The FleX-ray Lab: Past, Present and Future

Tristan van Leeuwen, Felix Lucka & Martin Fransen
X-ray Computed Tomography (CT)

Image credit: Daniël Pelt and University of Antwerp
Medical X-ray CT

math & algorithms
Computational Imaging

Mathematics

Computer Science

Imaging Science
The beginning of FleX-ray
The opening
The FleX-ray Lab
The FleX-ray Lab

Mathematics

Computer Science

Imaging Science
Selected Highlights
Cultural heritage & natural history
Michelangelo...or not?
Explorative imaging
Explorative imaging
RECAST3D

- Real-time quasi-3D reconstruction and visualization of arbitrary slices
- Plugin infrastructure for on-the-fly analysis
- Active experimental adaptation & control
Did someone say live demo?
Well...Murphy’s law
Dynamic real-time imaging and scan adaptation
Imaging dynamic processes
Imaging dynamic processes

$t = 14111$
AI in tomography

- data collections
- scaling
- robustness
- task-adaptation
- software coupling
- real-time
Open data collections for machine learning
Open data collections for machine learning
Open data

Computational Imaging -- Centrum Wiskunde & Informatica

Recent uploads

- **Trajectory with Overlapping Projections x-ray Computed Tomography (TOP-CT) dataset of 23 mandarins moving over a circular trajectory**
  - Dirk Elias Schut
  - Summary: This dataset is a collection of X-ray projection images of 23 mandarins moving over a circular trajectory in such a way that the projections of multiple adjacent mandarins overlap. The dataset was acquired to test out Trajectory with Overlapping Projections x-ray Computed Tomography (TOP-CT).
  - Uploaded on March 14, 2023

- **A collection of 131 CT datasets of pieces of modeling clay containing stones - Part 5 of 5**
  - Mathé T. Zeegers
  - Summary: This submission contains a collection of 131 CT scans of pieces of modeling clay (Play-Doh) with various numbers of stones inserted. The submission is intended as raw supplementary material to reproduce the CT reconstructions and subsequent results in the paper titled "A tomographic wo"
  - Uploaded on January 17, 2022

- **A collection of 131 CT datasets of pieces of modeling clay containing stones - Part 4 of 5**
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On-the-fly Machine Learning for superresolution
Efficient ML-based large-scale 3D tomography
Benchmarking AI

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Imaging for the Industry 4.0
Emulation of X-ray light-field cameras
Emulation of X-ray light-field cameras
Looking at colours the eye can’t see

Spectral X-ray imaging with Medipix3 in FleX-ray

Martin Fransen
Nikhef
Conventional X-ray image

X-ray source
(broad spectrum)

X-ray detector

grey scale image
X-ray transmission

Unique for each element!

Diagram showing transmission vs. photon energy for different thicknesses of Copper, Titanium, and Aluminium.
X-ray transmission

- Easy to identify materials, right?
- Not with conventional X-ray imaging, pixels record total amount of X-ray energy! → about the same shade of grey.

Also:
- Spectrum changes as X-rays traverse sample → beam hardening.
- Response to thickness and density variation is sensitive to thickness and density itself!
X-ray detection

- Easy to identify materials, right?
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Possible detector improvements:
- **Photon counting** (increasing ‘weight’ of low energy photons for better contrast)
- **Even better:** Measure each photon’s energy

Common alternative: modifying X-ray spectrum by means of ‘colour filters’. Some drawbacks:
- Limited choice in energy bands
- Lower X-ray intensity
- Multiple scans for multiple energy ranges
- ...
(Spectral) X-ray imaging with ‘Medipix3’

- Each absorbed X-ray photon releases charge proportional to its energy.
- Charge detected by pixels → detecting individual X-ray photons.
- Set 8 different detection thresholds → 8 energy bins.

Medipix3 detectors (electronics developed at Nikhef).
From grey scale to spectral

Metal foils (sample 3 x 3 cm).
X-ray energy scan

Metal foils.

Small egg.
Example 3d CT reconstruction
Beam hardening and CT scans

35 keV full spectrum.
Density gradient?

16-20 keV band.
Nope!
Medipix3 in FleX-ray

- Photon counting and energy binning.
- In addition to conventional X-ray imaging.
- Medipix3 detector in FleX-ray cabinet.
- Medipix3 based micro CT scanning set-up @ Nikhef.
The Future
A collaborative platform
Adaptive scanning
Quantitative imaging

FBP reconstruction

(mean $[\text{cm}^{-1}]$)

$x[\text{cm}]$

$y[\text{cm}]$

$x[\text{cm}]$

$y[\text{cm}]$

$\mu[\text{cm}^{-1}]$
Beyond images

Data

Processing and reconstruction

Reconstruction
Mathematicians

Computer Scientists

Imaging Scientists
Acknowledgements
Thanks!

- Joost Batenburg
- CWI, Tescan XRE, Nikhef, ASI
- Sophia B. Coban & Alexander Kostenko
- Willem Jan Palenstijn, Navrit Bal
- The Computational Imaging group
Partners & sponsors

CWI

XRE

GREEFA

Applus

WAGENINGEN UNIVERSITY & RESEARCH

ERCIM

European Research Consortium for Informatics and Mathematics

Amsterdam UMC

Universiteit Utrecht

ASA

meyn

Nikhef

PLANMECA

Universiteit Leiden

NWO
Tea & coffee time

Nick Veasey, VW Camper Van, 2019