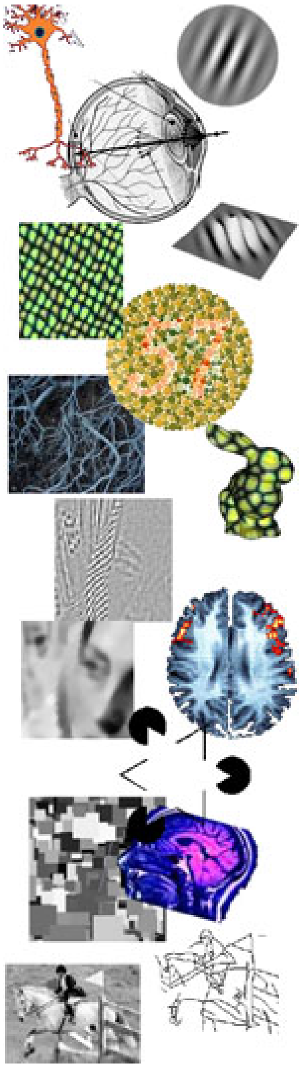

MIA 2023
Mathematics and Image Analysis

1-3 February 2023, Berlin

Humboldt-Universität zu Berlin,
Festsaal Luisenstrasse 56, 10117, Berlin

MIA

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Conference location

Humboldt-Universität zu Berlin,
Festsaal Luisenstrasse 56, 10117, Berlin

Programme

Wednesday, February 1

08:00 - 08:45	Registration
08:45 - 09:00	Welcome Message
09:00 - 09:45	Tatiana Bubba: **Deeply learned regularization for limited angle tomography**
09:45 - 10:30	Julia Schnabel: **AI-enabled medical imaging**
10:30 - 11:00	Coffee break
11:00 - 11:45	Mathieu Aubry: **Analysis by synthesis for interpretable image collection analysis**
11:45 - 12:30	Gloria Haro: **Faces and voices: leveraging visual information for speech and singing voice applications**
12:30 - 14:00	Lunch break
14:00 - 14:45	Michael Arbel: **Annealed flow transport Monte Carlo**
14:45 - 15:30	Laetitia Chapel: **Unbalanced optimal transport: efficient solutions for outlier-robust ML**
15:30 - 16:00	Coffee break
16:00 - 17:30	Poster pitch

Thursday, February 2

09:00 - 09:45	Florian Knoll: **Machine learning for inverse problems in MR image reconstruction**
09:45 - 10:30	Martin Burger: **From optimization to sampling in Imaging: A unified view based on coupling techniques**
10:30 - 11:00	Coffee break
11:00 - 11:45	Otmar Scherzer: **Inverse problems for acoustic attenuating media**
11:45 - 12:30	Audrey Repetti: **A distributed Gibbs sampler for image recovery Data**
12:30 - 14:00	Lunch break
14:00 - 14:45	Ulugbek Kamilov: **Plug-and-Play methods for integrating physical and learned models in computational imaging**
14:45 - 15:30	Pierre Weiss: **Training neural networks on families of operators**
15:30 - 16:00	Coffee break
16:00 - 16:45	Tom Goldstein: **Dataset privacy issues for image models**
16:45 - 18:30	Poster session

Friday, February 3

09:00 - 09:45	Sebastian Neumayer: (PhD Prize talk) **Learning convex regularizers: Does depth really help?**
09:45 - 10:30	Tomer Michaeli: **The implicit bias of SGD: A Minima stability analysis**
10:30 - 11:00	Coffee break
11:00 - 11:45	Nelly Pustelnik: **On the strong convexity for the understanding and design of (unfolded) algorithm**
11:45 - 12:30	Serena Morigi: **Image decomposition into structure, harmonic and oscillatory components**
12:30 - 14:00	Lunch break
14:00 - 14:45	Zorah Lähner: **Intrinsic neural fields: Learning functions on manifolds**
14:45 - 15:30	Vladimir Spokoiny: **Bayesian inference for complex models**
15:30 - 16:00	Closing remarks

Abstracts

Tatiana Bubba (University of Bath), Wednesday 1, 09:00 - 09:45

Deeply learned regularization for limited angle computed tomography

In recent years, limited angle CT has become a challenging testing ground for several theoretical and numerical studies, where both variational regularization and data-driven techniques have been investigated extensively. In this talk, I will present hybrid reconstruction frameworks that combine model-based regularization with data-driven deep learning by relaying on the interplay between sparse regularization theory, harmonic analysis and microlocal analysis. The underlying idea is to only learn the part that can provably not be handled by model-based methods, while applying the theoretically controllable sparse regularization technique to the remaining parts. The numerical results show that these approaches significantly surpasses both pure model- and more data-based reconstruction methods.

Julia Schnabel (TU Munich), Wednesday 1, 09:45 - 10:30

AI-enabled medical imaging

Artificial intelligence, in particular from the class of machine/deep learning, has shown great promise for application in medical imaging. However, the success of AI-based techniques is limited by the availability and quality of the training data. A common approach is to train methods on well annotated and curated databases of high-quality image acquisitions, which then may fail on real patient cases in a hospital setting. Another problematic is the lack of sufficient numbers of clinical label annotations in the training data, or examples for early markers of disease. In this talk I will present some of our recent approaches that aim to address some of these challenges, by using AI as an enabling technique for improved image reconstruction, realistic data augmentation and further downstream tasks.

Mathieu Aubry (LIGM-Imagine, ENPC, Paris), Friday 3, 11:00 - 11:45

Analysis by synthesis for interpretable image collection analysis

I will present our recent work on analyzing the content of image collections by learning a simple prototype-based model of images. I will start by introducing the idea and framework of Deep Transformation Invariant image analysis, where a simple modification of the standard K-means algorithm can lead to state of the art image clustering, while computing distances in data space (as opposed to feature space) and being easy to interpret. I will explain how it can be used for image [1], 3D shapes, and audio clustering. I will then show how the idea can be extended to perform object recovery [4], decomposing every image in a collection into layers derived from a small set of image prototypes. This can be applied to real world data, such as collection of Instagram images, and provide models and segmentation of repeated objects. Finally, I will explain how a similar idea can be used to perform single view reconstruction from a categorical image collection without any supervision [5].

1. Deep Transformation-Invariant Clustering, T. Monnier, T. Groueix, M. Aubry, NeurIPS 2020, http://imagine.enpc.fr/ monniert/DTIClustering
2. A Model You Can Hear: Audio Classification with Playable Prototypes, R. Loiseau, B. Bouvier, Y. Teytaut, E. Vincent, M. Aubry, L. Landrieu, ISMIR 2022, https://romainloiseau.fr/a-model-you-can-hear/
3. Representing Shape Collections with Alignment-Aware Linear Models, R. Loiseau, T. Monnier, M. Aubry, L. Landrieu, 3DV 2021, https://romainloiseau.github.io/deep-linear-shapes
4. Unsupervised Layered Image Decomposition into Object Prototypes, T. Monnier, E. Vincent, J. Ponce, M. Aubry, ICCV 2021, https://imagine.enpc.fr/ monniert/DTI-Sprites

5. Share With Thy Neighbors: Single-View Reconstruction by Cross-Instance Consistency, T. Monnier, M. Fisher, A. Efros, M. Aubry, ECCV 2022, https://imagine.enpc.fr/ monniert/UNICORN

Gloria Haro (University Pompeu Fabra), Wednesday 1, 11:45 - 12:30

Faces and voices: leveraging visual information for speech and singing voice applications

Human voice is highly correlated with face motions and in particular with lips motion. In this talk we address some audio applications in speech and singing voice and propose learning-based models that use not only the audio signal present in a video but also the visual information contained in the video frames. First, we consider the source separation problem, which is the automatic estimation of the individual isolated sources that make up an audio mixture. We show how leveraging visual and motion information from the target person's face is particularly useful when there are different voices present in the mixture or when the volume of the target voice is low. Then, we present a model that estimates if a sequence of lips motion and a voice signal in a video are synchronised or not. Finally, we show that the visual features learned by the synchronisation task generalize quite well to the problem of singing voice separation producing competitive results.

Michael Arbel (INRIA Grenoble), Wednesday 1, 14:00 - 14:45

Annealed flow transport Monte Carlo

Annealed Importance Sampling (AIS) and its Sequential Monte Carlo (SMC) extensions are state-of-the-art methods for estimating normalizing constants of probability distributions. We propose here a novel Monte Carlo algorithm, Annealed Flow Transport (AFT), that builds upon AIS and SMC and combines them with normalizing flows (NFs) for improved performance. This method transports a set of particles using not only importance sampling (IS), Markov chain Monte Carlo (MCMC) and resampling steps-as in SMC, but also relies on NFs which are learned sequentially to push particles towards the successive annealed targets. We provide limit theorems for the resulting Monte Carlo estimates of the normalizing constant and expectations with respect to the target distribution. Additionally, we show that a continuous-time scaling limit of the population version of AFT is given by a Feynman-Kac measure which simplifies to the law of a controlled diffusion for expressive NFs. We demonstrate experimentally the benefits and limitations of our methodology on a variety of applications.

Laetitia Chapel (Université de Bretagne Sud), Wednesday 1, 14:45 - 15:30

Unbalanced optimal transport: efficient solutions for outlier-robust ML

Discrete optimal transport (OT) aims at comparing probability distributions by providing a meaningful alignment between their samples. Over the last few years, OT has quickly become a central topic in machine learning (ML) and has been successfully employed in a wide range of challenging applications. All these successes have led to fruitful discussions between both the OT and ML communities and has raised new problems about OT. On the one hand, a key consideration of ML algorithms is their robustness or resilience to noisy or mislabelled observations. On the other hand, the OT formulation is sensitive to outliers since its objective function includes all the samples and features (through the cost matrix) and few outliers can disrupt the transport plan, driving the OT distance to unexpected large values. There is thus a need for solid theories and efficient mathematical frameworks that allows mitigating (or zeroing) the weights of the irrelevant samples. In this talk, I will review the unbalanced and partial optimal transport formulations that allow some mass variation in the formulation of the problem. I will details some efficient algorithmic solutions that provide the exact solution of the problem while being able to deal with large scale problems. Several ML scenario that benefit from the relaxation of the OT problem will also be discussed.

Florian Knoll (University of Erlangen-Nuremberg), Thursday 2, 09:00 - 09:45

Machine learning for inverse problems in MR image reconstruction

In 2016, machine learning techniques have been introduced to solve the inverse problem of MR image reconstruction from undersampled data from accelerated acquisitions [1,2,3]. Since then, the field has grown substantially, and a wide range of machine learning methods have been developed and applied to a wide range of imaging applications. In this talk, I will start with the background of a machine learning reconstruction that is based on iterative reconstruction methods used in compressed sensing and maps the numerical optimization problem that arises from the inverse problem of image reconstruction onto a neural network. I will discuss advantages and ongoing challenges, covering design of the network architecture and the training procedure, error metrics, computation time, generalizability, and validation of the results. This includes a discussion of the lessons learnt from the recent fastMRI image reconstruction challenges [4,5].

References

1. Learning a variational model for compressed sensing MRI reconstruction. Hammernik, et al. Proc. ISMRM p33 (2016).
2. Accelerating magnetic resonance imaging via deep learning. Wang et al. IEEEISBI 514-517 (2016).
3. Learning a Variational Network for Reconstruction of Accelerated MRI Data. Hammernik et al. MRM, 79:3055-3071 (2018).
4. Advancing machine learning for MR image reconstruction with an open competition: Overview of the 2019 fastMRI challenge. Knoll et al. MRM 84 (6), 3054-3070 (2020).
5. Results of the 2020 fast mri challenge for machine learning MR image reconstruction. Muckley et al. IEEE TMI 40 (9), 2306-2317(2021).

Martin Burger (University of Erlangen-Nuremberg), Thuerday 2, 09:45 - 10:30

From optimization to sampling in imaging: A unified view based on coupling techniques

While optimization techniques for variational problems in imaging and inverse problems have been an issue of major concern for the last decades, some focus has shifted to sampling of Bayesian posteriors and similar distributions recently. For this reason several sampling schemes motivated by randomized versions of optimization schemes have been introduced recently. While the implementation is usually a straight-forward extension of the one for optimization, the convergence analysis introduces additional difficulties in some cases. In this talk we discuss a generic approach to Wasserstein-type estimates for optimization-based sampling based on coupling techniques as introduced for stochastic processes and partial differential equations. We demonstrate that several estimates for the optimization techniques can be transfered directly to the sampling schemes this way and also introduce novel options for sampling. We also highlight similar issues in randomized optimization in machine learning.

Otmar Scherzer (University of Vienna), Thursday 2, 11:00 - 11:45

Inverse problems for acoustic attenuating media

Acoustic attenuation describes the loss of energies of propagating waves. This effect is inherently frequency dependent. Typical attenuation models are derived phenomenologically and experimentally without the use of conservation principles. Because of these general strategy a zoo of models has been developed over decades. In this talk we shall give a (certainly incomplete) survey on attenuation models and we discuss the basic mathematical properties which they have to satisfy in order to be well-posed (in mathematical terms). Inverse problems, which are considered in this talk, assume attenuation to be known, and consist in determining imaging parameters such as density, absorption, to name but a few, from measurements of waves at the boundary of the object of interest. We will consider two kinds of applications, which are motivated from photoacoustics and ultrasound-tomography. Photoacoustic imaging is a hybrid imaging technique where the object of interest is excited by a laser and the acoustic response of the medium is measured outside of the object. From this the ability of the medium to convert laser excitation into acoustic waves is computationally reconstructed. For photoacoustics, which is a linear inverse problem, we will determine its spectral values, and we shall see that there are two kind of attenuating models, resulting in mildly and severely inverse problems. In ultrasound-tomography the object of interest is excited by waves on the boundary and the acoustic response is measured (also at the boundary). We present an algorithm for the numerical solution of the nonlinear inverse problem and compare the effect of wrongly conjectured attenuation models on the reconstruction.

This is joint work with P. Elbau, C. Shi (University of Vienna) and Florian Faucher (INRIA).

Audrey Repetti (Heriot Watt University), Thursday 2, 11:45 - 12:30

A distributed Gibbs sampler for image recovery

Sampling-based algorithms are classical approaches to perform Bayesian inference in inverse problems. They provide estimators with associated credibility intervals, for uncertainty quantification. A main drawback of these methods is that they usually hardly scale to high dimensional problems. This issue has been partly addressed recently, by pairing them with optimisation techniques, such as proximal and splitting approaches. Such approaches pave the way to distributed samplers, that can split computation costs for faster and more scalable inference. We propose a distributed Gibbs sampler to efficiently solve such problems, considering posterior distributions with multiple smooth and non-smooth functions composed with linear operators. The proposed approach leverages a recent approximate augmentation technique reminiscent of primal-dual optimisation methods. It is further combined with a block-coordinate approach to split the primal and dual variables into blocks, leading to a distributed block-coordinate Gibbs sampler. The resulting algorithm exploits the hypergraph structure of the involved linear operators to efficiently distribute the variables over multiple workers. Experiments on an image deblurring problem show the performance of the proposed approach in high dimension, to produce high quality estimates with credibility intervals, while reducing drastically the computation cost compared to its non-distributed version.

Ulugbek Kamilov (Washington University in St. Louis), Thursday 2, 14:00 - 14:45

Plug-and-Play methods for integrating physical and learned models in computational imaging

Computational imaging is a rapidly growing area that seeks to enhance the capabilities of imaging instruments by viewing imaging as an inverse problem. Plug-and-Play Priors (PnP) is one of the most popular frameworks for solving computational imaging problems through integration of physical and learned models. PnP leverages high-fidelity physical sensor models and powerful machine learning methods to provide state-of-the-art imaging algorithms. PnP models alternate between minimizing a data-fidelity term to promote data consistency and imposing a learned image prior in the form of an "image denoising" deep neural network. This talk presents a principled discussion of PnP and recent results on PnP under inexact physical and learned models. Inexact models arise naturally in computational imaging when using approximate physical models for efficiency or when test images are from a different distribution than images used for training. We present several successful applications of our theoretical and algorithmic insights in bio-microscopy, computerized tomography, and magnetic resonance imaging.

Pierre Weiss (University of Toulouse), Thursday 2, 14:45 - 15:30

Training neural networks on families of operators

Model-based neural networks offer incomparable performance for many inverse problems. Simple experiments however reveal two significant limitations. First, they suffer from an adaptivity issue: when trained on a given operator, they do not extend well to a different one. Second, they critically lack robustness: a small imprecision in the forward operator results in a significant performance drop. To address this issue, we propose a different training method on families of forward operators. We suggest ways to choose a proper distribution of operators. We will show that this approach is competitive with more universal strategies such as plug & play priors. We will also explain how it allows attacking challenging issues such as blind inverse problems and Fourier sampling scheme optimization.

This is a joint work with Alban Gossard, Valentin Debarnot and Frédéric de Gournay.

Tom Goldstein (University of Maryland), Thursday 2, 16:00 - 16:45

Dataset privacy issues for image models

In this talk, I'll discuss dataset privacy issues that arise when training or deploying deep neural networks for imaging applications. I will present a number of situations where large models can leak private data from the training set. These leaks occur during distributed training of federated learning models, and during deployment of large diffusion models for image generation. I'll also discuss ways that adversarial learning methods can be used to protect user privacy.

Sebastian Neumayer, Friday 3, 09:00 - 09:45 (PhD Prize talk)

Learning convex regularizers: Does depth really help?

In this talk, we will revisit the state-of-the-art in learned convex regularization. As comparison, we propose a regularizer based on a one-hidden-layer neural network with (almost) free-form activation functions. For training this sum-of-convex-ridges regularizer, we rely on connections to gradient based denoisers. Our numerical experiments indicate that this simple architecture already achieves the best performance, which is very different from the non-convex case. Interestingly, even when learning both the filters and the activation functions of our model, we recover wavelet-like filters and thresholding-like activation functions. These observations raise the question if the fundamental limit is already reached in the convex setting.

Tomer Michaeli (Technion), Friday 3, 09:45 - 10:30

The implicit bias of SGD: A Minima stability analysis

One of the puzzling phenomena in deep learning, is that neural networks tend to generalize well even when they are highly overparameterized. This stands in sharp contrast to classical wisdom, since the training process seemingly has no way to tell apart "good" minima from "bad" ones if they achieve the precise same loss. Recent works suggested that this behavior results from implicit biases of the algorithms we use to train networks (like SGD). Here we analyze the implicit bias of SGD from the standpoint of minima stability, focusing on one hidden-layer ReLU networks trained with a quadratic loss. Specifically, SGD can stably converge only to minima that are sufficiently flat w.r.t. its step size. Here we show that this property enforces the predictor function to become smoother as the step size increases. Furthermore, we prove a depth-separation result: There exist functions that cannot be approximated by single hidden-layer networks corresponding to stable minima, no matter how small the step size is taken to be, but which can be implemented with two hidden-layer networks corresponding to stable minima. We show how out theoretical findings explain behaviors observed in practical settings.

Nelly Pustelnik (CNRS Lyon), Friday 1, 11:00 - 11:45

On strong convexity for the understanding and design of (unfolded) algorithms

Being fast, being flexible, handling with large dimensionality, and relying on a simple architecture are key issues for algorithms to be largely used in applicative fields such as image processing. Among the last twenty years, a huge number of proximal algorithms satisfying these constraints have been developed, but identifying the most appropriate for a specific problem stays a challenging task. One of the simplest tools to compare algorithmic schemes is the convergence rate, which can be at the price of assumptions such as the strong convexity. In this talk, motivated by data processing problems that turn out to be strongly convex: signal/image denoising and texture segmentation, we provide several elements for thought to identify an appropriate algorithm in an upstream of an implementation. We first establish a regime diagram with respect to Lipschitz and strong convexity constants allowing tight theoretical comparisons between standard first-order proximal schemes (forward-backward, Douglas-Rachford, Peaceman-Rachford). Numerical experiments in the context of unsupervised signal and image processing illustrate the tightness of these bounds. In the second part, we will detail how to take benefit of the strong convexity assumption in the design of supervised deep architecture. We explore the possibility to integrate knowledge about proximal algorithms, especially fast procedures, in order to design more efficient and robust neural network architectures. We place ourselves in the classical framework of image denoising and we study four unrolled architectures designed from forward-backward iterations in the dual, FISTA in the dual, Chambolle-Pock, and Chambolle-Pock exploiting the strong convexity. Performance and stability obtained with each of these networks will be discussed. A comparison between these architectures and state-of-the-art black-box approaches is also provided.

Serena Morigi (University of Bologna), Friday 3, 11:45 - 12:30

Image decomposition into structure, harmonic and oscillatory components

The task of decomposing signals/images into simpler components is of great interest for many applications. In this talk, we first consider variational decomposition models for separating a function, defined on both structured and unstructured domains, as the sum of piecewise constant, smooth homogeneous, and oscillatory components. This decomposition is motivated not only by image denoising and structure separation, but also by shadow and spot light removal. Finally, the challenging separation between textured and noisy components is resolved by a ternary image decomposition model with automatic parameter selection. Auto-correlation and cross-correlation principles represent the key aspects of this model. Numerical results show the potentiality of the proposed approaches for decomposing signals/images corrupted by different kinds of additive white noises.

Zorah Lähner (University of Siegen), Friday 3, 14:00 - 14:45

Intrinsic neural fields: Learning functions on manifolds

Neural fields have been shown to have incredible capabilities to non-linearly interpolate between sparse data points since they were introduced in NeRF to render a scene from new view points. However, most applications focus on settings in the Euclidean domain. This talk will show that using the eigenfunctions of the Laplace-Beltrami operator instead of positional coordinates gives superior results when the domain has has a manifold structure, introduce the theory behind this choice and discuss open questions in this direction. This formulation allows a differentiable representation of functions independent of discretization, for example rendering texture on point clouds or transfering the function to new objects with different topology without retraining.

Vladimir Spokoiny (Humboldt University and WIAS Berlin), Friday 3, 14:45 - 15:30

Bayesian inference for complex models

Uncertainty quantification (UQ) and reliability of complex models like deep neuronal networks is an important research question. This talk aims at describing novel numerically efficient methods for inference and UQ analysis of DNN with theoretical guarantees. Particular issues to address are high parameter dimension and non-convexity of the objective function. We propose a new insight on the problem using the recent progress in high dimensional Laplace approximation.

Posters

Poster pitch: Wednesday, February 1, 16:00 - 17:30
Poster session: Thursday, February 2, 16:45 - 18:30

The poster pitch session consists of very short (maximum 2 min) presentations of the posters.

Numerical solution of linear and non-linear partial differential equations using Legendre collocation method
Passant Abbassi (German University in Cairo)

The power of patches for training normalizing flows
Fabian Altekrüger (TU Berlin)

Non-uniform diffusion models
Georgios Batzolis (University of Cambridge)

Generalized inverse scale space iterations
Danielle Bednarski (University of Lübeck)

Self-certifying classification by linearized deep assignment
Bastian Boll (Heidelberg University)

Trigonometric approximations of sparse super-resolution in Wasserstein distances
Paul Catala (University of Osnabrück)

Recovery of sparse graph signals
Tarek Emmrich (University of Osnabrück)

Stability-accuracy trade-off in neural networks for ill-conditioned inverse problems
Davide Evangelista (University of Bologna)

Poisson equation with heterogeneous differential operators
Mattia Galeotti (University of Bologna)

Wavelet-based multiscale atlas estimation
Fleur Gaudfernau (Université de Paris/INRIA)

Image reconstruction and foreground removal in radio astronomy: From morphological separation to machine learning
Yanis Guimard (CEA Paris-Saclay, Paris-Saclay University)

A note on the regularity of images generated by convolutional neural networks
Andreas Habring (University of Graz)

The Rayleigh criterion and well-conditionedness of super resolution
Mathias Hockman (University of Osnabrück)

Drowsy driver detection system for poor light condition cases
Ahmed Ibnouf (King Fahd University of Petroleum & Minerals)

Domain decomposition algorithms for real-time homogeneous diffusion inpainting in 4K
Niklas Kämper (Saarland University)

Accelarating MCMC for imaging science by using an implicit Langevin algorithm
Teresa Klatzer (University of Edinburgh)

2DeteCT- A large 2D expandable, trainable, experimental computed tomography data collection for machine learning
Maximilian Kiss (Centrum Wiskunde & Informatica)

Solving linear inverse problems with invertible neural networks
Tobias Kluth (University of Bremen)

Gamma ray imaging with bidirectional Compton cameras
Lorenz Kuger (Friedrich-Alexander-Universität Erlanger-Nürnberg)

Proximal gradient algorithm for inverse problems in Banach spaces and Lebesgue spaces with a variable exponent
Marta Lazzaretti (University of Cote d'Azur & University of Genova)

Lifting-based Riemannian optimisation for cryo-EM
Jan Lellmann (University of Lübeck)

Quantum transformation estimation from point sets
Natacha Kuete Meli (University of Lübeck)

EM-driven network for efficient unsupervised motion segmentation
Etienne Meunier (INRIA)

Model-based demosaicking of sparse 3 color filter array acquisitions
Matthieu Muller (University of Grenoble)

Sparse integral Fourier holography
Inbarasan Muniraj (Alliance University)

Developing an adaptive particle representation for dynamic simulations of particle methods
Ayman Noureldin (CASUS, Center for Advanced Systems Understanding)

A Bregman learning framework for sparse neural networks
Tim Roith (Friedrich-Alexander-Universität Erlanger-Nürnberg)

Connections between Fourier neural operators and convolutional neural networks
Kabri Samira (Friedrich-Alexander-Universität Erlanger-Nürnberg)

Deep unfolded proximal interior point method for sparse-view computed tomography
Andrea Sebastiani (University of Bologna)

Two-parameter sums signatures and corresponding quasisymmetric functions
Leonard Schmitz (University of Greifswald)

A nonlinear inverse problem for quantitative magnetic resonance imaging
Clemens Sirotenko (WIAS)