Automatic Extraction and Analysis of Realistic Pore Structures from µCT Data for Pore Space Characterization of Graded Soil

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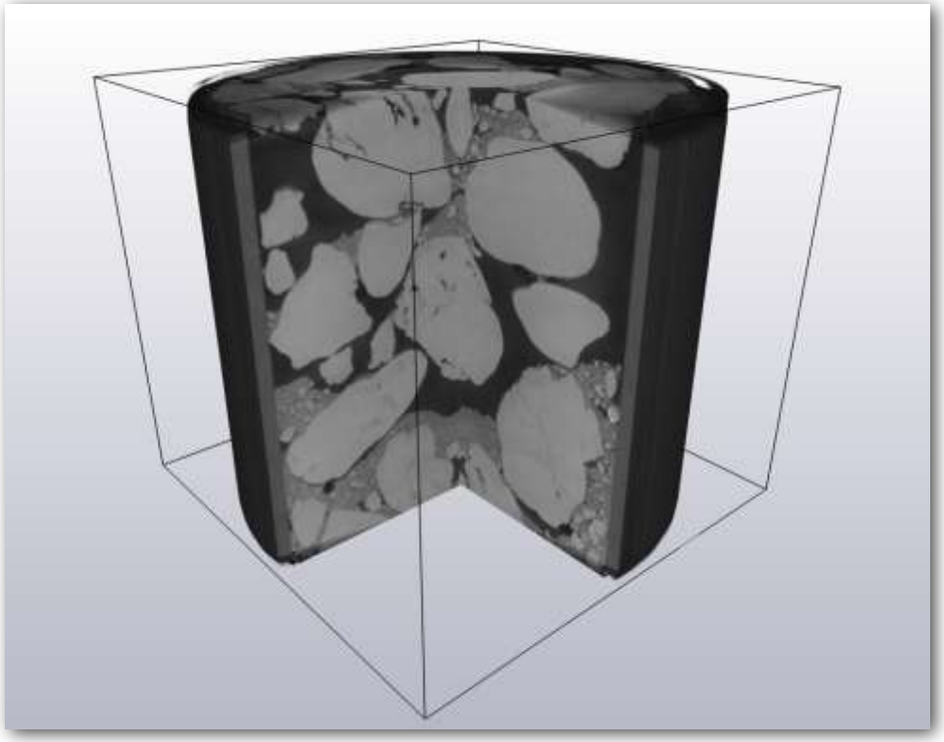
Dep. Visualization and Data Analysis

Context and Motivation

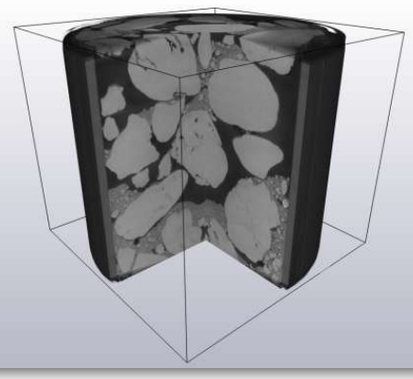
- Part of project: Conditions of suffosive erosion phenomena in soils

- Understanding the transport possibilities
- Describing the pore space by parameters (csd, psd, ...)
- Defining and extracting the pore structures from CT



Overview

CT Data

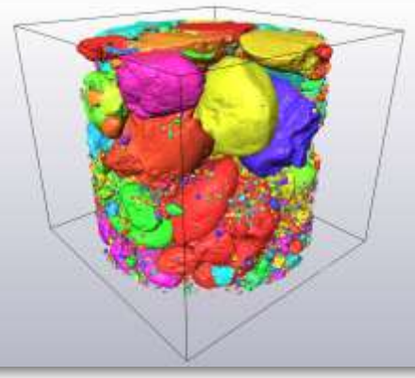


Geometric Description

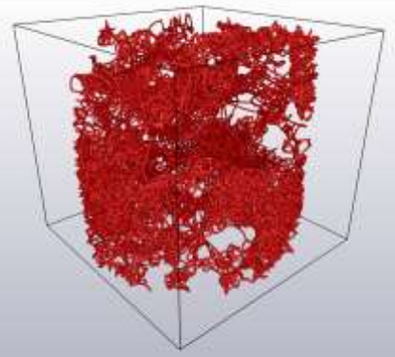
Application Specific Analysis

Pore Space

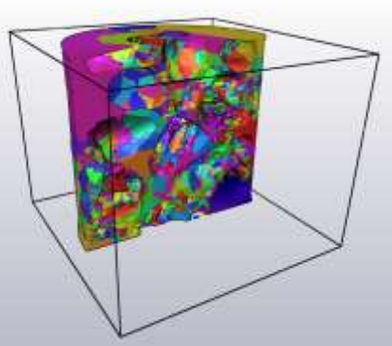
Particle Structure
[Homberg, 2009]



Pore Structure

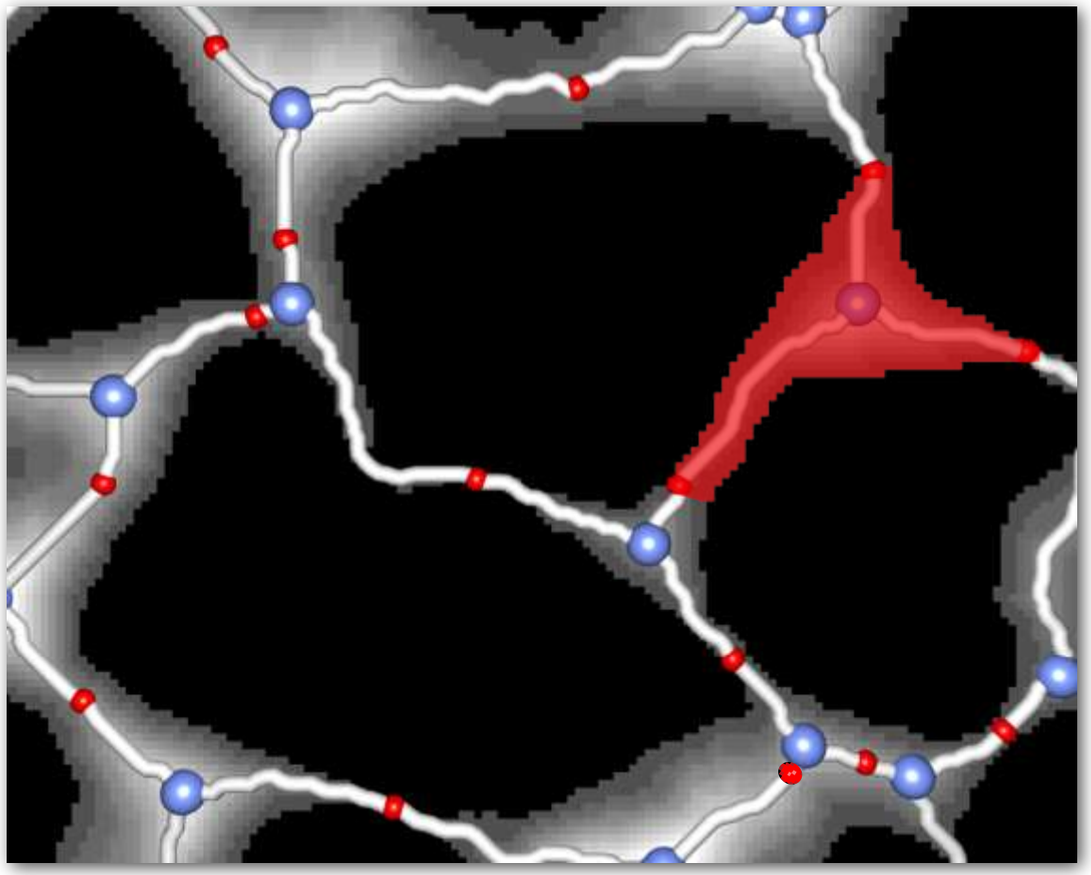


Pore Volume



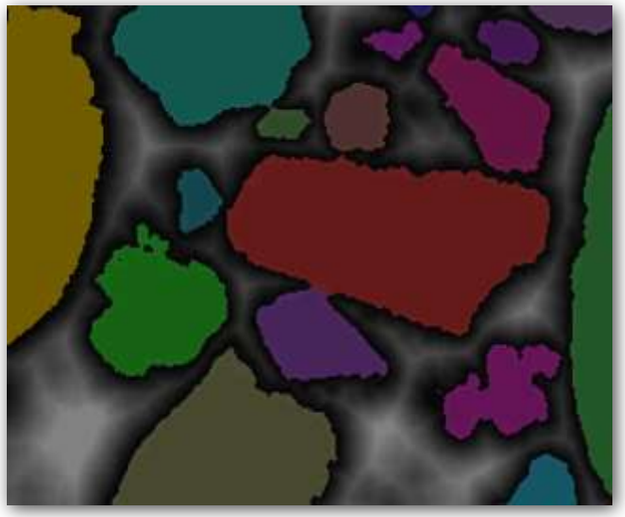
Pore Space: Definitions

- 3D distance map to the particle boundaries
- Elements of pore space:
  - Pore centers → maxima
  - Pore constrictions → 2-saddles
  - Pore paths → unstable manifolds of 2-saddles
  - Pore bodies → stable manifolds of maxima excl. the particle regions

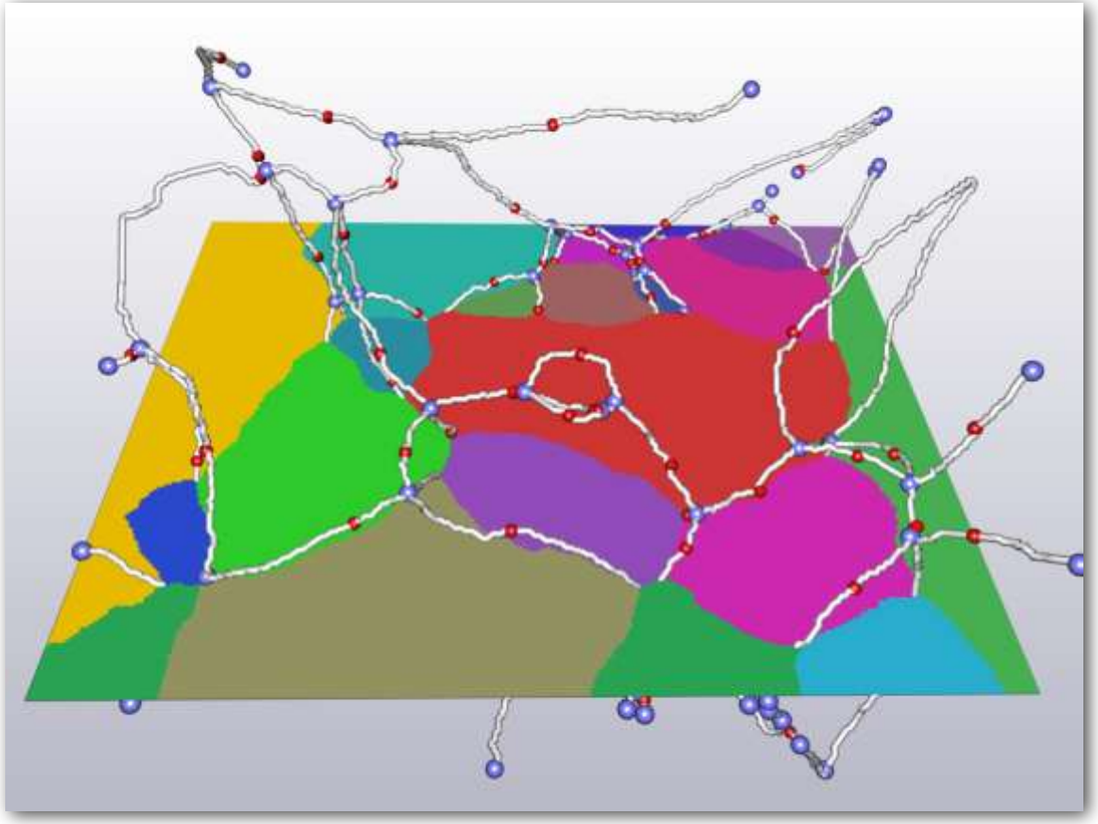


Example in 2D

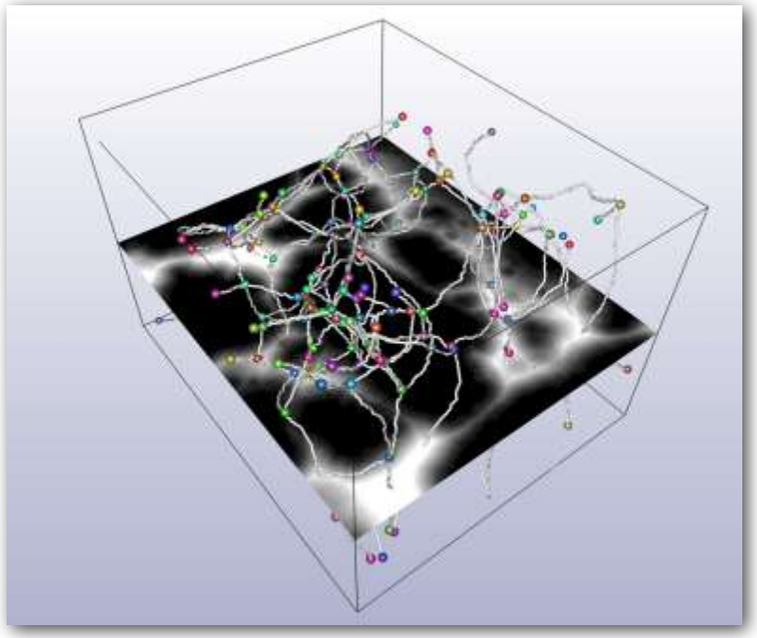
Pore Structure

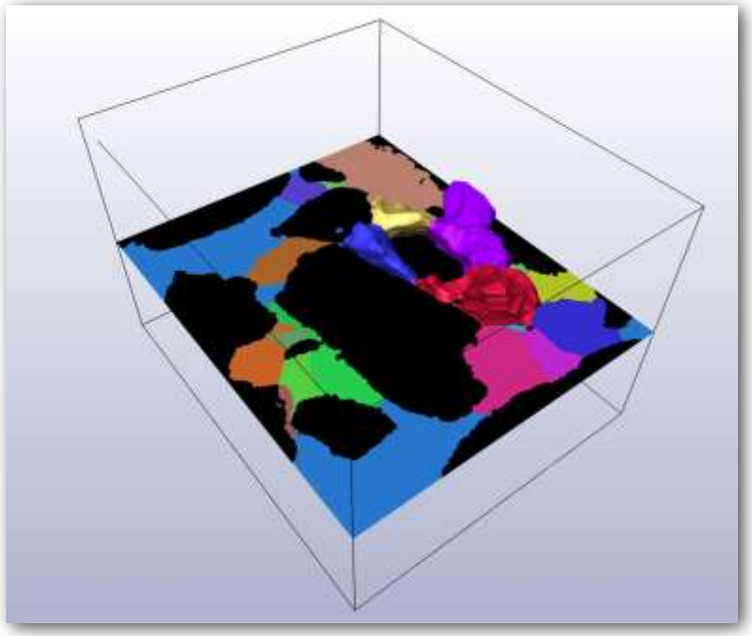


- Voronoi-like decomposition
- Pore Graph:
  - Edges: 3 particle regions
  - Nodes: >3 particle regions
  - Radius: distance information

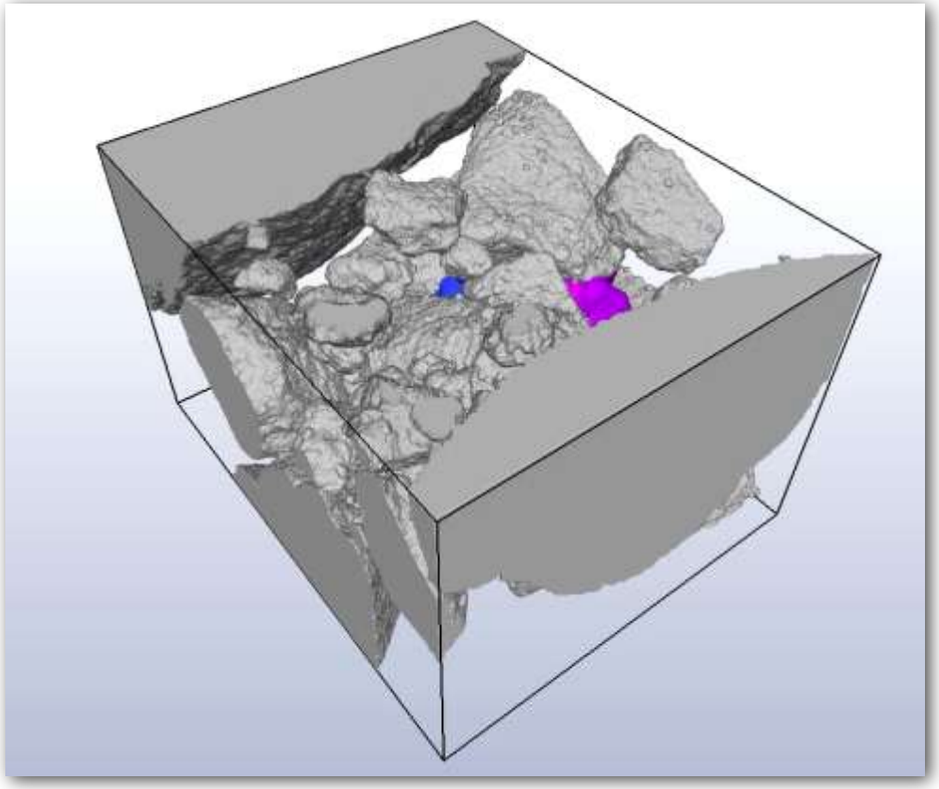


Pore Volume



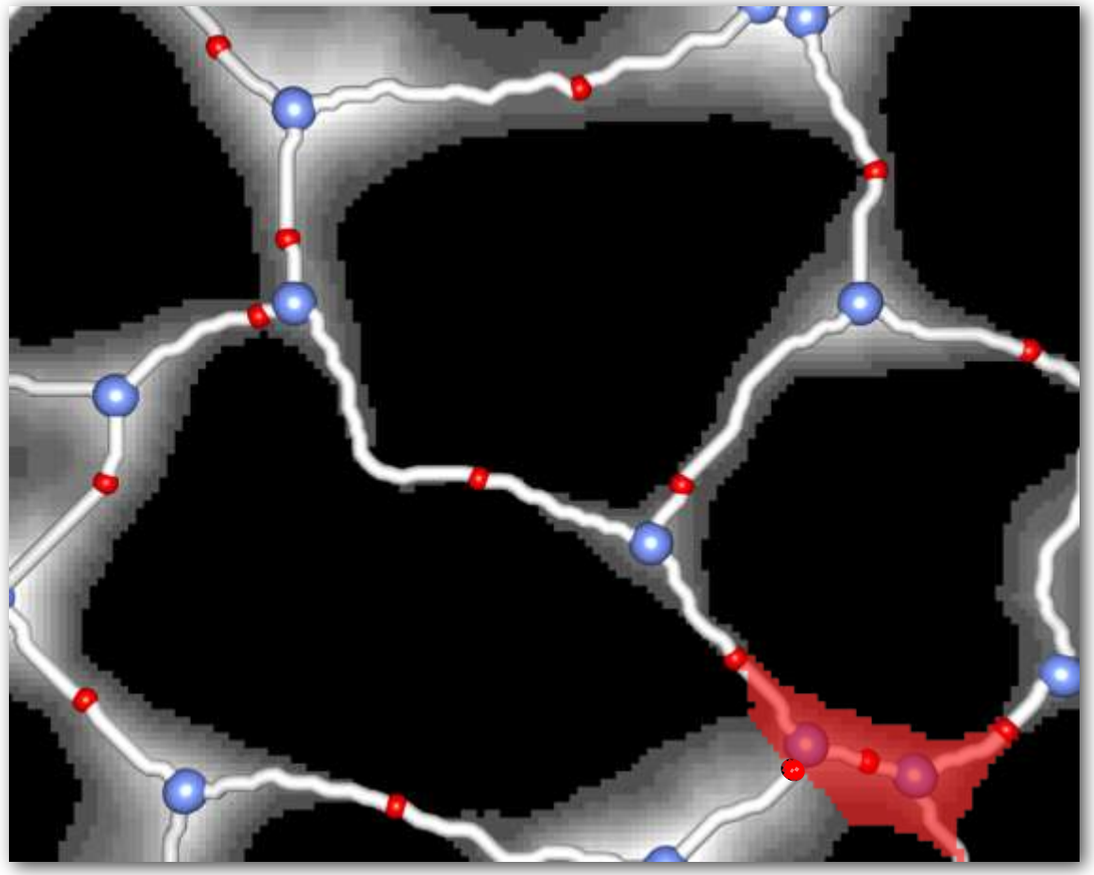


- Pore bodies: stable manifolds of maxima excl. the particle regions
- Propagating labeled pore centers



Pore Merge

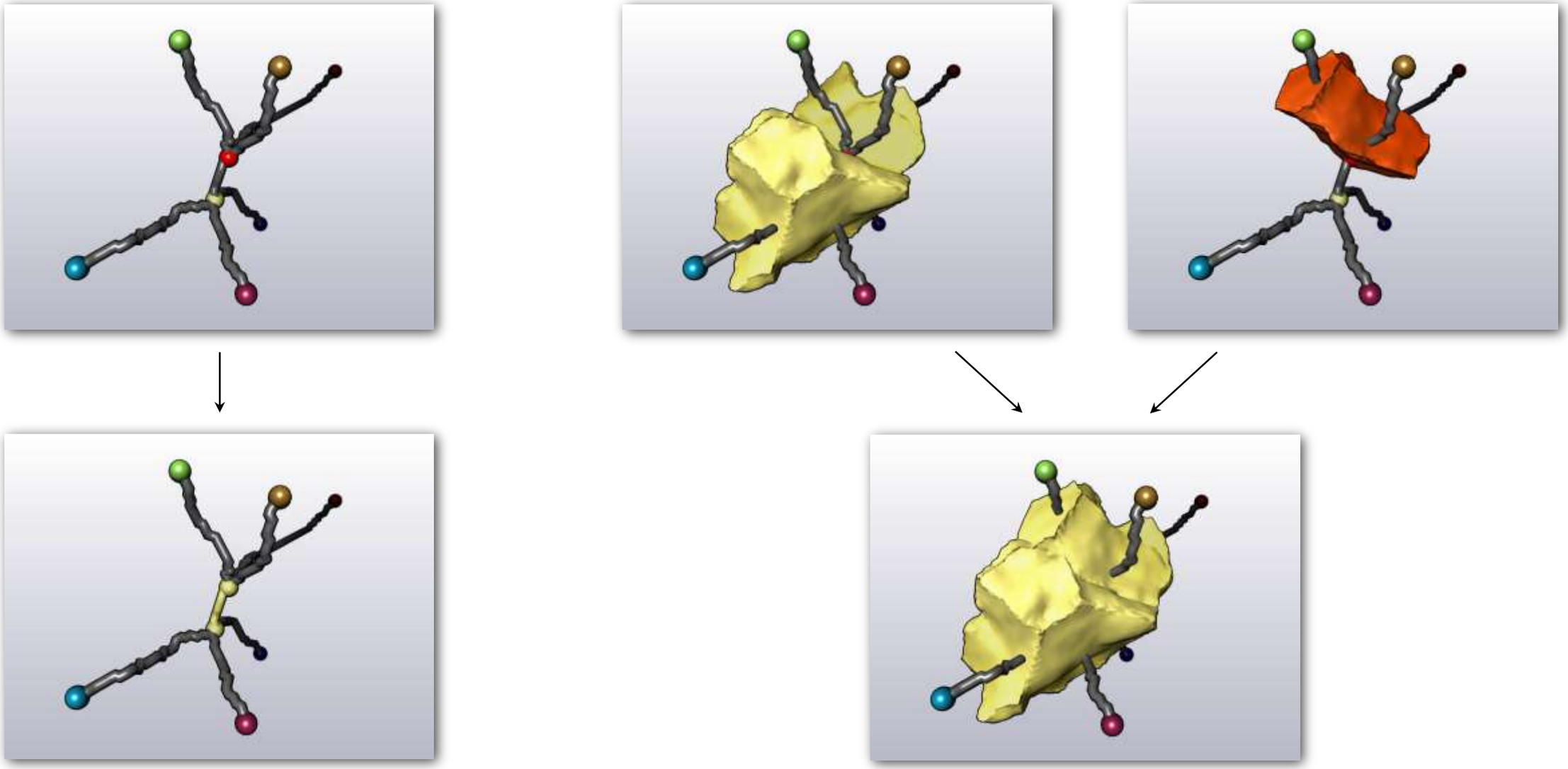
- Unstable pore separation
- Error reduction in quantification
- Topological persistence simplification [Edelsbrunner, 2002]
- Persistence measure based on distance information



Example in 2D

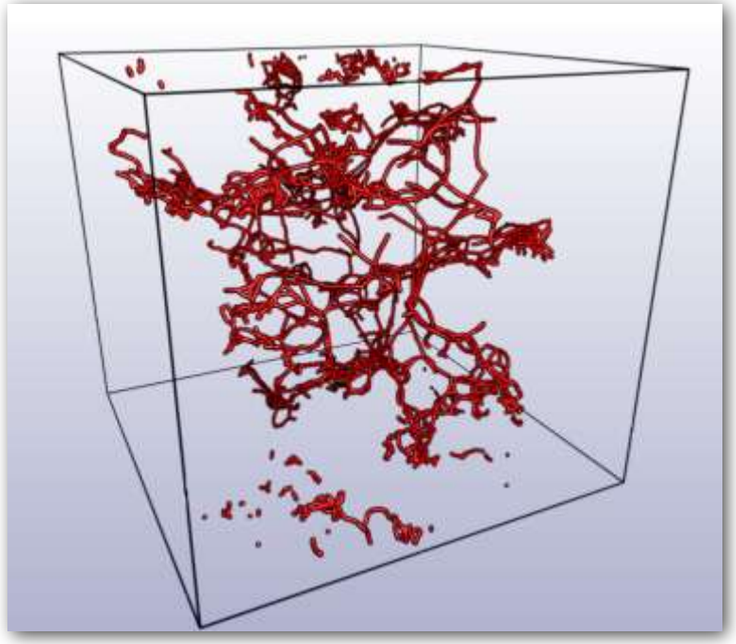
Pore Merge

- Merge on pore graph

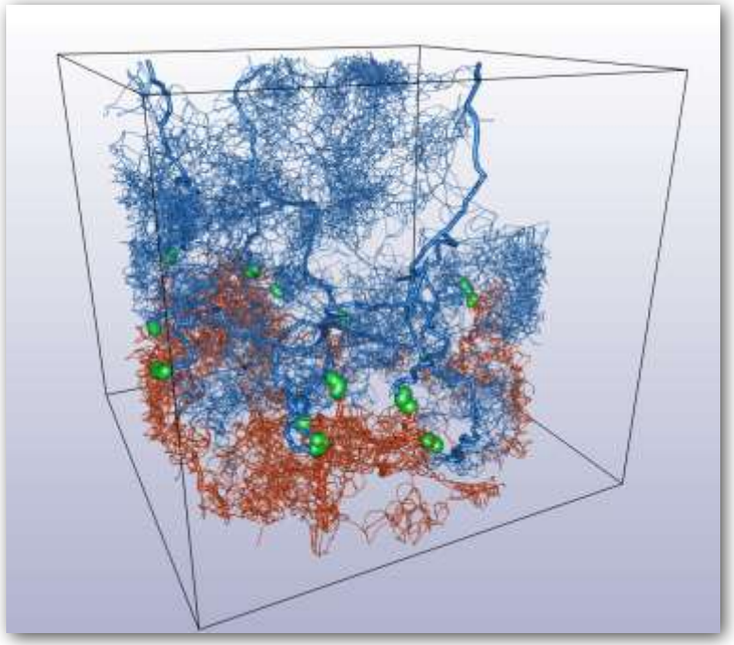


Conclusion

- Summary
  - Definition & extraction of pore space elements
  - Compact descriptions of pore space
  - Quantification of the elements, csd, psd, ...
  - Integration into the software system ZIBAmira



- Outlook – Graph-based Analysis
  - Path filtering
  - Particle size-dependent critical constrictions, paths, and depth of penetration



Cooperations

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U. Kalbe, BAM Federal Institute for Materials Research and Testing, Berlin

V. Slowik, University of Applied Sciences, Leipzig

References

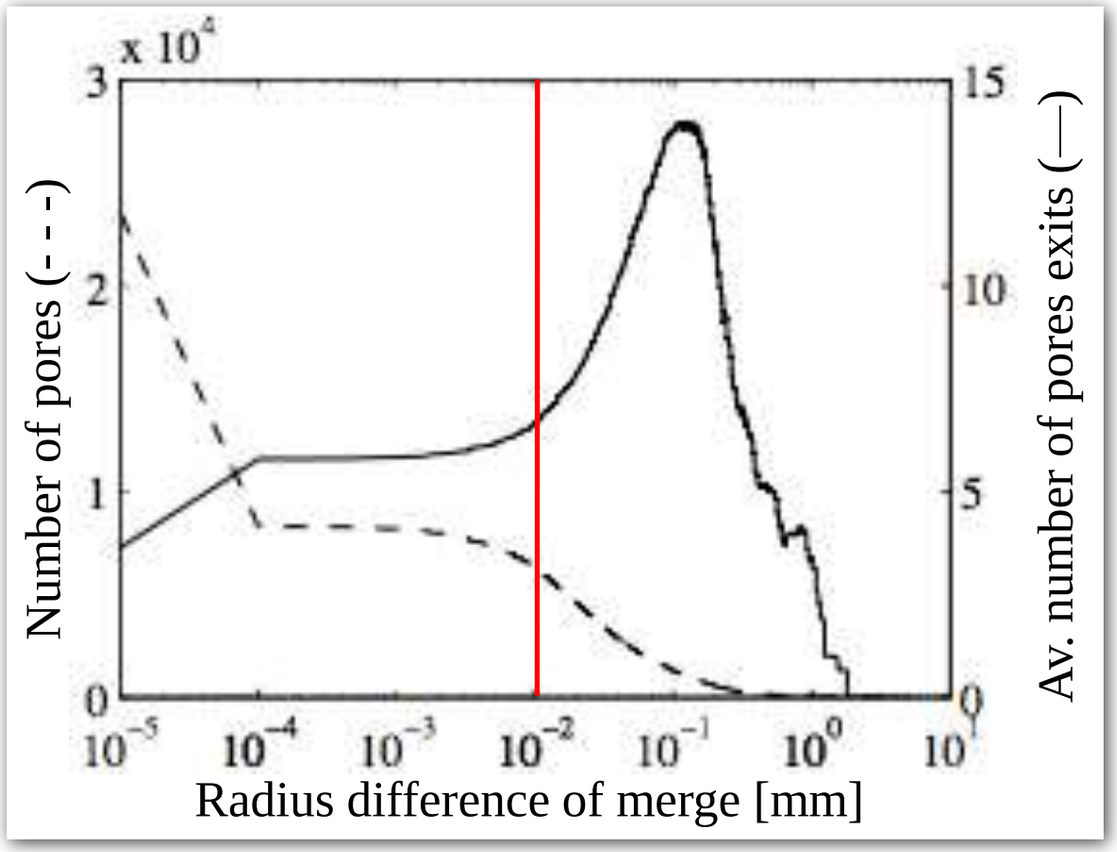
U. Homberg, R. Binner, S. Prohaska, V. J. Dercksen, A. Kuß, U. Kalbe: *Determining Geometric Grain Structure from X-Ray Micro-Tomograms of Gradated Soil*. In: Witt, K. J. (Ed.), Workshop Internal Erosion, Schriftenreihe Geotechnik (2009), 21, Verlag der Bauhaus Universität Weimar, 37-52.

U. Homberg, D. Baum, S. Prohaska, U. Kalbe, K. J. Witt: *Automatic Extraction and Analysis of Realistic Pore Structures from µCT Data for Pore Space Characterization of Graded Soil*. 6th International Conference on Scour and Erosion 2012 (ICSE-6).

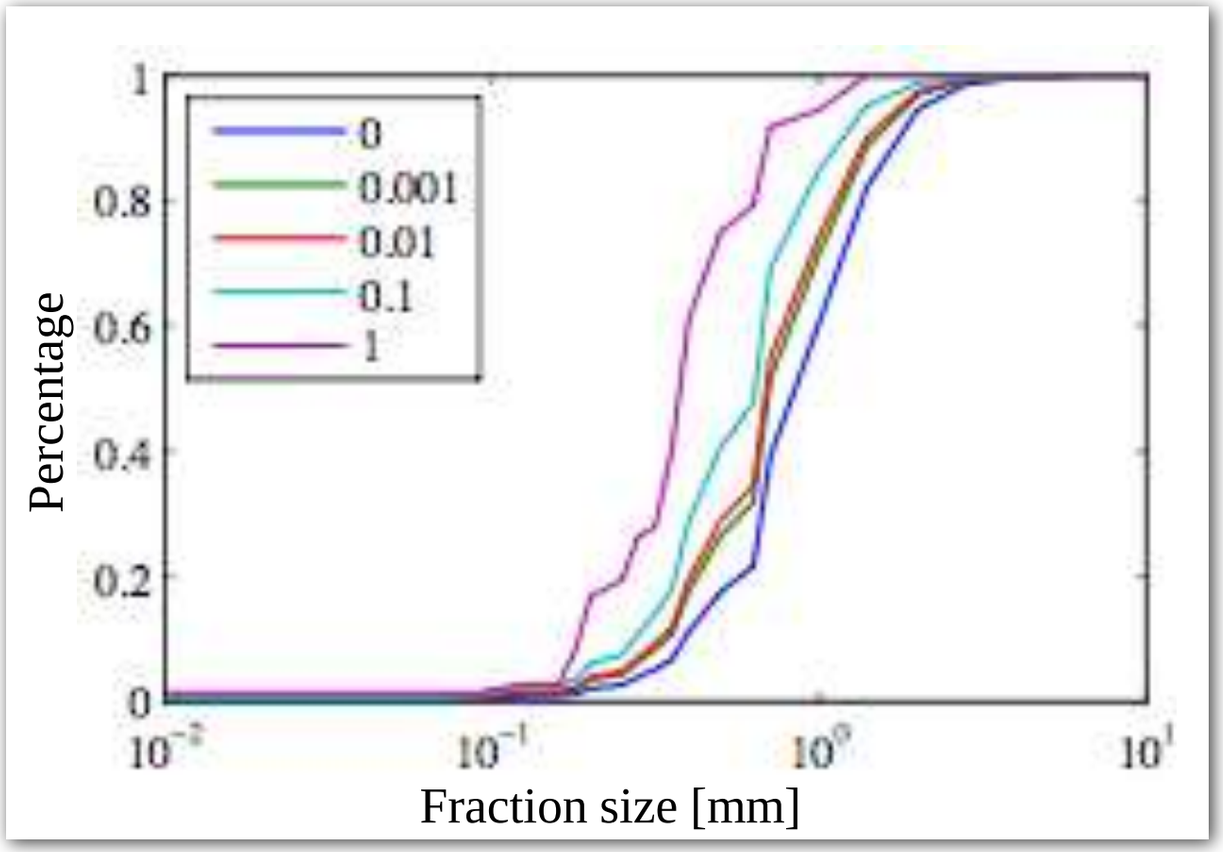
H. Edelsbrunner, D. Letscher and A. Zomorodian: *Topological Persistence and Simplification*. In: Discrete and Computational Geometry (2002), 28, 511-533.

Pore Merge vs. Constriction Size Distribution

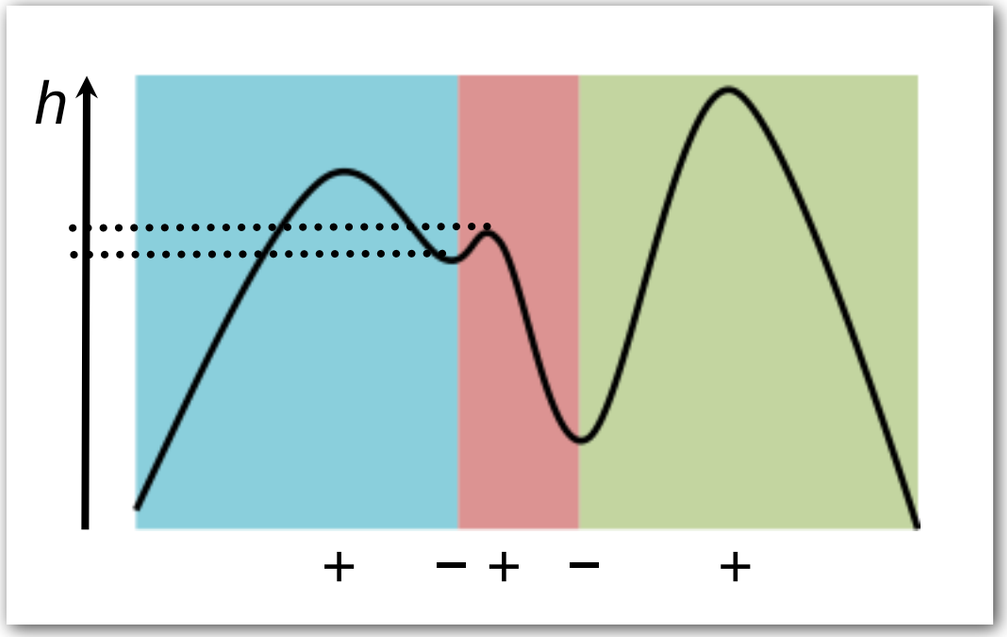
Merge Behavior

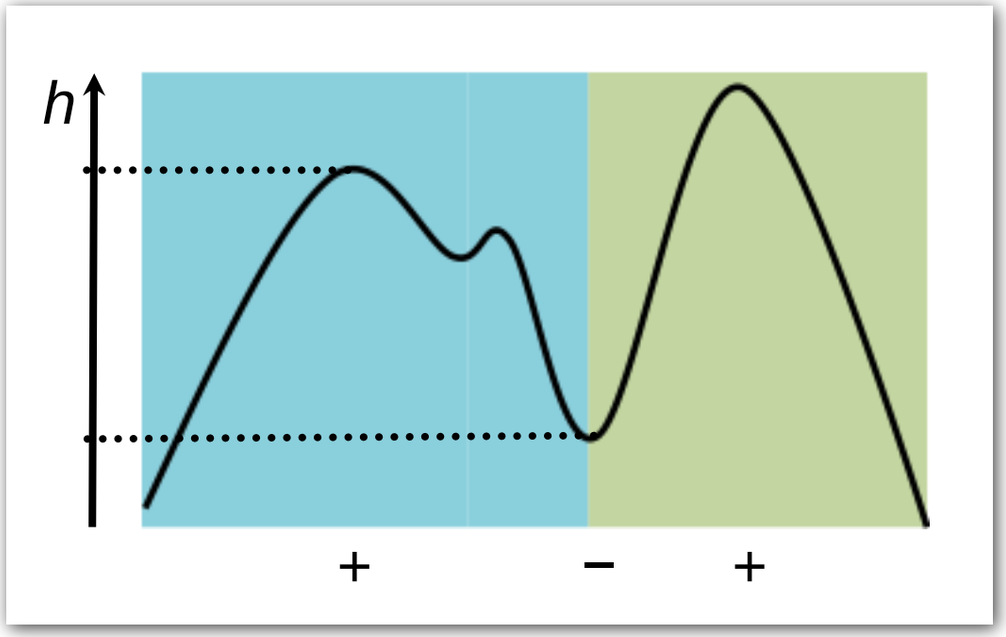


Constriction size distribution at different merge Thresholds



Simplification for Pore Merge





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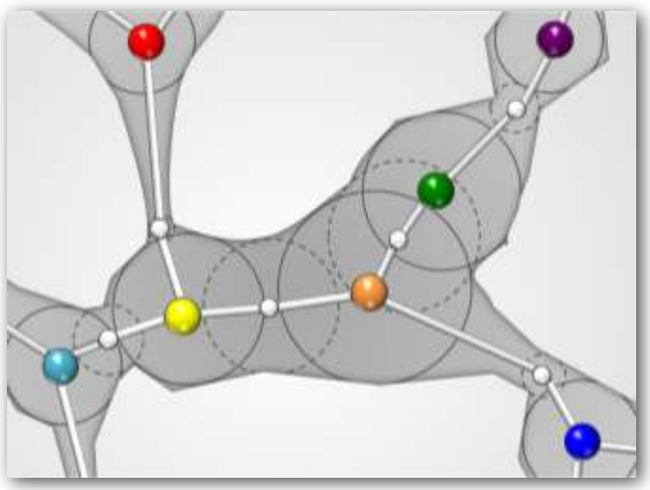
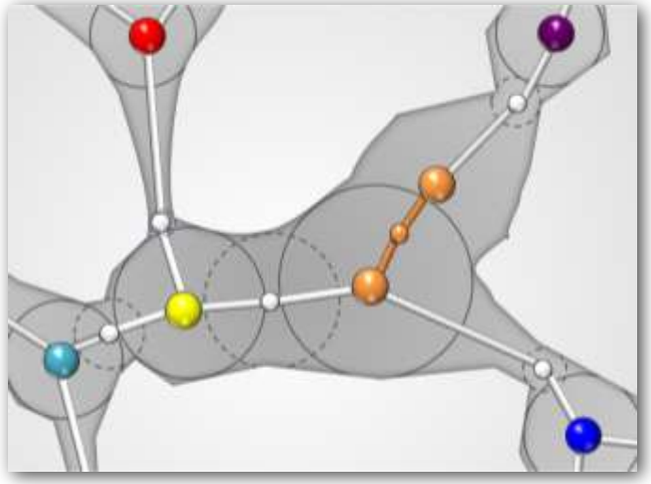
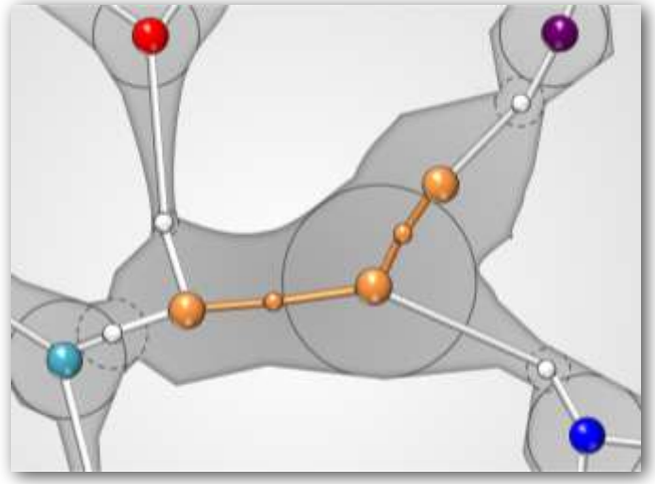
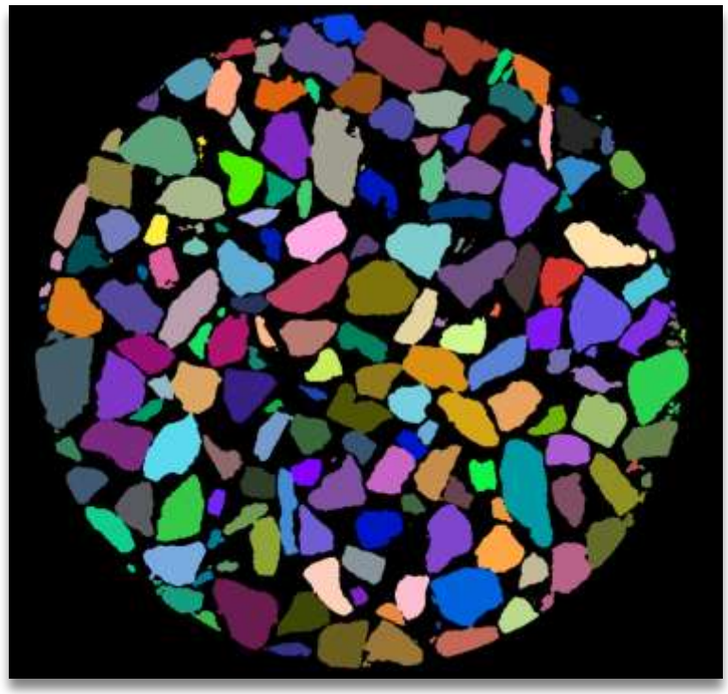




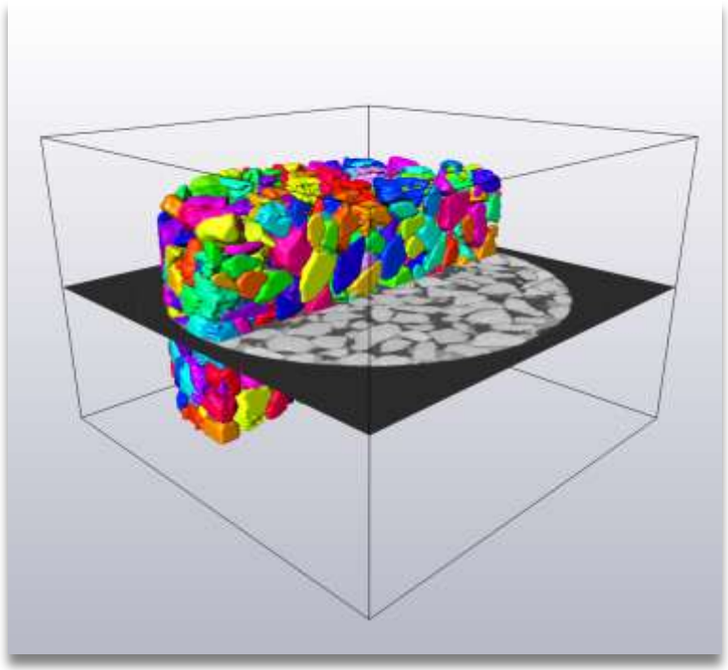


Particle Structure

- Pre-processing and thresholding
- Morphological separation
- Distance-based reconstruction

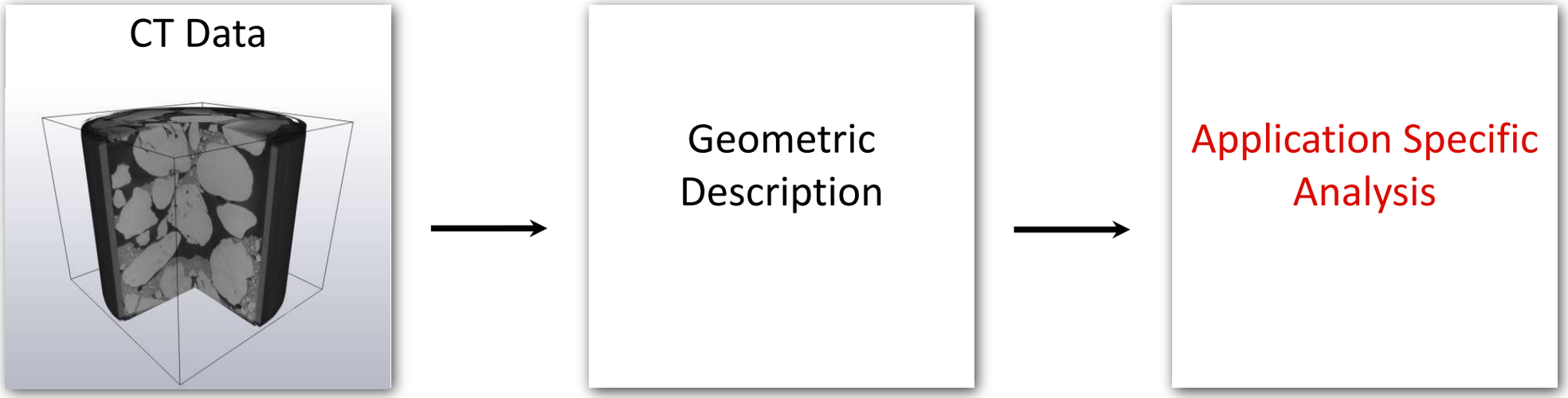


- Description: particle size, number, position, orientation ...
- Algorithm variations depending on specific problem



Data courtesy: BAM, A. Staude

Overview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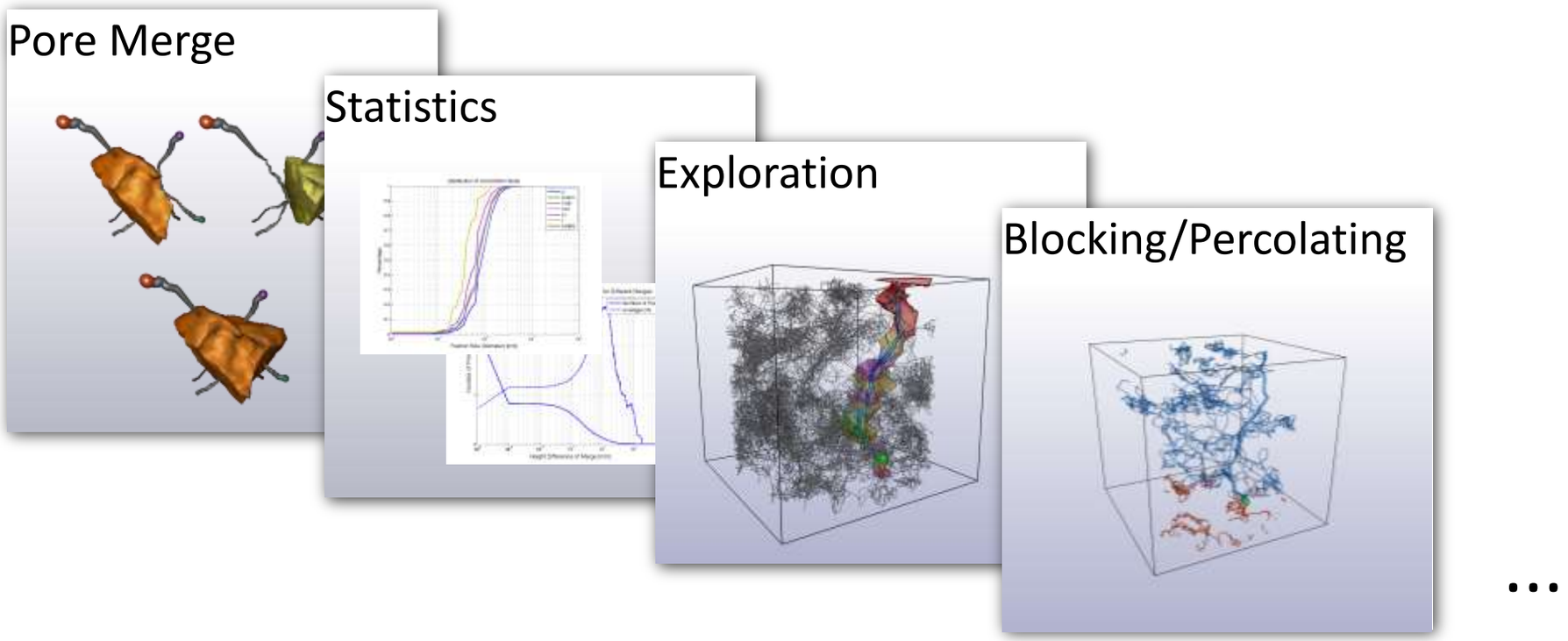
Pore Merge
Statistics
Exploration
Blocking/Percolating
...