MEETING ON TOMOGRAPHY AND APPLICATIONS

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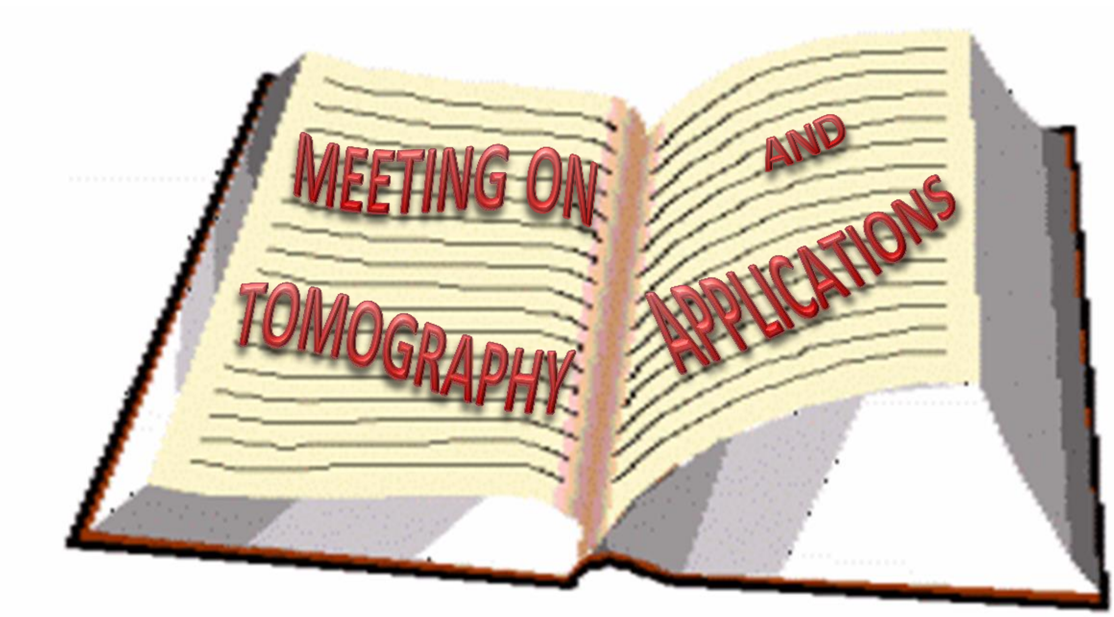
BOOK OF ABSTRACTS



● **Andreas Alpers** *Technische Universität München*

Super-Resolution Imaging in Discrete Tomography

ABSTRACT

Super-resolution imaging aims at improving the resolution of an image by enhancing it with other images or data that might have been acquired using different imaging techniques or modalities. In this talk we consider the task of doubling, in each dimension, the resolution of grayscale images of binary objects by fusion with double-resolution tomographic data that have been acquired from two viewing angles. It turns out that this task is polynomial-time solvable if the gray levels have been reliably determined. The problem becomes NP-hard if the gray levels of some pixels come with an error of +-1 or larger. The NP-hardness persists for any larger resolution enhancement factor. This means that noise does not only affect the quality of a reconstructed image but, less expectedly, also the algorithmic tractability of the inverse problem itself.

This is joint work with Peter Gritzmann.

● **Marina Bentivoglio** *Università di Verona*

The challenge of brain structural connectivity

ABSTRACT

Neurons, born to form a social ensemble, need to communicate through connections. Structural connectivity underlies behavioral output. Modeling the brain and its connectivity currently allows the elaboration of large scale data and therefore a novel insight in the human brain, and is leading to novel views on neural circuits working in functional networks. However, there are practical and conceptual gaps between the brain «nodes», «hubs», «edges» of connectomics approaches and the data on brain structural connectivity. These gaps need to be highlighted and filled with a constructive cross-disciplinary dialogue. Key issues at the microscale and mesoscale levels *versus* the macroscale level of brain studies are represented in the white matter by monosynaptic *versus* polysynaptic connections, crossing trajectories as well as multiple targets of fibers following the same trajectory, the heterogeneity of axon caliber, the organization of branched connections via axon collaterals, the role of glial cells. In the grey matter, examples are represented by neuronal heterogeneity (of size, molecular regulation, changes over time,

neurotransmitter and neuromodulator content, multiplicity of targets, vulnerability to challenges and disease), the composition of the neuropil and of the synaptic microenvironment, the relationships between neuronal compartments and glia. Brain pathologies cause connectopathies, but these are underlain by synaptopathies. The imaging and modeling of connectopathies at the macroscale has a high potential to serve diagnostic and prognostic endeavors, but the unraveling of pathogenetic mechanisms (essential to devise therapeutic strategies) requires efforts at the micro- and mesoscale. Computational views and reconstructions thus need to be reconciled with cardinal concepts of structural connectivity in the gray and white matter for a comprehensive, effective approach to brain wiring, functional output, alterations in disease.

● **Giulia Colacicco** *CWI Amsterdam*

Challenges in adaptive acquisition of tomography data

ABSTRACT

In May 2017, the FleX-Ray lab was established by the Computational Imaging group at CWI, in collaboration with partners XRE, Nikhef, and ASI. The lab is dedicated to advancements in new algorithmic techniques for 3D imaging, and combines an advanced, flexible CT scanner with high-performance computing facilities that can directly interface with the system.

One of the main features of the custom-built FleX-Ray CT scanner is the large freedom of placement and movement of the X-ray source, the sample and the detector. It allows to emulate many different experimental setups, with different scanning trajectories, tailored to various types and sizes of objects.

Moreover, it is possible to reliably scan both static 3D and dynamic 3D (i.e. 4D) objects. In the latter case, the behavior and the movement of the object are unknown a priori.

By adaptively changing the trajectory of both the source and the detector in response to the data that has already been collected, the quality of the reconstructions can in principle be improved by optimizing the trajectory for the specific characteristic of the sample. However, designing an accurate and efficient reconstruction process for arbitrary source/detector geometries comes with many challenges.

One of the elements that has to be taken into account is the flat-field acquisition: the image acquired at the detector when there is no sample present. Flat-fields

describe the shape of the X-ray beam and imperfections of the detector, and are used to preprocess the pixel-to-pixel sensitivity during the acquisition of the data. In standard CT scans, the flat-field is acquired once before the start of the imaging procedure. With an adaptive trajectory, it is no longer possible to use a flat-field that was previously acquired.
In this talk we will introduce the main concepts of adaptive tomography that are being developed in the FleX-Ray lab. We will then present the problem of computationally recovering the flat-field in the adaptive setting.

● **Maria M. Del Viva** *Università di Firenze*

Role of the cost of plasticity in determining the features of fast vision in humans

ABSTRACT
Several studies have demonstrated the usefulness of general principles of computational efficiency and maximum information preservation in predicting even rather detailed properties of early vision [1,2,3,4].
While all these studies have deeply examined the efficiency of the computation involved in the processing that actually occurs during the early visual analysis, not much attention has been devoted to the issue of the complexity of the computation required to determine the base ingredients of that processing themselves (neural Receptive Fields). Indeed, some of those algorithms require rather complex calculations in order to determine the shape of the RFs.
Considering the plasticity of the visual systems, one might expect that the algorithms employed by the visual system should not only be economical to execute, but also reasonably economical to set up, and to update when adapting to varying external conditions.
In this regards, it is an interesting question whether there are examples where the visual system has made a choice that is suboptimal from the point of view of the run-time performance, but lends to easier and more efficient updates and improvement. In this work we present results of a psychophysical experiment that appears to be such an example.
We start from a model of early vision[5], where the general principle of computational optimality takes the form of a maximization of transferred entropy within a limited bandwidth and from a fixed, finite number of discrete patterns, that are assumed to be the only information recognized by the system. This approach captures very well the problem faced by a system with finite computational resources, and has proved to be very effective in practice, in describing the actual human performance in fast vision in a number of situations[5,6]. In addition, it lends very well to comparing the

properties of mathematically optimal solutions to approximate, and therefore sub-optimal, solutions that easier to compute and update.

Specifically, the optimality condition that is imposed to the set of RF in this approach, can be formulated as a case of a class of well-known problems that go under the name of "knapsack problems" [7]. These problems admit exact numerical solutions, that in the general case are rather expensive to compute, and simpler approximate solutions that are slightly less optimal, as the one that has been heuristically adopted in Del Viva et al.[5]. We have found that application of these approaches to the extraction of optimal visual patterns lead to similar but nonetheless clearly distinguishable solutions, raising the interesting question of which of the two better describes the actual performance of fast vision in human subjects.

By performing psychophysical experiments we found clear evidence that the actual performance of human vision is in agreement with the simpler approximate solution rather than the mathematical optimum. While the latter is slightly better from the point of view of computational efficiency of the image analysis, the simpler solution is much easier to determine and update in case of the need to adapt to changes of the external conditions.

This experimental result thus seems to be evidence for a well-defined role of the "cost of plasticity", in shaping the features of the visual system.

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● **Paolo Finotelli** - *Politecnico di Milano*

Introduction to the neuroscientific section

ABSTRACT

This talk has the purpose of providing some basic notions on Neuroscience, in order to introduce the audience without a specific background, to the contributions of the neuroscience section of the Meeting. Firstly, some of the basic neurobiology behind the nervous system will be covered.

Then, it will be explained how Graph Theory could be a useful tool in Neuroscience, and some related applications. Finally, a recent model for evaluating the functional connectivity in a cerebral network will be introduced.

● **Caroline Garcia Forlim** *University Medical Center Hamburg*

Neuroimaging and Brain Networks

ABSTRACT

Brain imaging plays a central role in modern Neuroscience as the "window into the brain". The most used neuroimaging are MRI, fMRI, EEG, MEG, PET, DTI, among others providing measures of the structure and functionality of the brain. Each of them examines aspects of the brain at different spatial and temporal resolutions. Here I focus the discussion on the main characteristics of MRI, fMRI, EEG and DTI as well as their advantages and disadvantages. I will also present how brain networks can be extracted from the techniques above. Brain networks consist of structurally or functionally connected regions. Disruption in networks were found in many diseases, as schizophrenia, epilepsy, Alzheimer, ASD, depression, dementia etc. Finally I will present results of graph analysis applied to brain networks of schizophrenic patients.

● **Peter Gritzmann** *Technische Universität München*

On Dynamic Discrete Tomography

ABSTRACT

We consider the problem of reconstructing the paths of a set of points over time, where, at each of a finite set of moments in time the current positions of points in space are only accessible through some small number of their X-rays.

This particular particle tracking problem, with applications, e.g., in plasma physics, is the basic problem in dynamic discrete tomography.

We introduce and analyze various different algorithmic models. In particular, we determine the computational complexity of the problem (and various of its relatives) and derive algorithms that can be used in practice.

(joint work with Andreas Alpers)

● **Gloria Menegaz** *Università di Verona*

A multi-view perspective of neuroimaging

ABSTRACT

Brain imaging has different facets. Diffusion MRI (dMRI) allows for a non-invasive in-vivo virtual neuroanatomy, capturing the white matter (WM) wiring of the brain network. Functional neuroimaging captures the activity of brain regions following different paradigms, ranging from neurophysiological activity (EEG) to perfusion including blood-oxigen-level dependent contrast imaging (fMRI) and arterial spin labelling (ASL), just to mention a few. Such richness of information provides a multi-view and multi-scale picture of the brain structure and function, from tissue microstructure to connectivity networks. This lecture will provide an overview of the field as well as a closer look to some specific themes that is signal modeling in dMRI and microstructure-informed modeling of connectivity (structural and functional) networks.

● **Antal Nagy** *University of Szeged*

Segmenting Head & Neck MR images

Magnetic Resonance Imaging (MRI) is a non-ionizing radiation imaging technic, which gives a high level of information on tissue changing in human body. In my talk, I will present manly results on MRI organs at risk segmentation in Head & Neck region performed in a project with my colleagues. I will also show liver tumor segmentation and characterization achievements. Besides these outcomes, I will demonstrate the pre- and post-processing techniques, which were applied, during our work.

● **Nicolas Normand** *Université de Nantes*

Vandermonde-based tomography algorithms in periodic and non-periodic discrete spaces

ABSTRACT

Algorithms for discrete Radon transforms usually display quite different approaches in periodic and non-periodic spaces. Inversion of the Mojette transform (MT), a non-periodic example, can use corner-based or geometry-based algorithms. By contrast the Finite Radon Transform (FRT), the periodic example most similar to the Mojette Transform, can use exact back-projection, de-ghosting, Fourier and generalised Fourier transforms. Recently, a bridge between these methods was introduced by converting a non-periodic set of projections into a periodic one allowing to reconstruct Mojette projection data using Finite Radon Transform tools. This presentation focuses on a new approach for tomographic reconstruction that is based on the Vandermonde structure of discrete Radon transforms. We show that Björck's algorithm for solving Vandermonde systems can be adapted to tomographic problems in both periodic and non-periodic spaces by the use of the proper operators applied to each row of a matrix of projection data or, equivalently, to a matrix of their Fourier coefficients. The link with Katz' criterion on uniqueness of reconstruction will be discussed.

● **Alice Presenti** (2 talks) *University of Antwerp*

A CAD projector for X-ray polychromatic projection-based inspection

ABSTRACT

3D Computed Tomography is increasingly used in inspection and metrology to measure the deviation of the acquired geometry from the reference geometry, usually defined in a Computer Aided Design (CAD) model. However, the conventional CAD based X-ray inspection workflow can suffer from substantial error propagation. This can be avoided by coupling the 3D inspection back to the projection space. To this aim, we present a CAD projector for the ASTRA Toolbox, an efficient tool capable of simulating poly-energetic X-ray radiographs directly form CAD data in STL format, and integrated with a 3D registration framework that estimates the CAD model position from few-view projection data.

Graph Model Simulation of Human Brain's Functional Activity

ABSTRACT

It is commonly accepted that the various parts of the human brain interact as a network both at a macroscopical and microscopical level. Recently, different network models have been proposed to mime the brain behavior both at resting state and during tasks: our study concerns one of those model that tries to combine both the physical and the functional connectivity of the brain and also includes a time related variable that spans over the whole life period. We provide evidence of the soundness of the model by means of an artificial dataset based on the existing literature concerning the active areas at resting state. Furthermore, we consider Ruzicka similarity measure in order to stress the predictive capability of the model. Some network statistics are finally provided

● **Samuli Siltanen** *University of Helsinki*

Dynamic sparse X-ray tomography

ABSTRACT

In recent years, mathematical methods have enabled three-dimensional medical X-ray imaging using much lower radiation dose than before. One example of products based on such approach is the 3D dental X-ray imaging device called VT,

manufactured by KaVo Kerr. The idea is to collect fewer projection images than traditional computerized tomography machines and then use advanced mathematics to reconstruct the tissue from such incomplete data. The idea can be taken further by placing several pairs of X-ray source and detector "filming" the target from many directions at the same time. This allows in principle recovering the three-dimensional inner structure as a function of time. For example, one could observe the internal organs of a living and un-sedated organism such as a laboratory mouse. Tentative computational results are shown, based on both simulated and measured data. Several mathematical approaches are discussed and compared: generalized level-set method and shearlet-sparsity in spacetime, dimension-reduced Kalman filter, and sparsity-promoting regularization based on optical flow. It is expected that each method performs differently with different dynamic applications.

● **Nathanael Six** *University of Antwerp*

Discrete reconstruction from polychromatic X-ray projection data

Abstract

Discrete tomographic reconstruction (e.g. DART) can suffer heavily from the effects of beam hardening. This is due to the double effect of the polychromatic source on these techniques: on the one hand, beam hardening artefacts such as cupping and streaks appear and on the other hand, the mismatch between the assumed linear model and the real non-linear acquisition leads to wrongly assumed grey values. Discrete reconstruction techniques are, however, of great interest as they can generate reconstructions from a low sampled projection space. By introducing a non-linear forward model in the reconstruction, discrete tomography on datasets from polychromatic sources becomes possible. The drawbacks are the need of extra prior knowledge on the X-ray source and a larger computation time per iteration. We present a method to improve DART's behavior in this setting. On simulated data, the reconstructions no longer suffer from beam hardening artefacts, while retaining DART's ability to generate accurate reconstructions from undersampled data.

● **Lama Tarsissi** *Polytechnique Sophia Antipolis, Nice*

New perspectives in the reconstruction of convex polyominoes from orthogonal projections

Abstract

The family of (digitally) convex polyominoes, that are the discrete counterpart of Euclidean convex sets, combines the natural constraints of convexity and connectedness.

Several years ago, many researchers in this community tried to study their reconstruction. In this talk, I use some results by Brlek.al which allow to express digital convexity by the properties of the words encoding the boundary word of the polyomino. I give some examples to show that, in order to maintain the convexity, the addition of one point or two points imposes the inclusion of other points in the neighbor areas. While the addition of points during the reconstruction process does not influence neighborhood areas only under strong geometrical constraints.

● **Stefano Tebaldini** - *Politecnico di Milano*

Three-dimensional Radar imaging of distributed media

Abstract

Synthetic Aperture Radar (SAR) Tomography (TomoSAR) is a microwave imaging technology to recover the 3D structure of the illuminated scene by flying a Radar sensor along multiple trajectories. At microwave regime, electromagnetic waves are capable of penetrating into natural media that are non-transparent at optical frequencies, for example vegetation, snow, ice, and sand. This feature makes TomoSAR sensitive to the vertical structure of those media, hence providing a substantial advantage over optical sensors.

The downside is that TomoSAR signal processing involves a number of challenging aspects as compared to conventional 2D SAR focusing, such as: 3D migration, focusing in the presence of propagation velocity variations, sub-wavelength data-based retrieval of platform position.

The aim of this talk is to present different aspects relative to tomographic SAR imaging and its applications, such as:

- Basic imaging principles
- Advanced signal processing
- Polarimetry & Tomography
- Added value for forestry, snow-pack and glacier remote sensing
- Possibilities for spaceborne tomography

● **Robert Tijdeman** *Leiden University*

Algorithms for fast reconstruction in discrete tomography.

ABSTRACT

We present an algorithm that for any given rectangle *A* in **Z**^2 and set of primitive directions *D* enables us to compute the values of any real function *f* on *A* outside the convex hull of the union of the switching components in linear time from its line sums in the directions of *D*. In particular, the algorithm enables us to reconstruct *f* completely if there are no switching components. We present a simpler algorithm in case the directions satisfy some monotonicity condition. Finally we suggest how to choose the directions so that only a small number of directions is needed to reconstruct *f*.

This is joint work with Silvia Pagani.

● **Nicola Vigano'** - *CWI Amsterdam*

A tomography approach for the quantitative scene reconstruction from light-field images

Abstract

Portable plenoptic cameras have recently become increasingly popular and accessible.

An attractive feature of these cameras is that they provide a wide palette of computational photography opportunities which do not exist with traditional cameras.

These include post-acquisition refocusing and depth estimation.

To manipulate the acquired light-fields, current computational methods parametrize the ray geometry inside the plenoptic camera. This parametrization, together with some common approximations, can lead to errors in the estimation of object sizes and positions.

In this talk, we present a parametrization that can offer correct reconstruction of object sizes and leads to the accurate estimation of their distances from the camera. This is obtained by showing that light-field photography problems can be formulated as cone-beam tomography problems with limited-angle data.

The strong connection with tomographic problems is then also used to critically and quantitatively analyze the parametrization impact on image refocusing, depth estimation and volumetric reconstructions.
Finally, we present and discuss a set of numerical examples to show the impact of the developed methods on the quantitative estimation of object sizes and distances.

● **Laurent Vuillon** *Université de Savoie*

Convexity concepts for discrete tomography

ABSTRACT
In this talk, we make a focus on discrete convexity concepts for discrete tomography. In fact, the convexity is a usual tool in order to construct geometrical objects which inherit nice mathematical properties. We first make a survey of these properties based on the work of Marcel Berger and on convex geometry. In a second time, we investigate many notions of discrete convexity and we discuss of the pertinence of these concepts for discrete tomography problems. In a third time, we explore these notions for polyominoes and for polycubes, the goal is to add convexity constraints to discrete tomography in 2D and 3D. We, in particular, investigate many examples of convexity properties like HV-convexity, Q-convexity, 1L-convexity, 2L-convexity and kL-convexity. In a fourth part of this talk, we explain how to use discrete convexity to reconstruct 2L-convex polyominoes. At the end, we state a catalogue of open convexity problems for discrete tomography approaches.