Advanced X-ray Tomography:

Building Bridges between Computational Science and Real-World Experiments

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Advanced X-ray imaging

- Synchrotrons
- Advanced lab setups
X-ray Tomography: contrast generation

Absorption  Phase  Diffraction  Fluorescence
Tomography: Reconstruction

- Classical algorithms known for more than 50 years
- Recently: breakthroughs in limited data reconstruction
  - Compressive Sensing
  - Discrete Tomography

Slice of rat femur, reconstructed from 20 projections using classical methods (left) and discrete tomography (right)
Advanced X-ray tomography: challenges

- Mechanical instabilities
- Nonlinear image formation
- Dose and time constraints

Standard algorithms are used, which were never designed for these challenges
Why does almost everyone still use classical methods?

- Methods are parameter-less
- Easy to understand
- Easy to implement
- Computationally efficient
- Only way to convince users is to make a breakthrough in image quality
Current landscape

- Two separate communities
  - Experimental X-ray imaging
  - Mathematical imaging / Algorithm development
- Desire to collaborate, but also reluctance to enter new fields
- Little interaction between both communities
- Different focus, need to align the questions

We need to bridge this gap
EU Network grant for 2013-2017
Goal: to establish an active, interdisciplinary research network that bridges the gap between the experimental X-ray tomography community and the mathematical image reconstruction community

Instruments:
- Workshops
- Short Term Scientific Missions (STSMs)
- Training Schools
- MC + Working Groups
• Separate funding entity in Brussels, funded by FP7 / H2020
• 300 running networks in 9 domains
• Administration for each network is localized at a Grantholder Institute
Aim of the network

- To bridge the gap between both communities
  - Active, interdisciplinary research network
  - Broad representation of both fields

- to enable the development of next generation X-ray tomography techniques and algorithms
  - Tailored algorithms
  - Combine state-of-the-art from both fields
How to reach the objectives by networking

- Working Groups
  - WG structure that encourages collaboration
- Joint workshops
  - Lead to common frame of reference
- STSM’s
  - Mainly between groups from both communities
- Training schools
  - Aimed at cross-fertilization between both fields
- Events with industry
  - To showcase research results from an early stage
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Scientific Focus

- Focused on the development of state-of-the-art software and algorithms
  - For various X-ray imaging modalities
  - Computational solutions to experimental problems

- Requires accurate experiments, models, and algorithms
  - And expert knowledge in each of these fields

- Concerted effort between experimentalists, mathematicians, algorithm developers
Current interest

Key figures:
- 80 participants
- 20 countries
- 50 experimental
- 30 algorithmic
- 7 synchrotrons

- Interest is still expanding and comes from both communities, as well as industry
Example I: X-ray diffraction tomography
Example I:
X-ray diffraction tomography

undeformed case

deformed case
Example I: X-ray diffraction tomography

Twin boundary (original)  Twin boundary (reconstruction)

Joint work between CWI and Nicola Vigano, ESRF
Example II: 4D Tomography
4D tomography: challenges

- Many experimental challenges
- Bandwidth/throughput limitations
- Reconstruction from limited data
- ... Huge amounts of data
- Exploit prior knowledge
- Exploit temporal correlations
- Optimize the acquisition of projections
- Reconstruct in real-time
Example II: 4D Tomography

Joint work between CWI and Geert van Eyndhoven, Univ. Antwerp
Conclusions

- Major challenges in advanced X-ray imaging
- Mathematics and algorithms can solve these problems
- Both communities are willing, but miss the coordinating platform
- CWI now has a leadership role in bringing these communities together