International Workshop on Characterization of Material Properties based on X-ray Tomography

20 - 22 April, 2016, Panagyurishte, Bulgaria

PROGRAM and ABSTRACTS

Wednesday, April 20

12:00 Lunch and Registration

14:15 Opening

14:30 - 17:00

Katja Schladitz (Fraunhofer Institut für Techno- und Wirtschaftsmathematik)
3D image analysis and stochastic geometry models for materials structures

Zhichao Zhong (Centrum Wiskunde en Informatica)
Advanced X-ray and Electron Tomography: Building Bridges between Computational Science and Real-World Experiments

Jan De Beenhouwer (University of Antwerp)
Overview of dynamic CT reconstruction at Vision Lab

19:00 Dinner

Thursday, April 21

9:30 - 12:00

Svetozar Margenov (Institute of Information and Communication Technologies)
HPC applications in IICT-BAS

Ivan Georgiev (Institute of Information and Communication Technologies)
Industrial X-ray tomography applications

Maria Datcheva (Institute of Mechanics)
Material properties evaluation for Wood Polymer Composites based on micro and macro experimental data and numerical analysis

12:00 Lunch

13:30 Visit to the historical museum

15:00 - 17:00

Stanislav Harizanov (Institute of Information and Communication Technologies)
Improved 3D reconstruction of industrial CT data

Yavor Vutov (Institute of Information and Communication Technologies)
Parallel Segmentation of 3D Images

19:00 Dinner

Friday, April 22

9:30 - 11:00

Dragomir Tachev (Institute of Physical Chemistry)
Computed microtomography in IPC-BAS: determination of porosities, volume fractions and size

Wolfgang Lieske (Ruhr-Universität Bochum)
X-ray microtomography analysis of granular materials

11:00 Closing

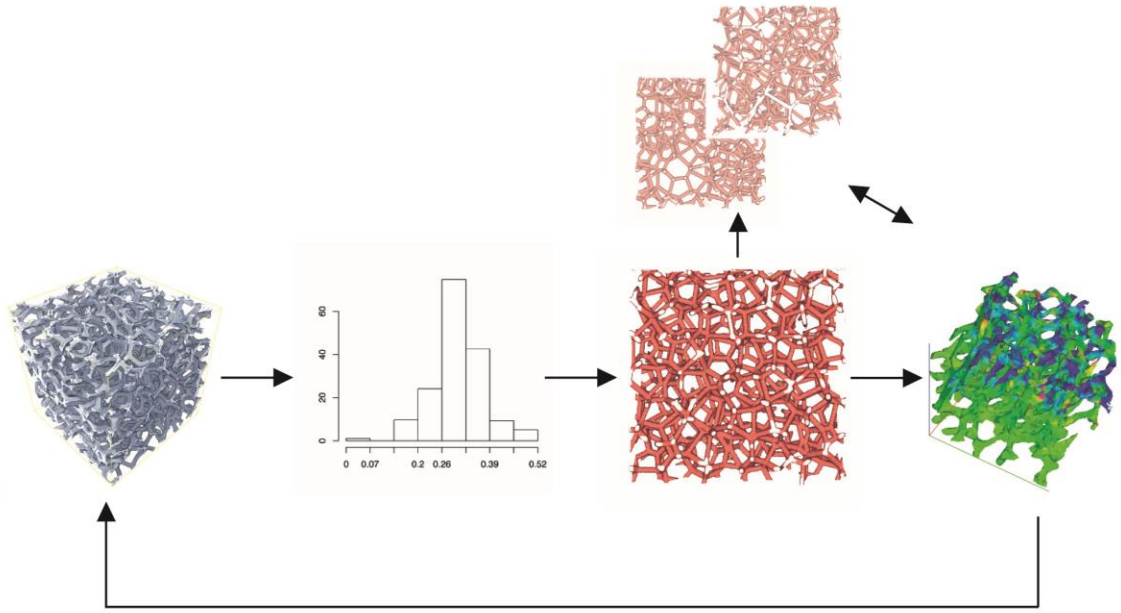
12:00 Lunch and Departure

3D image analysis and stochastic geometry models for materials structures

Katja Schladitz

Fraunhofer Institute for Industrial Mathematics ITWM, Department of Image Processing

The development of modern high-performance materials requires a deeper understanding of the complex relations between a material's micro-structure geometry and its macroscopic properties. Quantitative image analysis combined with stochastic micro-structure modelling is a promising approach to study these relations.
A key ingredient for this is a reliable geometric description provided by the quantitative analysis of images of the materials micro-structures. Here the focus is on 3D imaging techniques like micro computed tomography, as they capture the full spatial information on the observed microstructure.
The focus of this talk is on methods and prerequisites for estimation of basic geometric characteristics from (3D) image data. Typical application examples, like fibre reinforced polymer, rigid foams, particle systems, and multiscale porous media are discussed.
Moreover, the corresponding model classes from stochastic geometry are introduced as well as strategies for fitting them to the observed micro-structures.
Based on either the structure deduced directly from the image data or realisations of the fitted model, macroscopic properties can be simulated on the micro scale and the results can subsequently be upscaled. Using the stochastic geometry models, allows additionally to study in detail, how microstructural changes influence the macroscopic properties.



Advanced X-ray and Electron Tomography: Building Bridges between Computational Science and Real-World Experiments

Zhichao Zhong

Centrum Wiskunde & Informatica, Computational Imaging Group

In recent years, there have been major advances in the capabilities of X-ray and electron imaging instruments, allowing us to see projections of structures with unprecedented contrast and resolution. By combining these imaging techniques with tomography, 3D reconstructions of material structures can be obtained using mathematical reconstruction algorithms. At the same time, there has been major progress in the development of reconstruction algorithms that can deal with limited and noisy data. Despite these advances, the classical backprojection methods that were developed decades ago are still used in the vast majority of real-world experimental settings. In this lecture I will discuss the reasons for this gap between the experimental and algorithmic tomography communities, and present an overview of our strategies to bring recent algorithmic techniques closer to experimental practice.

Overview of dynamic CT reconstruction at Vision Lab

Jan De Beenhouwer

University of Antwerp

iMinds-Vision Lab (VLAB) is a research lab of the department of physics at the University of Antwerp, Belgium. Our research is focused on the development of new techniques for tomographic image reconstruction, processing and analysis. iMinds-Vision Lab has unique expertise in the algorithmic and computational aspects of tomography: Whereas most tomography research takes place within specific application fields, such as medical imaging or materials science, our group focuses on the underlying general reconstruction problems that are shared between these applications. More specifically, we develop algorithms that cope with limited data problems, such as few view 3D reconstruction and 4D dynamic CT, by exploiting prior knowledge within the reconstruction. Our group is well known for its expertise in tomography, thanks to the development of the ASTRA toolbox, an open source platform for GPU-accelerated tomographic reconstruction that is used worldwide through numerous industrial and academic collaborations. This talk will provide an overview of the research at our lab.

HPC applications in IICT-BAS

Svetozar Margenov
Institute of Information and Communication Technologies
Bulgarian Academy of Sciences

The Institute of Information and Communication Technologies (IICT-BAS) has a leading position in South Eastern Europe in the field of HPC infrastructure. Avitohol, the most recent parallel system is a high performance cluster integrating 150 servers with 2 Intel Xeon E 2650 v2 CPUs and 2 Intel Xeon Phi 7120P and total number of 20 700 cores. Avitohol is currently ranked at number 388 in TOP500 list, November 2015 http://www.top500.org/system/178609.
The list of recent HPC applications includes: (i) finite element computer simulation of strongly heterogeneous media; (ii) microstructure analysis of composite/porous materials; (iii) Monte Carlo methods for sensitivity analysis of large mathematical models; (iv) biomedical applications; (v) environmental applications; (vi) nonlinear dynamics of structures.

Industrial X-ray tomography applications

Ivan Georgiev
Institute of Information and Communication Technologies
Bulgarian Academy of Sciences

In the beginning of the talk will be presented the 3D imaging and digitization facilities at IICT-BAS. Then we will continue with industrial CT scanning applications in various areas of science and engineering. Problems of particular interest includes: (i) numerical upscaling and homogenization with application in advanced composites and porous materials; (ii) Porosity and inclusion analysis with application in Non-Destructive Testing (iii) 3D digitization in archeology and paleoanthropology.
The obtained microstructure and polygonal models are used for visualization, measurements, and as a computational domain for HPC simulations.

Material properties evaluation for Wood Polymer Composites based on micro and macro experimental data and numerical analysis

M. Datcheva, R. Iankov, M. Natova, Institute of Mechanics, BAS
I. Georgiev, Institute of Information and Communication Technologies, BAS
V. Georgiev, Institute of Polymers, BAS
Y. Ivanova, T. Partalin, Sofia University "St. Kliment Ohridski",
C. Furst, A. Haider, Wood K Plus GmbH, Austria

The elastic modules of 10% and 20% wood-flour polypropylene composites were investigated on micro-level by means of numerical homogenization based on X-ray CT composite microstructure reproduction and of local nanoindentation testing. On the other hand, the linear elastic properties were obtained performing standard macro tests - static tensile test and dynamic vibration and ultrasound tests. A cross verification was done by finite element modal and stress-strain numerical analyses of the experimental data.

Improved 3D reconstruction of industrial CT data

Stanislav Harizanov, Ivan Lirkov, Yavur Vutov, and Ivan Georgiev

Institute of Information and Communication Technologies, BAS

Accurate 3D Computed Tomography (CT) reconstruction of microstructures is not only crucial for future realistic numerical simulations of their macro characteristics, but also a quite nontrivial task, due to the presence of noise in the image and the (usually) complicated material structure. In this talk we deal with both the above problems. To get rid of the Poisson noise in the 2D radiographic projections, related to the particle counting process at the flat panel detector of the scanner, we use a TV-regularized Anscombe-constrained mathematical model. To better capture the structure information, we incorporate some of the physical characteristics of the material into the reconstruction process via performing a volume-constrained 2-phase graph-based segmentation with connected solid (material) phase. The corresponding numerical algorithms are parallelly implemented and tested on a supercomputer. High-resolution images can be efficiently processed and the quality of the reconstruction is significantly improved.

Parallel Segmentation of 3D Images

Stanislav Harizanov, Yavor Vutov

Institute of Information and Communication Technologies, BAS

We are considering 3D constrained two phase segmentation of voxel images obtained from X-ray computed tomography. The constrain is the volume of the one of the phases.

The choosen algorithm requires assembly and solution of a large system of linear equation.

In this talk, we focus on some computational aspects of parallel implementation of 3D segmentation. This includes file input and output, communication organization and computation distribution.

Computed microtomography in IPC-BAS: determination of porosities, volume fractions and size distributions

D. Tachev, G. Avdeev

Institute of Physical Chemistry, Bulgarian Academy of Sciences

R. Harizanova

Department of Physics, University of Chemical Technology and Metallurgy

The tomography studies of several samples will be presented; a meteorite from Saricicek, Turkey as obtained and melted, and a glass-ceramics with composition $Na_2O/BaO/TiO_2/SiO_2/B_2O_3/Fe_2O_3/Al_2O_3$. The glass-ceramics can be well approximated as a two-phase system, while the meteorite contains up to 5 different phases. Tomography and X-ray diffraction are combined to identify the phases in the samples. Determination of volume fractions and particle or voids size distributions in terms of structure thickness distributions and associated problems will be reported. Porosity analysis of the meteorite crust will be presented.

X-ray microtomography analysis of granular materials

Wolfgang Lieske

Ruhr-Universität Bochum

The mechanical behavior of soils is primarily determined by the fabric, that means the arrangement of the particles. For coarse grains like sand the response to mechanical stresses is circumscribed by the friction of the particular grains. Using the micro-tomography it is possible to analyze the contact between this grains and investigate the affect of added fines like silt.
Another issue is porosity in clayey soils. Since the compression behaviour in clay depends on shape and tortuosity of pores, the micro-tomography was used to asses the porosity.
The presentation will show the basic results and limitations using micro-tomography in soil mechanics.

Real-time parallel Poissonian denoising of industrial CT data

Ivan Georgiev, Krassimir Georgiev, Stanislav Harizanov, Ivan Lirkov

Institute of Information and Communication Technologies, BAS

Marcin Paprzycki

Systems Research Institute, Polish Academy of Sciences

We study the restoration of blurry images corrupted by Poisson noise. Poisson type data typically occurs in imaging processes, where the images are obtained by counting particles that hit a surface, e.g. in Computed Tomography, where an X-ray beam hits a detector behind the scanned object. Using variance-stabilizing transformations, such as the Anscombe transform, the Poisson noise can be approximated by a Gaussian one, for which classical denoising filters can be used.

We consider an algorithm which solves an Anscombe-transformed constrained optimization problem, based on Least Squares techniques. Thus, it allows for complete splitting of the pixel data and allows for their independent treatment within each iteration. Furthermore, it was experimentally observed that the convergence rate of the

algorithm heavily depends on both the image size and the choice of input parameters, making the sequential realization of the algorithm impractical for large-scale industrial images.

Our work considers hybrid parallelization based on the MPI and OpenMP standards. It is motivated by the need to maximize the parallel efficiency of the implementation of the proposed algorithm. The implementation was tested on Linux clusters with Intel processors and on an IBM supercomputer.

POSTERS

I. Georgiev, K. Georgiev, S. Harizanov, I. Lirkov, M. Paprzycki
Real-time parallel Poissonian denoising of industrial CT data

R. Zaharieva, D. Iankov, R. Iankov, M. Datcheva
Numerical Simulation of Nano-Indentation of Systems Containing Piezoelectric Material Layer

I. Georgiev, S. Harizanov, S Margenov, Y. Vutov, L. Zikatanov
Volume Constraint Segmentation of Porous Media

F. Heidenreich, H. Haase, T. Schanz, I. Georgiev
Analysis of micro-CT data of geomaterials regarding soil mechanical issues

I. Georgiev, S. Harizanov, J. Stary
Structure and properties characterization of fiber-reinforced silicate composites by CT scanning and numerical simulations.