Fachhochschule Salzburg University of Applied Sciences

SPEED OPTIMIZATION OF CT-BASED MICROSTRUCTURE DETERMINATION USING MATRIX DECOMPOSITION

Simon Kranzer, Gernot Standfest, Karl Entacher

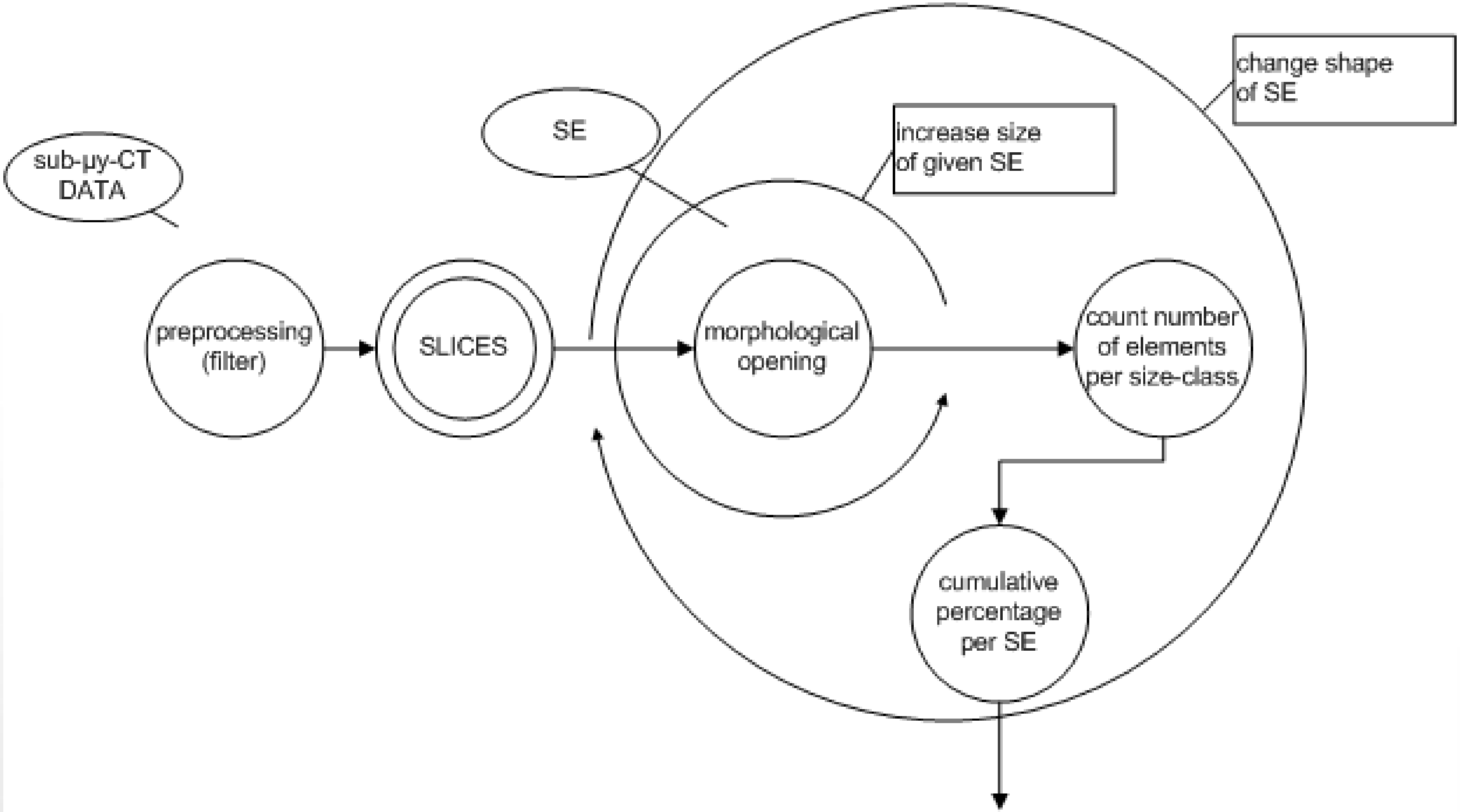
School of Information Technologies and Systems-Management
Salzburg University of Applied Sciences

{simon.kranzer, gernot.standfest, karl.entacher}
@fh-salzburg.ac.at

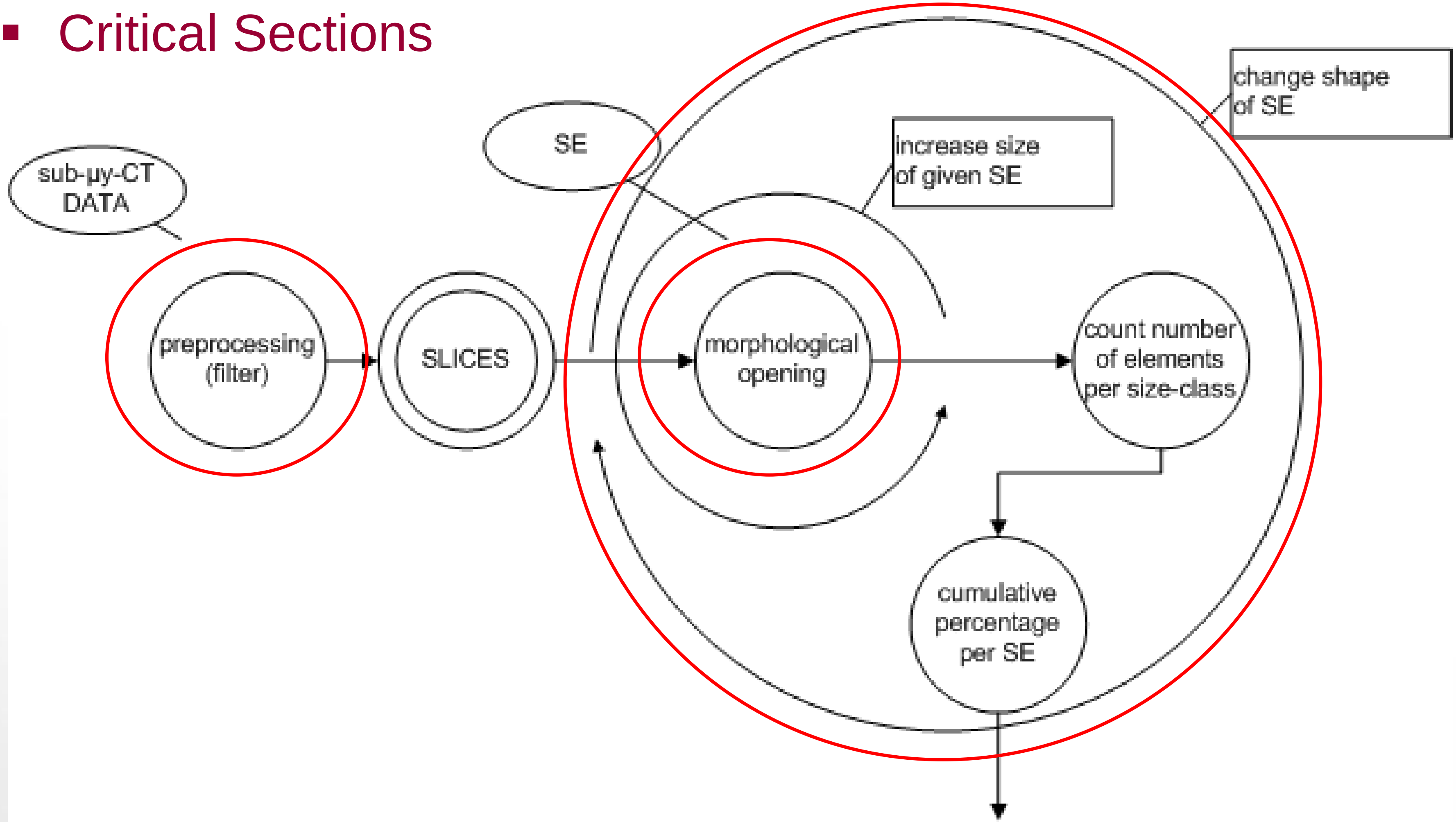
- Method for determining the micro-structure
  - Critical Sections
  - Parallelization?
- Mathematical morphology
  - Basic Operations
  - Opening, Closing, Structural Elements (SE)
  - Complexity

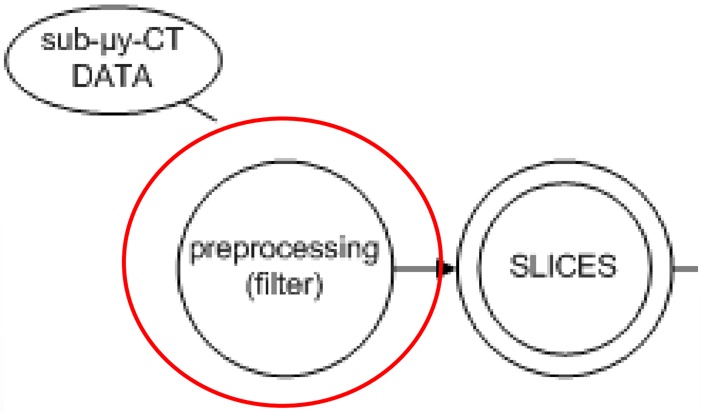
- Reducing complexity by decomposing SEs
  - Methods
  - Restrictions
  - Parallelization Challenge
- Multi-level decomposition of Euclidean spheres
- Performance measurements

1. Preprocess slices aquired by (sub)-µCT
   - Reduce noise
   - Convert to binary (threshold)
2. Loop for each slice
   - Loop for each SE
     - Apply opening using smallest SE
     - Count number of structures per size
     - Increase size of SE


sub-µy-CT DATA
SE
change shape of SE
increase size of given SE
preprocessing (filter)
SLICES
morphological opening
count number of elements per size-class
cumulative percentage per SE

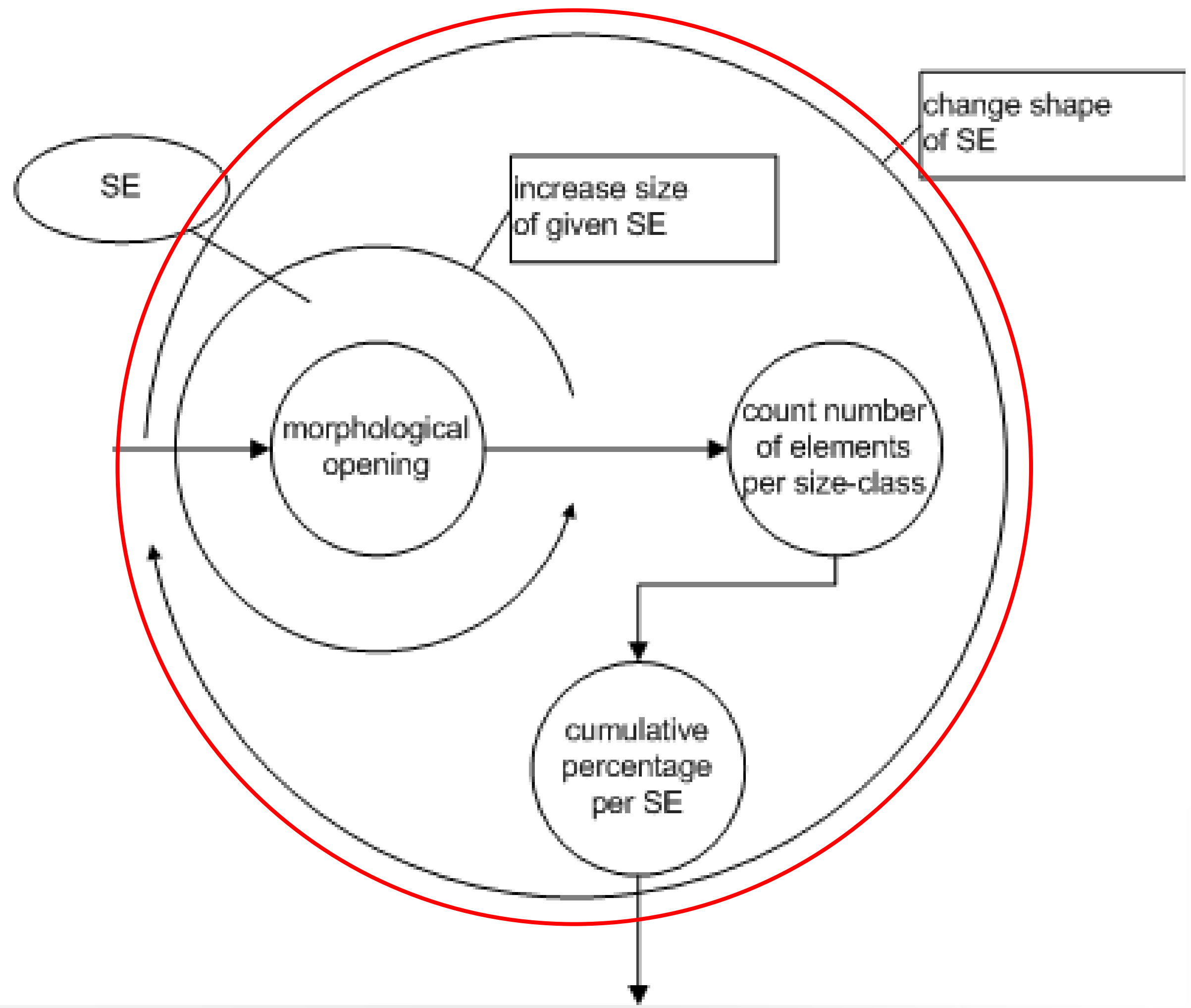
- Critical Sections



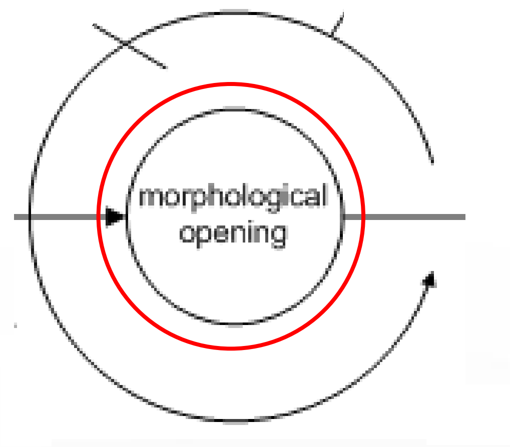


- ✓ Processing of multiple slices in parallel

- ✓ Processing of different SEs in parallel

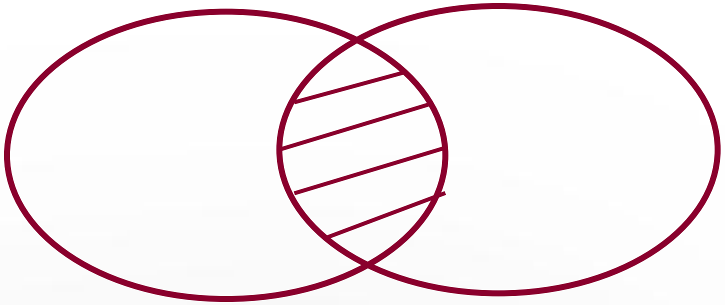


- ‼ Result of antecedent iteration is needed
- ‼ More than one slice involved within each iteration
- ‼ Sequential processing needed



- Goal
  - Identify possible points of action within opening algorithm

- Strong mathematical basis in Set theory
- Basic operations
  - Erosion
  - Dilation



$$A \bigcap B := \{x \mid x \in A \wedge x \in B\}$$

- Dilation

$$X \oplus SE := \{x + se \mid x \in X \wedge se \in SE\}$$

- Erosion
  - Dual of dilation

- Complexity of direct implementation of Dilation, Erosion (2-D)

$$o\left(n^2 \cdot A\right)$$

n^2 … Imagesize(n*n)
A … Size of SE

- 3-D

$$o\left(n^3 \cdot A \cdot hA\right)$$

hA … height of SE

- Morphological opening
  - A combination of dilation and erosion

$$A \circ B := dilate\left(erode\left(A, B\right), B\right)$$

- Morphological closing
  - Change order of dilate and erode

- A lot of effort has been made to reduce the complexity of morphological operations using matrix-decomposition
  - Overview: [Droogenbroeck and Buckley, 2005]

- For binary images for some special shapes of SEs there are efficient algorithms available

- Limitations
  - Shapes, binary, 1-D, 2-D, hard to implement
- Several algorithms were formally evaluated based on publications
- Multi-level decomposition of Euclidean spheres by [Vaz, Kiraly and Mersereau, 2007] chosen for impl.

Fachhochschule Salzburg University of Applied Sciences

- MLD decomposes any convex and symmetric SE into a union of partitions

$$SE = \bigcup_{0<i<n} P_i \qquad n \in \mathbb{N}$$

- Each P consist of largest cube that can open the partition without changing it and of a sparse factor

$$SE = \bigcup_{0<i<n} C_i \oplus S_i$$

- Applied to a binary image I erosion is given as

$$I \oplus SE = \bigcup_{0<i<n} I \oplus P_i$$

- To perform an erosion instead of dilatation, dilate (⊕) has to be substituted by erode

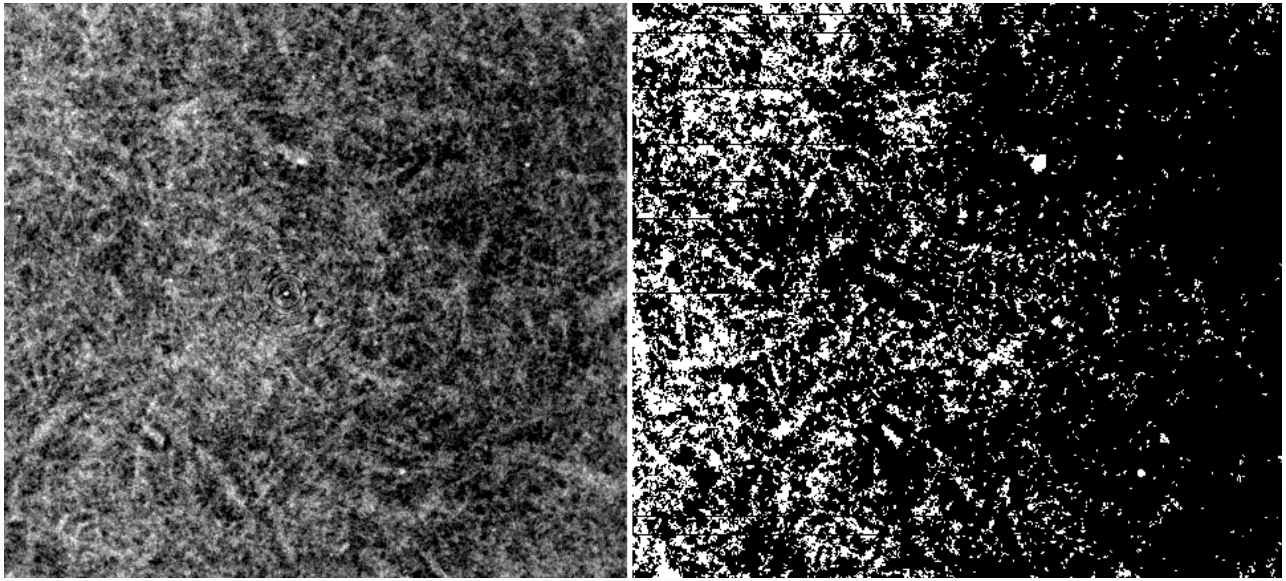
- Determination of Ci and Si is described in detail in [Vaz, Kiraly and Mersereau, 2007]
- Limitations
  - Only convex, symmetric SEs
- Possible improvements
  - Further decomposing Ci (LD, HGW)

- All measurements where carried out on a laptop:
  - Intel® Core™ i5 CPU M520 @2.4GHz
  - Using 3.8 of its 4.0 GB RAM
  - Windows 7 Enterprise Edition x64
  - MATLAB R2010a.

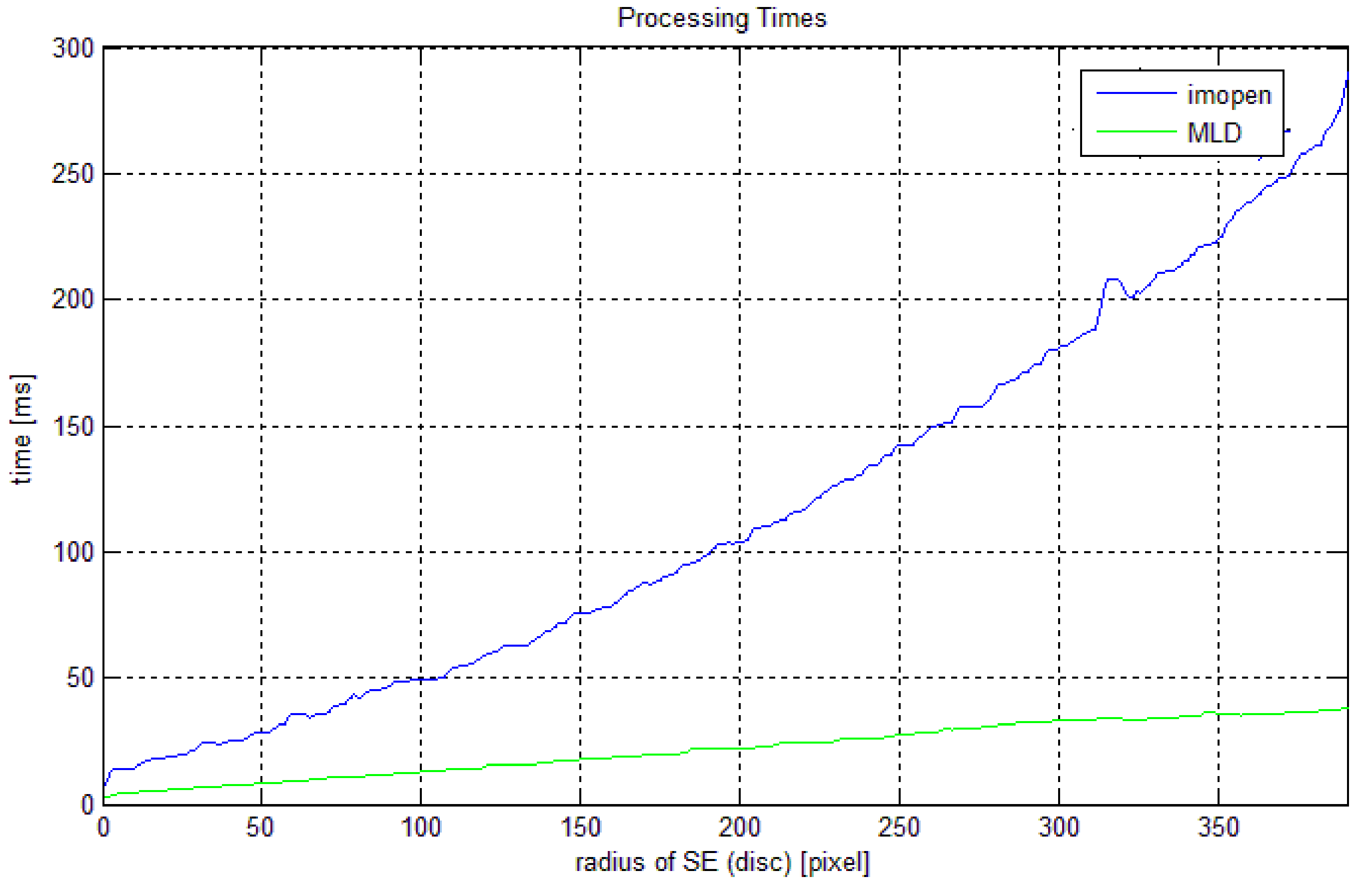
Fachhochschule Salzburg University of Applied Sciences

- MLD was implemented using MATLAB and compared to MATLABs „imopen“ from the „Image Processing“-toolbox
- „imopen“ tries to decompose a given SE
- Applied to 1000 different slices (1106x1106p) twice averaged using a mean score

Fachhochschule Salzburg University of Applied Sciences



µCT-Data (grayscale, binary) - medium density fiberboard


Processing Times
imopen
MLD
time [ms]
radius of SE (disc) [pixel]
0
50
100
150
200
250
300
350

- MLD seams to perform even on large SEs so
  - Turning MATLAB code into C/C++
  - 3-D implementation
  - Using GPU for parallelization
- Algorithms independent of the size of the SE
- Integrating everything into one application

References

Fachhochschule Salzburg University of Applied Sciences

[Droogenbroeck and Buckley, 2005]

M. Van Droogenbroeck and M.J. Buckley, “Morphological erosions and openings: Fast algorithms based on anchors,” *Journal of Mathematical Imaging and Vision, vol.*22, pp. 121–142, 2005

[Vaz, Kiraly and Mersereau, 2007]

Vaz, M. and Kiraly, A. and Mersereau, R., “Multi-level decomposition of Eclidean speres”, Proceedings of the 8th International Symposium on Mathematical Morphology, Rio de Janeiro, Brazil, Oct. 10 –13, 2007

THANK YOU