (alternatively, you can take bus no. 13 from Coesfelder Kreuz, platform B2, in direction Münster Hauptbahnhof/Hbf and get off at Aegidiimarkt/LWL Museum).

Map C: Conference Dinner



The restaurant is 15 minutes walking distance from the seminar building (take Hittorfstraße, Hüfferstraße, Himmelreichallee). Its address is: Annette-Allee 3, 48149 Münster

Tuesday, Feb 28 Time	Speaker / Program	Title
13:00	Registration Main Hall, Seminar building (map A, no.5)	
13:50-14:00	Welcome address	
14:00-14:40	Gabriele Steidl (TU Kaiserslautern)	Restoration Methods for Manifold-Valued Images
14:40-15:20	Andreas Weinmann (TU München)	Edge preserving variational methods for manifold valued data
15:20-15:40	José Iglesias (Johann Radon Institute, Linz)	A level set method for the matching of implicit surfaces
15:40-16:10	Coffee break	
16:10-16:50	Francis Bach (École Normale Supérieure)	Stochastic Variance Reduction Methods for Saddle-Point Problems
16:50-17:30	Silvia Bonettini (Universita di Ferrara)	Variable metric forward-backward methods for convex and non convex optimization

Wednesday, March 1 Time	Speaker / Program	Title
09:00-09:40	Marc Teboulle (Tel Aviv University)	A Novel Framework for First Order Methods with Non-Lipschitz Continuous Gradient
09:40-10:20	Tuomo Valkonen (University of Liverpool)	Block-proximal methods for image processing
10:20-10:50	Coffee break	
10:50-11:10	Christoph Vogel (TU Graz)	A Neural Inference Machine for Low-Level Vision Problems
11:10-11:50	Hugues Talbot (ESIEE Paris)	Image restoration using a Discrete Calculus formulation of the Ambrosio-Tortorelli functional
11:50-12:30	Jalal Fadili (Université de Caen)	Exponential weighted aggregation vs penalized estimation: theoretical guarantees and algorithms
12:30-14:00	Lunch & Posters	
14:00-14:40	Andrea Mennucci (Scuola Normale Superiore)	Designing metrics for curves
14:40-15:20	Simon Masnou (Université Lyon 1)	Volume reconstruction from slices
15:20-15:40	Thomas Möllenhoff (TU München)	Sublabel-Accurate Relaxation of Nonconvex Energies
15:40-16:10	Coffee break	
16:10-16:50	Dirk Lorenz (TU Braunschweig)	Optimization methods for optimal transport in imaging
16:50-17:30	Filippo Santambrogio (Université Paris Sud)	A fractal shape optimization problem in branched transport
18:30-20:00	Guided city tour	for those who signed up

Thursday, March 2 Time	Speaker / Program	Title
09:00-09:40	Grégoire Allaire (École Polytechnique)	On the mathematical modelling of some manufacturing constraints in topology optimization of structures
09:40-10:20	Kathrin Welker (University of Trier)	PDE Constrained Shape Optimization in Shape Spaces
10:20-10:50	Coffee Break	
10:50-11:10	Jura Malitsky (TU Graz)	A first-order primal-dual algorithm with linesearch
11:10-11:50	Barbara Kaltenbacher (University of Klagenfurt)	Minimization based formulation of inverse problems and their regularization
11:50-12:10	Felix Lucka (University of Cambridge)	Enhancing Compressed Sensing Photoacoustic Tomography by Simultaneous Motion Estimation
12:10-12:30	Michael Möller (University of Siegen)	Following the solution paths: Homotopy and inverse scale space methods for sparse recovery
12:30-14:00	Lunch & Posters	
14:00-14:40	Francois-Xavier Vialard (Université Paris-Dauphin)	Unbalanced optimal transport and its link to fluid dynamics
14:40-15:20	Carola Schönlieb (University of Cambridge)	Anisotropic surface interpolation
15:20-15:40	Luca Calatroni (École Polytechnique)	Infimal convolution of data discrepancies for mixed noise removal in images
15:40-16:10	Coffee break	
16:10-16:50	Olivier Fercoq (École Nationale Supérieure des Télécommunications)	A smooth Prima-Dual Optimization Framework for Nonsmooth Composite Convex Minimization
16:50-17:30	Shoham Sabach (Technion)	First Order Methods for Solving Convex Bi-Level Optimization Problems
18:30	Conference dinner	

Friday, March 3 Time	Speaker / Program	Title
09:00-09:40	Martin Rumpf (University of Bonn)	A Posteriori Error Control for the Binary Mumford-Shah Model
09:40-10:20	Maks Ovsjanikov (École Polytechnique)	Operator-based Techniques for Shape Analysis
10:20-10:50	Coffee Break	
10:50-11:10	Gwenael Mercier (Johann Radon Institute)	Critical yield numbers of rigid particles settling in Bingham fluids and Cheeger sets
11:10-11:50	Peter Ochs (University of Freiburg)	Local Convergence of the Heavy-ball Method and iPiano for Non-convex Optimization
11:50-12:30	Kristian Bredies (University of Graz)	Accelerated and preconditioned Douglas-Rachford algorithms for the solution of variational imaging problems
	End of Workshop	

Book of Abstracts

<u>Gabriele Steidl (University of Kaiserslautern)</u>
<u>Restoration Methods for Manifold-Valued Images</u>

Abstract: The talk gives an overview over denoising and inpainting models for manifold-valued images recently developed in our group. This includes variational models as well as nonlocal patch-based approaches using second order statistics. The convergence of corresponding minimization algorithms is addressed.
This is joint work with
M. Bacak (MPI Leipizg), R. Bergmann, F. Laus, J. Persch (TU Kaiserslautern) and A. Weinmann (U Darmstadt).

<u>Andreas Weinmann (TU München)</u>
<u>Edge preserving variational methods for manifold valued data</u>

Abstract: Nonlinear spaces appear in various contexts in image processing and imaging. Important examples are nonlinear color spaces, the Euclidean motion group, the Riemannian manifold of positive matrices and shape spaces. Although very prominent for scalar and vector space valued data, algorithms for total variation regularization for manifold-valued data have been considered only recently. In this talk, we present our algorithmic schemes for the TV regularization of manifold-valued data. Another means to deal with the preservation of edges are free-discontinuity models such as the Blake-Zisserman and the Potts model. We further present our approaches for these problems for manifold-valued data.

<u>José Iglesias (RICAM, Linz)</u>
<u>A level set method for the matching of implicit surfaces</u>

Abstract: A recent trend in shape analysis is to use variational models of nonlinear elasticity, since they manage to balance adequate geometric invariance with being amenable to both analysis and numerical simulation. In this direction, we consider the problem of matching two smooth surfaces embedded in R3 under large deformations. In particular, we aim to measure the difference between the embeddings, and not only the intrinsic geometry of the surfaces. A dimension-independent level set formulation for this problem, inspired on variational models for elastic shells, is proposed. Exploiting the information available in a surface matching scenario, we obtain a deformation energy involving only first-order derivatives for which existence of minimizers can be proved, while still reflecting resistance to compression and bending. Injectivity is obtained through volume regularization. For its numerical solution, we propose a discretization through conforming multilinear finite elements on adaptive octree grids, and a coarse-to-ne multi-level minimization. This approach allows for high-resolution computations on real data.
Research carried out in collaboration with M. Rumpf (Bonn) and O. Scherzer (Wien).

Francis Bach (École Normale Supérieure)
Stochastic Variance Reduction Methods for Saddle-Point Problems

Abstract: We consider convex-concave saddle-point problems where the objective functions may be split in many components, and extend recent stochastic variance reduction methods (such as SVRG or SAGA) to provide the first large-scale linearly convergent algorithms for this class of problems which are common in machine learning. While the algorithmic extension is straightforward, it comes with challenges and opportunities: (a) the convex minimization analysis does not apply and we use the notion of monotone operators to prove convergence, showing in particular that the same algorithm applies to a larger class of problems, such as variational inequalities, (b) there are two notions of splits, in terms of functions, or in terms of partial derivatives, (c) the split does need to be done with convex-concave terms, (d) non-uniform sampling is key to an efficient algorithm, both in theory and prac- tice, and (e) these incremental algorithms can be easily accelerated using a simple extension of the “catalyst” framework, leading to an algorithm which is always superior to accelerated batch algorithms.

Silvia Bonettini (Universita di Ferrara)
Variable metric forward-backward methods for convex and nonconvex optimization

Abstract: Forward-backward methods are a very useful tool for optimization problems whose objective function is given by the sum of two terms, as the ones arising from inverse problems in variational form, where a fit to data term plus a regularization functional have to be minimized. The main drawback of these methods in their basic implementation is that they can exhibit a very slow convergence. In the recent literature, we can devise two acceleration approaches which have been proposed and studied by several authors: variable metric/scaling techniques and inertial/extrapolation strategies. In this talk we focus on variable metric forward-backward algorithms, where the underlying metric may change at each iteration to better capture the local features of the objective function and of the constraints. Their main theoretical convergence properties will be described in the convex and nonconvex case and practical implementation issues will be discussed.

Marc Teboulle (Tel Aviv University)
A Novel Framework for First Order Methods with Non-Lipschitz Continuous Gradient

Abstract: A central property required by first order methods is to have the differentiable part of an objective function to have a Lipschitz continuous gradient, hence precluding their use in many important applications. We introduce a novel and simple framework, which allows to circumvent the intricate question of Lipschitz continuity of the gradient. It naturally translates into a new descent Lemma and corresponding first order scheme. We prove a global sublinear rate of convergence, and as a by-product, global pointwise convergence is also derived. This provides a new path for tackling a broad spectrum of problems arising in key applications, which were until now considered as out of reach via first order methods. We illustrate this potential by showing how our new approach can be applied to build new and simple schemes for Poisson inverse problems. This talk is based on joint work with H.Bauschke and J. Bolte.

Tuomo Valkonen (University of Liverpool)
Block-proximal methods for image processing

Abstract: We study a class of primal–dual block-coordinate descent methods based on blockwise proximal steps. The methods can be executed either stochastically, randomly executing updates of each block of variables, or the methods can be executed deterministically, featuring performance-improving blockwise (e.g. pixelwise) adapted step lengths. We observe mixed O(1/N^2) + O(1/N) performance, and test the proposed methods on various image processing problems.

Christoph Vogel (TU Graz)
A Neural Inference Machine for Low-Level Vision Problems

Abstract: In the past, classic energy optimization techniques were the driving force in many innovations and are a building block for almost any problem in computer vision. Efficient algorithms are mandatory to achieve real-time processing, needed in many applications like autonomous driving. However, energy models - even if designed by human experts - might never be able to fully capture the complexity of natural scenes and images.
Similar to optimization techniques. Deep Learning has changed the landscape of computer vision in recent years and has helped to push the performance of many models to never experienced heights. In this work we seek to solve optimization problems directly with a deep neural network. Our idea of a neural inference machine is to combine the structure of regular energy optimization techniques with the flexibility to adapt to the statistics of data of Deep Learning. We apply our inference machine on known models from the Total Variation family, graph-cuts and on Markov Random Field problems, and show that our learned algorithm can deliver high-quality approximate solutions for all these models in only a few iterations.

Hugues Talbot (ESIEE Paris)
Image restoration using a Discrete Calculus formulation of the Ambrosio-Tortorelli functional

Joint work with Marion Foare and Jaques-Olivier Lachaud

Abstract: The Mumford-Shah (MS) functional is a classical variational formulation of image segmentation, simplification and restoration. The full MS functional is non-convex and difficult to optimise, as it requires to jointly define a sharp set of contours and a smooth version of the initial image. Various relaxations of the original formulations have been proposed. Among these, the Ambrosio-Tortorelli (AT) parametric functional is particularly interesting, because it has been shown to gamma-converge to MS. However this convergence is difficult to achieve numerically because discontinuities need to be represented explicitly rather than implicitly.
In this work, we propose to formulate AT using the full framework of Discrete Calculus (DC), which is able to sharply represent discontinuities thanks to a more sophisticated topological framework. We present our proposed formulation, its resolution, and results on synthetic and real images. We show that we are indeed able to represent sharp discontinuities and as a result significantly better stability to noise, compared with finite differences and even multigrid finite elements schemes.
Keywords: segmentation, denoising, simplification, Mumford-Shah functional, variational formulation, optimisation, inverse problems.

Jalal Fadili (Université Caen)
Exponential weighted aggregation vs penalized estimation: theoretical guarantees and algorithms

Abstract: In this work, we consider high-dimensional linear inverse problems. We present a unified analysis of the performance guarantees of exponential weighted aggregation and penalized estimators with a general class of priors which encourage objects which conform to some notion of simplicity/complexity. More precisely, we show that these two estimators satisfy (i) sharp oracle inequalities for prediction, and (ii) estimation error bounds ensuring their good theoretical performances. We also highlight the differences between them. The results are then exemplified on several instances including the Lasso, the group Lasso, their analysis-type counterparts, the infinity norm and the nuclear norm regularizers. When the noise is random, we provide oracle inequalities in probability under mild assumptions on the noise distribution. We also propose a framework based on proximal splitting to efficiently implement these estimators.

Andrea Mennucci (Scuola Normale Superiore)
Designing metrics for curves

Abstract: In the first part we rivist some key notions. Let M be a Riemannian manifold. Let G be a group acting on M. We discuss the relationship between the quotient M/G, “horizontality” and “normalization”. We discuss the distinction between path-wise invariance and point-wise invariance and how the former positively impacts the design of metrics, in particular for the mathematical and numerical treatment of geodesics. We then discuss a strategy to design metrics with desired properties. In the second part we design a Riemannian metric in the space of planar curves, based on the “delta” operator, that possesses many useful properties.

Simon Masnou (Université Lyon 1)
Volume reconstruction from slices

Abstract: Reconstructing a 3D volume from 2D slices is a classical problem in medical imaging. The main difficulty is how to incorporate the constraints because, depending on the situation, sharp constraints are sometimes needed, whereas loose constraints must be used in case of noisy or inaccurate data. In a joint work with Elie Bretin and François Dayrens, we propose a variational model involving a surface regularization term, typically the perimeter or curvature-based energies, and density constraints for the slices. We prove that this model can be well approximated with a phase-field approach, for which Gamma-convergence results can be established in the case of perimeter.
We propose an efficient numerical scheme, whose performances are illustrated on various examples involving various types of slices:
planar or not, parallel or not, surface-like or point-like. The method can also be extended to multiple volumes, which is of particular interest for the reconstruction of segmented data.

Thomas Möllenhoff (TU München)
Sublabel-Accurate Relaxation of Nonconvex Energies

Abstract: Many practical tasks in imaging such as stereo matching or optical flow lead to nonconvex optimization problems. One classical principle to tackle such problems is functional lifting, where the idea is to lift the original problem to a higher dimensional space in order to obtain more faithful convex approximations. While this allows to draw upon the powerful tools of convex optimization, the increase in dimensionality leads to high memory and runtime requirements. In this talk, I will present recent advances in finding more accurate and efficient convex relaxations which address the aforementioned drawbacks.

Dirk Lorenz (TU Braunschweig)
Optimization methods for optimal transport in imaging

Abstract: The problem of optimal transport asks "How to move some pile of mass to form another pile of mass with the least effort?" and has triggered contributions from many different fields of mathematics such as linear programming, partial differential equations, measure theory or Riemannian geometry in its over 200 years of history. Today, optimal transport can be viewed from many different angles and has found applications in many different fields, probably most prominently in economics.
In this talk we will investigate applications of techniques from optimal transport in the context of mathematical imaging. Distances based on optimal transport can be used to capture spatial geometric features and can lead to interesting effects. We will introduce optimal transport, treat different formulations and then focus on a particular functional analytic framework which is well suited for optimization in applications in imaging. We also highlight challenges in the numerical treatment of optimal transport problems, present some concrete applications and illustrate the effects with pictures.

Filippo Santambrogio (Université Paris Sud)
A fractal shape optimization problem in branched transport

Abstract: After recalling the basis of branched transport (a model where mass can be transported on a network, which is also part of the optimization, with a cost for transporting a mass m on an edge of length ℓ of the form ℓm^α) and of its continuous formulation, I will present the following natural optimization problem: which is the shape $E\subset R^n$ of unit volume, which can be irrigated at minimal cost starting from a single source located at 0 ? If $\alpha=1$, the answer would be the ball, but for $\alpha<1$ we expect it to be a set with a more fractal boundary. I will present the theoretical and numerical results obtained with Paul Pegon (Orsay) and Qinglan Xia (Davis), using tools involving the so-called "landscape function" and a phase-field approximation.

Grégoire Allaire (École Polytechnique)
On the mathematical modelling of some manufacturing constraints in topology optimization of structures

Abstract: Topology optimization algorithms are known to produce optimal structural shapes which may be difficult to manufacture, either by classical methods (molding, milling) or even by additive manufacturing techniques. Among topology optimization algorithms, the level set method is a very attractive tool by its capacity of defining a clear notion of boundary for the admissible shapes. In particular, the level set method is associated to the signed distance function which is a key ingredient to define various geometrical constraints linked to minimal or maximal thicknesses, holes sizes, or molding direction. We shall describe those constraints and new ones, as well as their implementation in optimization algorithms, and demonstrate their potential usefullness in classical as well as additive manufacturing processes.
This is a joint work with Ch. Dapogny, A. Faure, F. Jouve and G. Michailidis

Kathrin Welker (University of Trier)
PDE Constrained Shape, Optimization in Shape Spaces

Abstract: Shape optimization problems arise frequently in technological processes which are modelled in the form of partial differential equations (PDEs). In many practical circumstances, the shape under investigation is parametrized by finitely many parameters, which on the one hand allows the application of standard optimization approaches, but on the other hand limits the space of reachable shapes unnecessarily. Shape calculus presents a way out of this dilemma. Major effort in shape calculus has been devoted towards expressions in so-called Hadamard-forms, i.e., in forms of integrals over the surface of the shape under investigation. It is often a very tedious process to derive such surface expressions. Along the way, there appear volume formulations in the form of integrals over the entire domain as an intermediate step. In this talk, domain integral formulations of shape derivatives are coupled with optimization strategies on shape spaces. Efficient shape algorithms reducing analytical effort and programming work are presented. In this context, a novel shape space is proposed.

Yura Malitsky (TU Graz)
A first-order primal-dual algorithm with linesearch

Abstract: We propose a line search for the primal-dual method to solve a saddle point problem. In contrast with the basic primal-dual algorithm that uses fixed step sizes during all iterations, the proposed method does not require to compute the operator norm and, in addition, allows to make larger steps. Each iteration of the line search requires to update only the dual (or primal) variable. Moreover, the step sizes may increase from iteration to iteration. We prove the convergence of the algorithm under quite general assumptions. In case when one of the prox-functions is strongly convex, we modify our method to get a better convergence rate. Also we show that in many important cases the primal-dual algorithm with line search preserves the same complexity of iteration as the standard primal-dual method does. In particular, our method, applied for any regularized least-squares problem, uses the same number of matrix-vector multiplication per iteration as proximal gradient method or FISTA (with fixed step size) do, but does not require to know a matrix norm and, in addition, uses adaptive steps. Finally, we propose the line search for a saddle point problem with an additional smooth term. Several numerical examples are given to illustrate the efficiency of proposed methods.

Barbara Kaltenbacher (University of Klagenfurt)
Minimization based formulation of inverse problems and their regularization

Abstract: The conventional way of formulating inverse problems such as identification of a (possibly infinite dimensional) parameter, is via some forward operator, which is the concatenation of the observation operator with the parameter-to-state-map for the underlying model. Recently, all-at-once formulations have been considered as an alternative to this reduced formulation, avoiding the use of a parameter-to-state map, which would sometimes lead to too restrictive conditions. Here the model and the observation are considered simultaneously as one large system with the state and the parameter as unknowns. A still more general formulation of inverse problems, containing both the reduced and the all-at-once formulation, but also the well-known and highly versatile so-called variational approach (not to be mistaken with variational regularization) as special cases, is to formulate the inverse problem as a minimization problem (instead of an equation) for the state and parameter. Regularization can be incorporated via imposing constraints and/or adding regularization terms to the objective. In this talk, after giving a motivation by formulating the electrical impedance tomography problem by means of the classical Kohn-Vogelius functional, we will dwell on the regularization aspects for such variational formulations in an abstract setting. Indeed, combination of regularization by constraints and by penalization leads to new methods that are applicable without solving forward problems. In particular, for the EIT problem we will consider a method employing box constraints in a very natural manner to incorporate the discrepancy pronciple for regularization parameter choice as well as a priori information on the searched for conductivity.

Felix Lucka (University of Cambridge)
Enchancing Compressed Sensing Photoacoustic Tomography by Simultaneous Motion Estimation

Abstract: The acquisition time of current high-resolution 3D photoacoustic tomography (PAT) devices limits their ability to image dynamic processes in living tissue (4D PAT). In previous work, we demonstrated that images with acceptable spatial resolution can be obtained from suitably sub-sampled PAT data if sparsity-constrained image reconstruction techniques such as total variation regularization enhanced by Bregman iterations are used. Now, we will show how a further increase of image quality or dynamic frame rate can be achieved by exploiting the temporal redundancy of the data. For this, we couple the spatial image reconstruction models with sparsity-constrained motion estimation models. While simulated data from numerical phantoms will be used to illustrate the concept and potential of the developed methods, we will also discuss the results of their application to different measured data sets. Furthermore, we will outline how to combine GPU computing and state-of-the-art optimization approaches to cope with the immense computational challenges imposed by 4D PAT.

Michael Möller (University of Siegen)
Following the solution paths: Homotopie and inverse scale space methods for sparse recovery

Abstract: Ell^1 regularization is frequently used in linear inverse image and signal processing problems, either in the framework of variational methods or in the framework of Bregman iterations. Finding the right trade-off between data fidelity and regularity, which, for instance, manifests in the choice of a suitable regularization parameter, is a delicate issue. In this talk I will present numerical methods that follow the solution paths of the aforementioned techniques from zero to the ell^1 minimizing solution of the underlying linear system. In particular, I will present novel results on generalizing the celebrated homotopy method to degenerate cases in which multiple indices may enter or leave the support of the solution at distinct regularization parameters.

Francois-Xavier Vialard (Université Paris-Dauphine)
Unbalanced optimal transport and its link to fluid dynamic

Abstract: In this talk, I will present the equivalent of the Wasserstein L^2 metric on the space of positive Radon measures,and in particular the associated dynamic and static formulations. Scaling algorithms associated with entropic regularization will be also discussed. In the second part of the talk, the link with the Camassa-Holm equation will be presented as well as some applications of this point of view which generalizes Yann Brenier’s approach to the incompressible Euler equation.

Carola-Bibiane Schönlieb (University of Cambridge)
Anisotropic surface interpolation

Abstract: In this talk we discuss the use of anisotropic total variation regularisation for interpolating highly structured functions. We will motivate the modelling, discuss its numerical solution and show applications to digital elevation maps and limited angle tomography.
This talk includes joint work with M. Benning, C. Brune, J. Lellmann, S. Masnou, J.-M. Morel, S. Parisotto

Luca Calatroni (École Polytechnique)
Infimal convolution of data discrepancies for mixed noise removal in images.

Abstract: In several real-word imaging applications such as microscopy, astronomy and medical imaging, transmission and/or acquisition faults result in a combination of multiple noise statistics in the observed image. Variational data discrepancy models designed to deal with such mixtures linearly combine standard data fidelities used for single-noise removal or make use of either approximated and cheap or exact but computationally expensive log-likelihood functionals. Using a joint MAP estimation, we derive a statistically consistent variational model combining data fidelities associated to single noise distributions in a handy infimal convoution fashion by which individual noise components corrupting the data are modelled appropriately and decomposed from each other. After showing the well-posedness of the model in suitable function spaces, we propose a semismooth Newton-type scheme to compute its numerical solution efficiently.

Olivier Fercoq (École Nationale Supérieure des Télécommunications)
A Smooth Primal-Dual Optimization Framework for Nonsmooth Composite Convex Minimization

Abstract: We propose a new first-order primal-dual optimization framework for a convex optimization template with broad applications. Our optimization algorithms feature optimal convergence guarantees under a variety of common structure assumptions on the problem template. Our analysis relies on a novel combination of three classic ideas applied to the primal-dual gap function: smoothing, acceleration, and homotopy. The algorithms due to the new approach achieve the best known convergence rate results, in particular when the template consists of only non-smooth functions. We also outline a restart strategy for the acceleration to significantly enhance the practical performance. We demonstrate relations with the augmented Lagrangian method and show how to exploit the strongly convex objectives with rigorous convergence rate guarantees. We provide numerical evidence with two examples and illustrate that the new methods can outperform the state-of-the-art, including Chambolle-Pock, and the alternating direction method-of-multipliers algorithms.

Shoham Sabach (Technion)
First Order Methods for Solving Convex Bi-Level Optimization Problems

Abstract: We study convex bi-level optimization problems for which the inner level consists of minimization of the sum of smooth and nonsmooth functions. The outer level aims at minimizing a smooth and strongly convex function over the optimal solutions set of the inner problem. We analyze two first order methods and global sublinear rate of convergence of the methods is established in terms of the inner objective function values. The talk is based on two works: one with Amir Beck (Technion) and one with Shimrit Shtern (MIT).

Martin Rumpf (University of Bonn)
A Posteriori Error Control for the Binary Mumford-Shah Model

Abstract: The binary Mumford-Shah model is a widespread tool for image segmentation and can be considered as a basic model in shape optimization with a broad range of applications in computer vision, ranging from basic segmentation and labeling to object econstruction. We present robust a posteriori error estimates for a natural error quantity, namely the area of the non-properly segmented region. To this end, a suitable uniformly convex and non-constrained relaxation of the originally non-convex functional is investigated. Repin's functional approach for a posteriori error estimation is used to control the numerical error for the relaxed problem in the L^2-norm. In combination with a suitable cut out argument, fully practical estimates for the area mismatch are derived. Numerical experiments show qualitative and quantitative properties of the estimates and demonstrate their usefulness in practical applications.This is joint work with Benjamin Berkels and Alexander Effland.

Maks Ovsjanikov (École Polytechnique)
Operator-based Techniques for Shape Analysis

Abstract: In the past few years, several approaches have been proposed for analyzing shapes and their relations by considering linear operators acting on real-valued functions defined on the them. Although this point of view has been common in some areas of mathematics, it has only recently been adopted in digital geometry processing, where it has led to novel insights and efficient algorithms for a wide variety of problems. In this talk I will describe what such representations entail for mappings or correspondences, tangent vector fields and shape distortions. Finally, I will describe how surfaces themselves can be represented and manipulated in a coordinate-free fashion via a functional characterization of the first and second fundamental forms.

Gwenael Mercier (RICAM, Linz)
Critical yield numbers of rigid particles settling in Bingham fluids and Cheeger sets

Abstract: We consider the fluid mechanical problem of identifying the critical yield number of a solid inclusion settling under gravity within a bounded Bingham fluid with an exterior no-slip condition. This can be seen as a minimization of the total deformation energy with suitable boundary conditions. In the 2D framework with antiplane velocities, we show that a solution can be obtained by solving two Cheeger type problems.
We also present numerical results (both with antiplane and more general velocities)

Peter Ochs (University of Freiburg)
Local Convergence of the Heavy-ball Method and iPiano for Non-convex Optimization

Abstract: In this talk, a local convergence result for abstract descent methods in non-convex optimization is presented. In particular, the analysis is tailored to inertial methods. The result can be summarized as follows: The sequence of iterates is attracted by a local (or global) minimum, stays in its neighborhood and converges within this neighborhood. This result allows algorithms to exploit local properties of the objective function. Moreover, it reveals an equivalence between iPiano (a generalization of the Heavy-ball method) and inertial averaged/alternating proximal minimization and projection methods. Key for this equivalence is the attraction to a local minimum within a common neighborhood and the fact that, for a prox-regular function, the gradient of the Moreau envelope is locally Lipschitz continuous and expressible in terms of the proximal mapping. In a numerical feasibility problem, the inertial alternating projection method significantly outperforms its non-inertial variants.

Kristian Bredies (University of Graz)
Accelerated and preconditioned Douglas-Rachford algorithms for the solution of variational imaging problems

Joint work with Hongpeng Sun

Abstract: We discuss basic, accelerated and preconditioned versions of the Douglas-Rachford (DR) splitting method for the solution of convex-concave saddle-point problems that arise in variational imaging. While the basic DR iteration admits weak and ergodic convergence with rate $O(1/k)$ for restricted primal-dual gaps, acceleration leads to convergence rates of $O(1/k^2)$ and $O(q^k)$ for some $0<q<1$ under appropriate strong convexity assumptions. Further, preconditioning allows to replace the potentially computationally expensive solution of a linear system in each iteration step in the corresponding DR iteration by fast approximate solvers without the need to control the error. The methods are applied to non-smooth and convex variational imaging problems. We discuss denoising and deconvolution with L^2 and L^1 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 accelerated and preconditioned iteration schemes are discussed.

Poster Presentation

Pavel Dvurechensky (WIAS, Berlin)
Gradient method with inexact oracle for non-convex optimization

Alexander Effland (University of Bonn)
Extrapolation in the Space of Images

Jonas Geiping (University of Siegen)
Infimal Convolution Regularization for Video Super Resolution

Ulrich Hartleif (University of Münster)
Curvature regularisation with line and surface measures using an adaptive grid

Kerstin Hammernik (TU Graz)
Learning a Variational Network for MRI Reconstruction

Behrend Heeren (University of Bonn)
Geodesic calculus in shell spaces

Laurent Hoeltgen (BTU Cottbus)
Sparse l1 Regularisation of Matrix Valued Models for Acoustic Source Characterisation

Martin Holler (University of Graz)
Variational decompression of image data from DjVu encoded files

Pascal Huber (University of Bonn)
Smooth Interpolation of Key Frames in a Riemannian Shell Space

Asatur Khurshudyan (University of Münster)
Mechanical models of morphogenesis

Petar Kunstek (University of Zagreb)
Numerical approximation of classical optimal design on annuli

Erich Kobler (TU Graz)
From Variational Methods to Deep Learning: The Role of Incremental Methods, Early Stopping, and Convexity

Simone Rebegoldi (University of Medona)
Optimization methods for phase estimation in differential-interference-contrast (DIC) microscopy

Christian Reinbacher (TU Graz)
Intensity Image Reconstruction and Camera Tracking for Event Cameras

Carolin Rossmanith (University of Münster)
Optimal transportation networks as Mumford-Shah-type optimization problems

Adrian Martin (University of Graz)
A Maximum Deconvolution Model for Scanning Tunneling Microscope

Stefan Simon (University of Bonn)
Numerical Simulation of Optimal Transport on Markov Chains

Paul Striewski (University of Münster)
Elastic 2D/3D Image Registration

Sascha Tölkes (University of Bonn)
Stochastic dominance constraints in elastic shape optimization

David Vicente (University of Graz)
A perfect recovery property for PDE-constrained total variation minimization

List of Participants

Akar	Diren	diren.akar@gmail.com
Allaire	Gregoire	gregoire.allaire@polytechnique.fr
Bach	Francis	francis.bach@inria.fr
Bergmann	Ronny	bergmann@mathematik.uni-kl.de
Boink	Yoeri	y.e.boink@utwente.nl
Bonettini	Silvia	silvia.bonettini@unife.it
Bredies	Kristian	kristian.bredies@uni-graz.at
Brinkmann	Eva-Maria	e.brinkmann@uni-muenster.de
Brune	Christoph	c.brune@utwente.nl
Burger	Martin	martin.burger@uni-muenster.de
Calatroni	Luca	luca.calatroni@polytechnique.edu
Chambolle	Antonine	antonin.chambolle@polytechnique.fr
Clason	Christian	christian.clason@uni-due.de
Coli	Vanna Lisa	vannalisa.coli@unimore.it
Dabrock	Nils	nils.dabrock@tu-dortmund.de
Dvurechensky	Pavel	pavel.dvurechensky@gmail.com
Effland	Alexander	alexander.effland@ins.uni-bonn.de
Facca	Enrico	facca@math.unipd.it
Fadili	Jalal	Jalal.Fadili@greyc.ensicaen.fr
Fercoq	Olivier	olivier.fercoq@telecom-paristech.fr
Ferrari	Luca	luca.ferrari@polytechnique.edu
Föcke	Janic	janic.foecke@uni-muenster.de
Frerking	Lena	lena.frerking@uni-muenster.de
Geiping	Jonas	jonas.geiping@uni-siegen.de
Hammernik	Kerstin	hammernik@icg.tugraz.at
Hartleif	Ulrich	ulrich.hartleif@wwu.de
Heeren	Behrend	behrend.heeren@ins.uni-bonn.de
Hoeltgen	Laurent	hoeltgen@b-tu.de
Holler	Martin	martin.holler@uni-graz.at
Huber	Pascal	pascal.huber@ins.uni-bonn.de
Iglesias	José	jose.iglesias@ricam.oeaw.ac.at
Jukic	Mia	mia.jukic2@gmail.com
Kaltenbacher	Barbara	barbara.kaltenbacher@aau.at
Khurshudyan	Asatur	khurshudyan@ysu.am
Klatzer	Teresa	klatzer@icg.tugraz.at
Knöbelreiter	Patrick	knoebelreiter@icg.tugraz.at
Kobler	Erich	erich.kobler@icg.tugraz.at
Kunis	Stefan	skuni@uos.de
Kunstek	Petar	petarkunstek@gmail.com

List of Participants

Lorenz	Dirk	d.lorenz@tu-braunschweig.de
Lucka	Felix	f.lucka@ucl.ac.uk
Malitsky	Yurii	y.malitsky@gmail.com
Mannweiler	Dirk	dirk.mannweiler@uni-muenster.de
Martin	Adrian	adrian.martin@uni-graz.at
Masnou	Simon	masnou@math.univ-lyon1.fr
Mennucci	Andrea Carlo	andrea.mennucci@sns.it
Mercier	Gwenael	wenael.mercier@ricam.oeaw.ac.at
Möllenhoff	Thomas	thomas.moellenhoff@in.tum.de
Möller	Michael	michael.moeller@uni-siegen.de
Nagel	Dominik	dominik.nagel@uni-osnabrueck.de
Ochs	Peter	ochs@informatik.uni-freiburg.de
Ovsjanikov	Maks	maks@lix.polytechnique.fr
Persch	Johannes	persch@mathematik@uni-kl.de
Pock	Thomas	pock@icg.tugraz.at
Rasch	Julian	julian.rasch@uni-muenster.de
Rebegoldi	Simone	simone.rebegoldi@unimore.it
Reinbacher	Christian	reinbacher@icg.tugraz.at
Rossmanith	Carolin	carolin.rossmanith@wwu.de
Rumpf	Martin	martin.rumpf@ins.uni-bonn.de
Sabach	Shoham	ssabach@ie.technion.ac.il
Santambrogio	Filippo	filippo.santambrogio@math.u-psud.fr
Schindler	Felix	felix.schindler@wwu.de
Schönlieb	Carola-Bibiane	cbs31@cam.ac.uk
Shekhovtsov	Alexander	shekhovtsov@icg.tugraz.at
Silvain	Arguillere	arguillere@math.univ-lyon1.fr
Simon	Stefan	s6stesimo@uni-bonn.de
Steidl	Gabriele	steidl@mathematik.uni-kl.de
Striewski	Paul	paul.striewski@uni-muenster.de
Sutour	Camille	camille.sutour@gmail.com
Talbot	Hugues	hugues.talbot@esiee.fr
Teboulle	Marc	teboulle@post.tau.ac.il
Tölkes	Sascha	sascha.toelkes@ins.uni-bonn.de
Valkonen	Tuomo	Tuomo.Valkonen@liverpool.ac.uk
Vialard	Francois-Xavier	f.vialard@imperial.ac.uk
Vicente	David	david.vicente@uni-graz.at
Vidal-Nunez	José	jose.vidal@ua.es
Vogel	Christoph	christoph.vogel@icg.tugraz.at
Weinmann	Andreas	andreas.weinmann@tum.de
Welker	Kathrin	welker@uni-trier.de
Wirth	Benedikt	benedikt.wirth@wwu.de
Wübbeling	Frank	frank.wuebbeling@wwu.de
Zeune	Leonie	l.l.zeune@utwente.nl

For further information during the workshop please contact:

Carolin Gietz - Office 120.001 (Orléansring 10, 2nd floor)
0251-83 35052
01520-6559998
carolin.gietz@uni-muenster.de