Methods for analysis and visualization of industrial XCT-data of fibre reinforced composites

Christoph Heinzl

FH OÖ Forschungs & Entwicklungs GmbH • Hagenberg • Linz • Steyr • Wels

Team

RESEARCH GROUP
Computed Tomography

DI(FH) Michael Reiter
- Software development, simulation, dimensional measurement

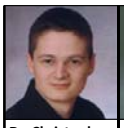
Andreas Reh, MSc
- Software development, visualization

DI Johannes Weissenböck
- Software development, visualization

Mustafa Arikan
- Software development, fibre extraction

Dr. Artem Amirkanov
- Software development, visualization

DI Bernhard Föhler
- Software development, visualization



Dr. Christoph Heinzl
- Senior researcher, Software development + visualization

Dr. Johann Kastner
- Head of Research group Computed Tomography

DI Dietmar Salaberger
- Research project manager NDT plastics

currently 3 Master students

2 open positions
(NDT, Software development, see www.interaqct.eu)

DI(FH) Bernhard Plank
- NDT plastics

DI Christian Gusenbauer
- RayScan 250E, NDT metals

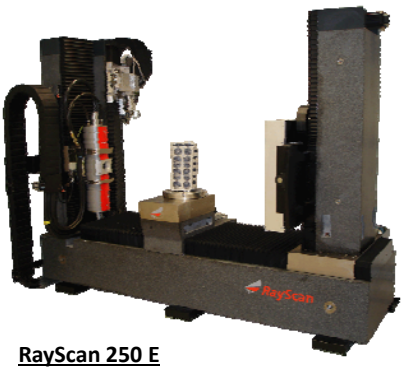
Sascha Senck, PhD
- NDT plastics

Christian Hannesschläger, MSc
- NDT metals

Eva Kremshuber, BA
- Project assistant EU-FP7

Mag. Elena Sell
- Project assistant FFG

Devices



RayScan 250 E

- 225 kV microfocus X-ray source
  variable focal spot size > 5 µm
- 450 kV minifocus X-ray source
  fixed focal spot size: 0,4 mm
- 2048² pixel flat panel detector

GE phoenix nanotom s

- 180 kV sub-microfocus
  variable focal spot size > 0,5 µm
- 2304² pixel flat panel detector
- In-situ loading stage

Projects

FFG – ZPT

- K-Project for Non-destructive Testing and Tomography
- 2009-2014, 6 M€
- www.nondestructive.at

ZERSTÖRUNGSFREIE PRÜFUNG UND TOMOGRAFIE

EU-FP7 NanoXCT

- Compact X-ray computed tomography system for non-destructive characterization of nano materials
- 2012-2015, 4.5 M€
- www.nanoxct.eu

NanoXCT

EU-FP7 QUICOM

- Quantitative inspection of complex composite aeronautic parts using advanced X-ray techniques
- 2012-2015, 5.1 M€)
- www.quicom.eu

QUICOM

further European and national projects

Expertise and Methods

Expertise:

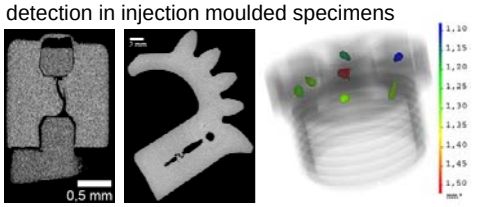
- Non destructive testing, materials characterization and 3D micro structure analysis
- 3D-Metrology
- Quality control and assurance
- 3D Image Processing and Visualization

Methods:

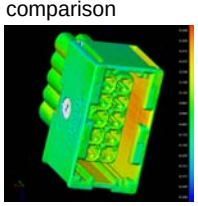
- Macro-, Micro- und Sub-micro-Xray Computed tomography, (especially quantitative XCT)
- In-situ stages
- XCT-Simulation
- Advanced Image Processing and Visualization techniques

XCT applications for polymers

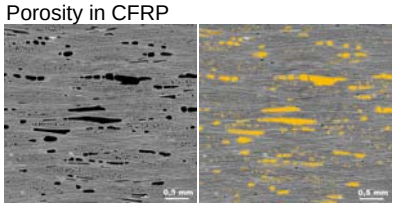
Non destructive testing, e.g., Crack + pore detection in injection moulded specimens



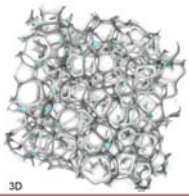
Actual – nominal comparison



Quantitative analysis, e.g., Porosity in CFRP



Cellulose distribution in PUR foam



Cellulose fibre characterisation

Fiber extraction

CT resolution

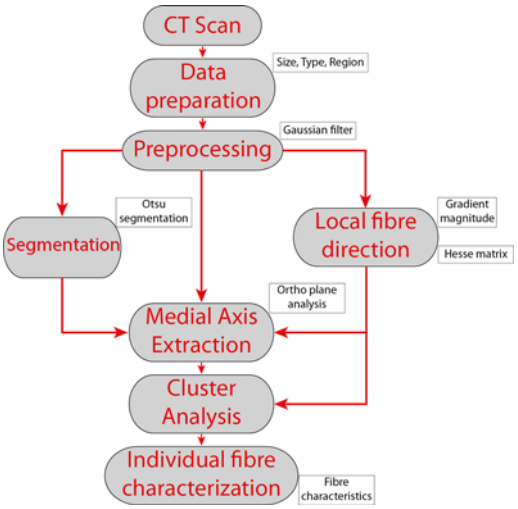
- ~ fibre diameter / 6
- e.g. 2 µm per voxel

Analysis volume

- 5 x 3 x 3,7 mm³

Duration

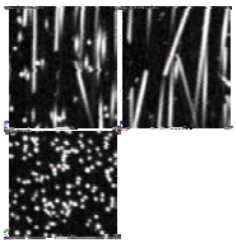
- Scan: 5 hours
- Data analysis: 1,5 hours



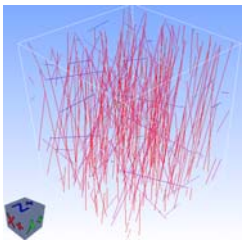
Fiber extraction

Individual fiber characteristics

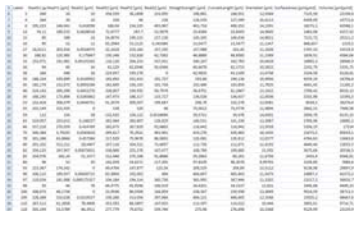
- Position, Length
- Diameter, Orientation
- Surface, Volume, etc.



CT slice images of original data set (PP-GF30)
Voxelsize: 2 µm



3D image of extracted fibres colour coded according to orientation (PP-GF30)



Export of individual fibre characterization in *.csv format

Accuracy and Reproducibility

Reference

- XCT simulation: fibers as cylinders

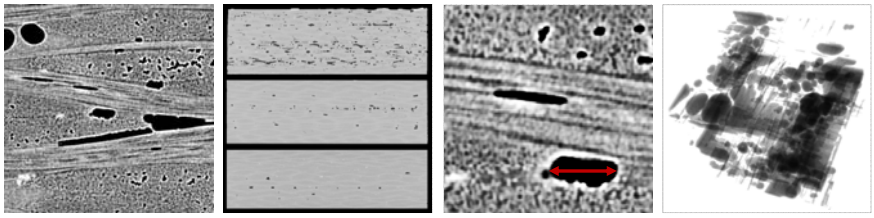
Fiber characterization

- Simulated data, constant fiber diameters
- Simulated data, varying fiber diameters
- Real world scan

Results

- Correctly extracted fibres:
  - > Simulated data, constant fiber diameters: 90,9 %
  - > Simulated data, varying fiber diameters: 80,7 %
  - > Real world scan (voxelsize 2 µm): 82,7 %
- Errors mainly due to:
  - > Breakage, Wrong connection

Visual Analysis of Porosity



Task 1: Quantitative porosity

Task 2: Porosity overview

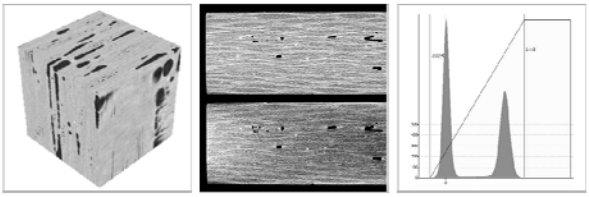
Task 3: Local pore properties

Task 4: Best viewpoint

A. Reh et al., Porosity Maps–Interactive Exploration and Visual Analysis of Porosity in Carbon Fiber Reinforced Polymers, Computer Graphics Forum 31, 1185-1194

Porosity Maps Pipeline

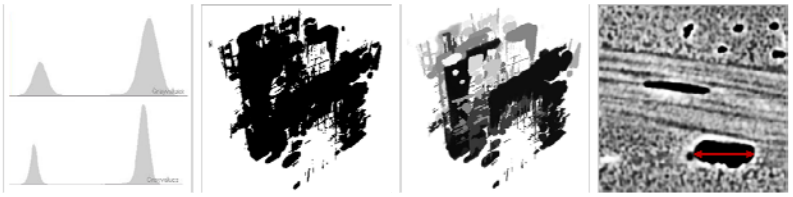
Data Acquisition → Pre-Computation → Visual Analysis of Porosity



CT Measurement | Beam Hardening Correction | Data Mapping

Porosity Maps Pipeline

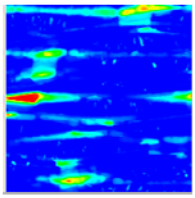
Data Acquisition → Pre-Computation → Visual Analysis of Porosity



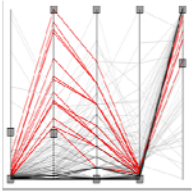
Anisotropic Diffusion | Otsu Thresholding | Connected Components | Porosity Determination

Porosity Maps Pipeline

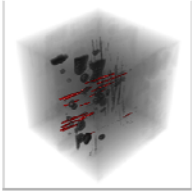
Data Acquisition → Pre-Computation → Visual Analysis of Porosity



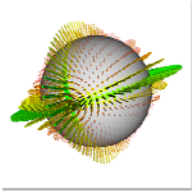
Porosity Maps



Parallel Coordinates View

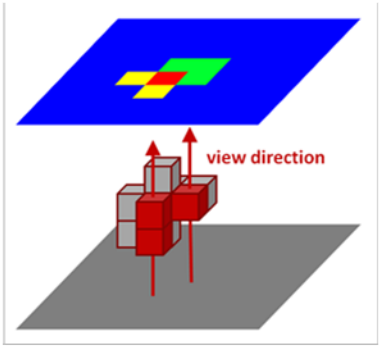


Interactive Exploration

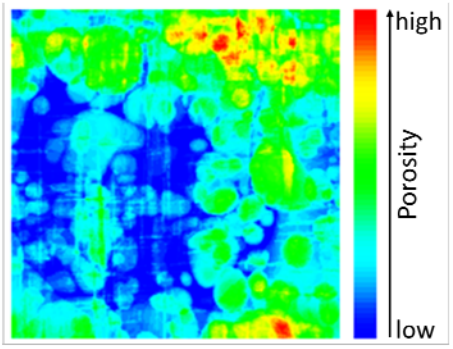


Best Viewpoint Widget

Porosity Maps Calculation

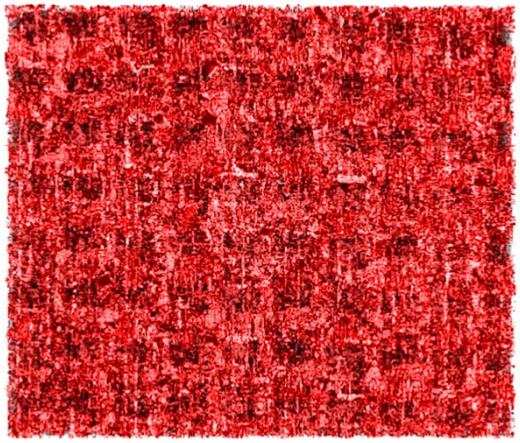


Porosity Map calculation



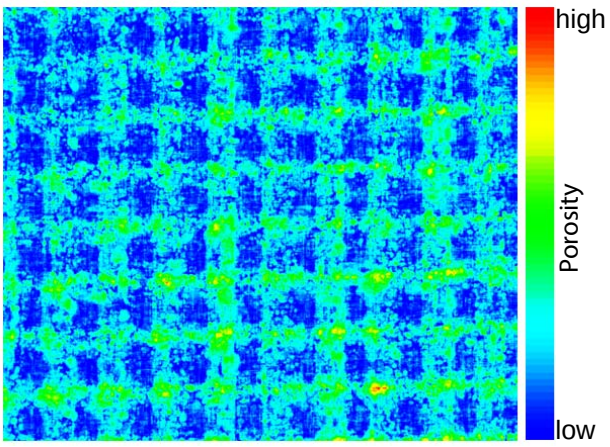
Porosity Map

Results: Porosity Maps



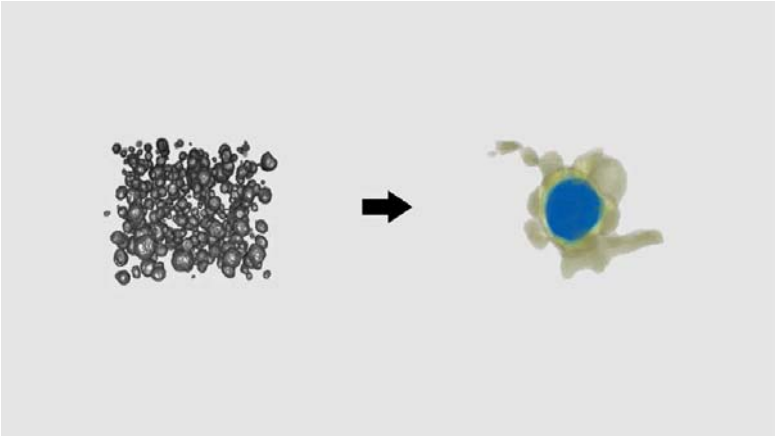
XZ view

Results: Porosity Maps



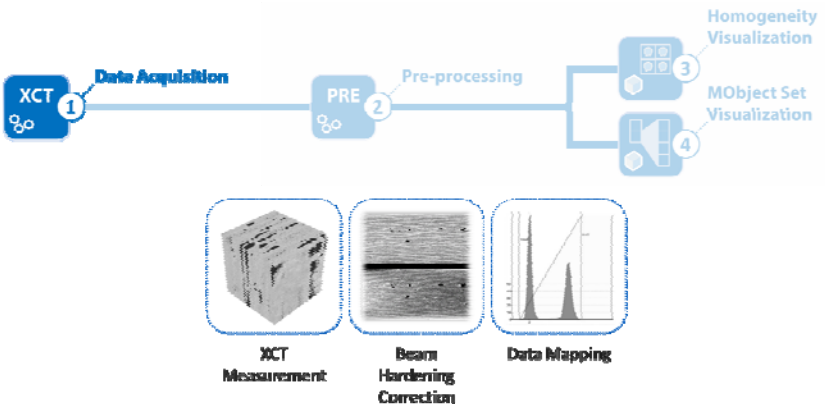
XZ porosity map

Mean object representations

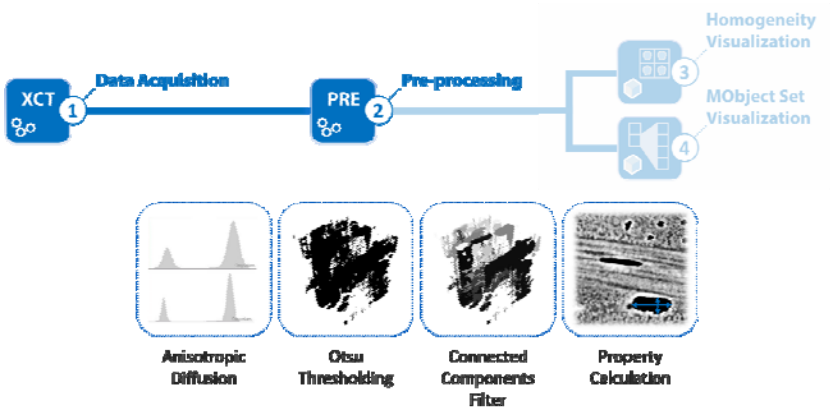


A. Reh et al., MObjects - A Novel Method for the Visualization and Interactive Exploration of Defects in Industrial XCT Data, Visualization and Computer Graphics, IEEE Transactions on 19 (12), 2906-2915

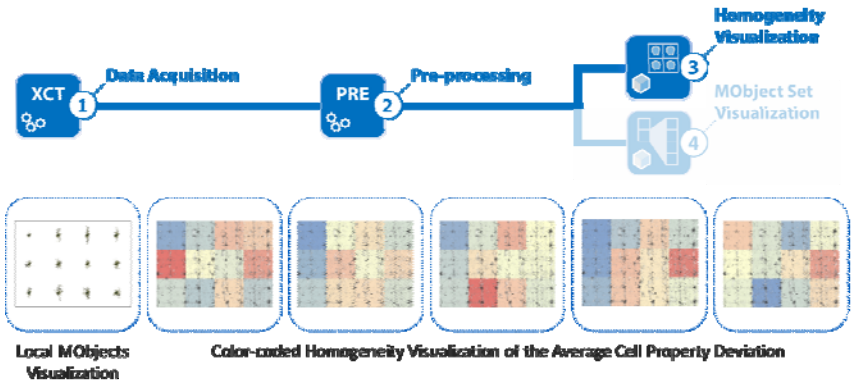
MObjects Pipeline Overview



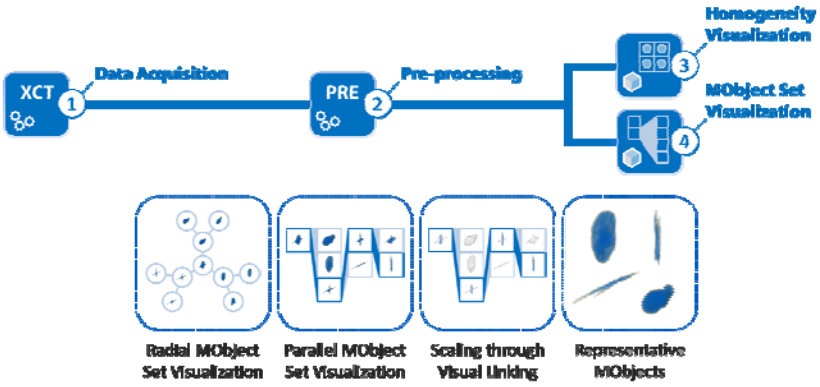
MObjects Pipeline Overview



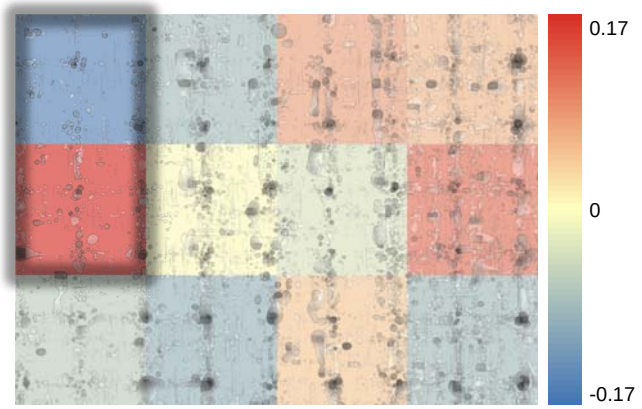
MObjects Pipeline Overview



MObjects Pipeline Overview

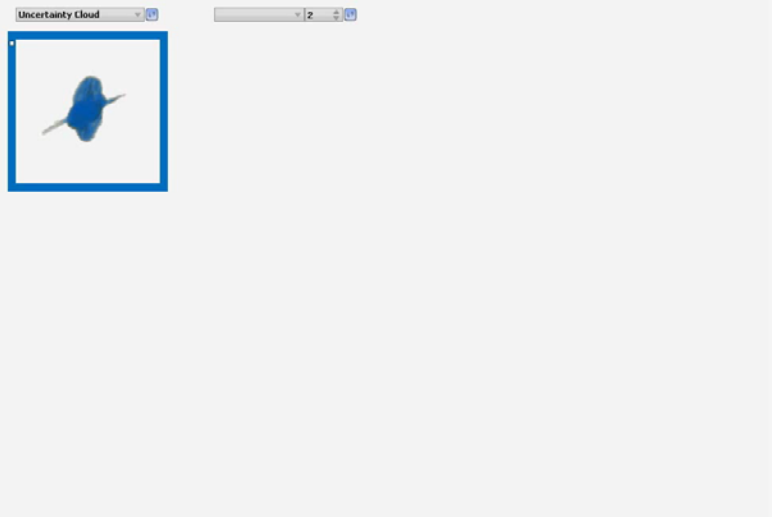


Results: Homogeneity Visualization



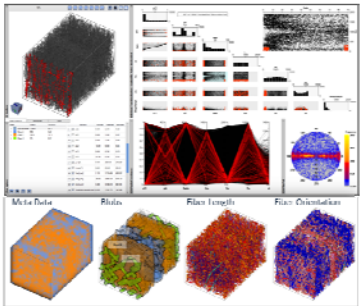
Deviation from avg. pore dimension X [mm]

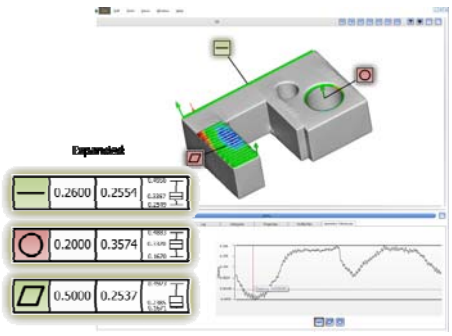
Results: MObject Set Visualization



Further Activities

- Individual Fiber Visualization
- Fuzzy 3D metrology
- Multimodal Visualization
- XCT Simulation



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25