Segmentation and Volumetric Analysis Detection and Tracking of Individual Fibers

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DTU Compute

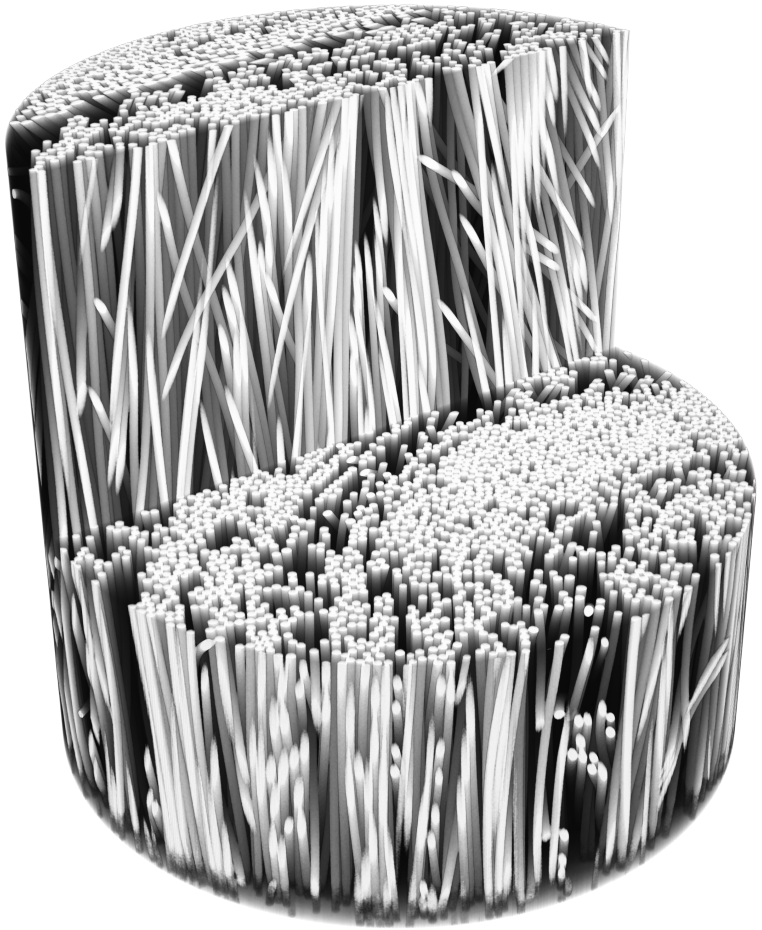
Plan

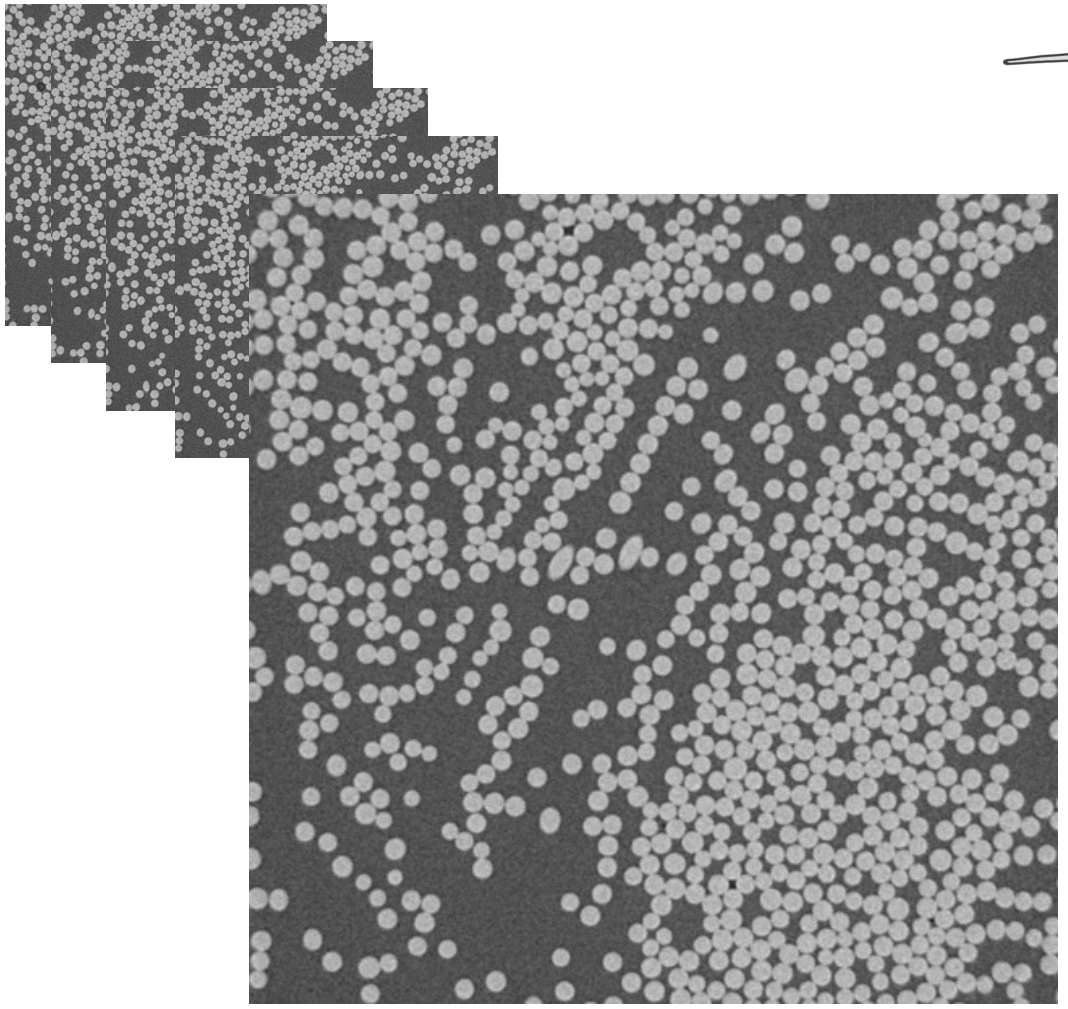
- Segmentation
- Detection using segmentation
- Visualization
- Quantification

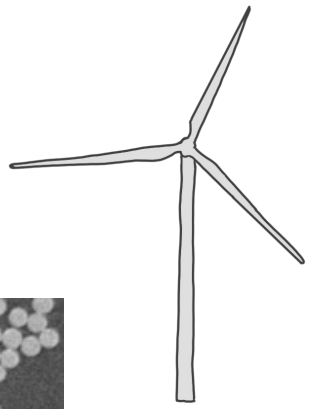
Learning objectives

- Segmentation based on machine learning
  - The principle of dictionary-based segmentation
  - Model parameters
- Use segmentation for feature detection
- Visualization for inspection and verification
- Quantification
  - Tracking of structures (fibers)
  - Structural statistics

Fiber analysis







Segmentation introduction

Segmentation – why?

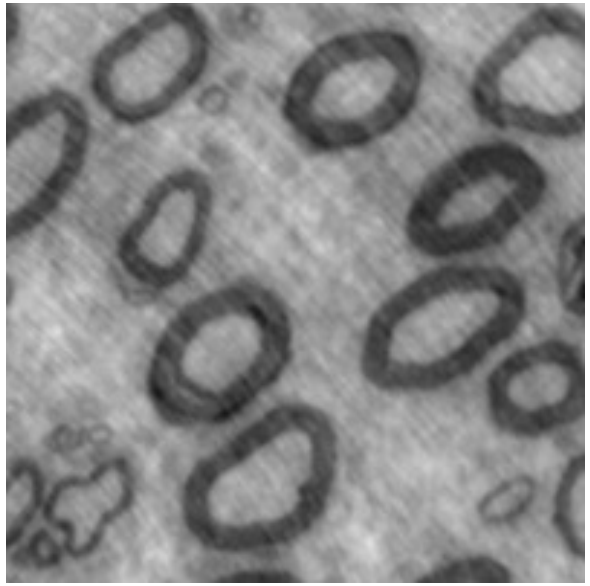
- Transform an image – measure something easier
- Visualize something
- Understand the material better
- More?

What is a segmentation?

- Labeling of an image
- Set of discrete labels:
- Mapping from image domain to labels:

$$\mathcal{L} = \{1, 2, ..., n\}$$

$$g(\mathbf{x}) \rightarrow l \quad \text{where} \quad l \in \mathcal{L}$$



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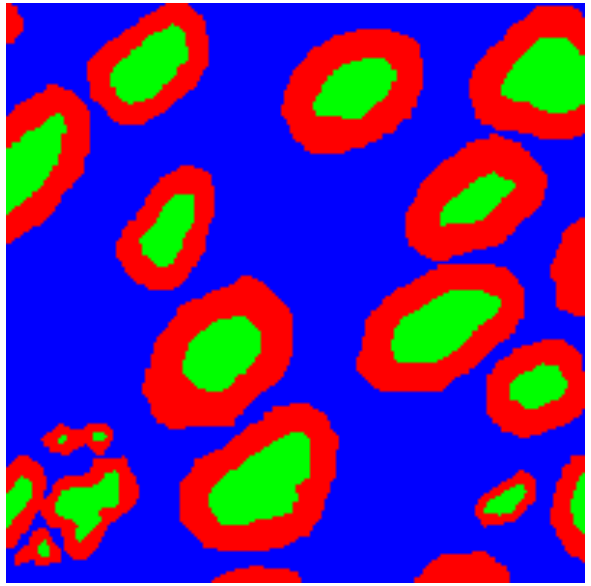
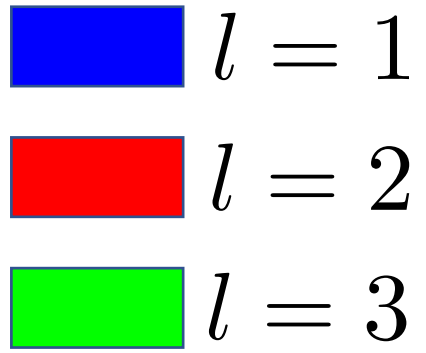




Representation of segmentation

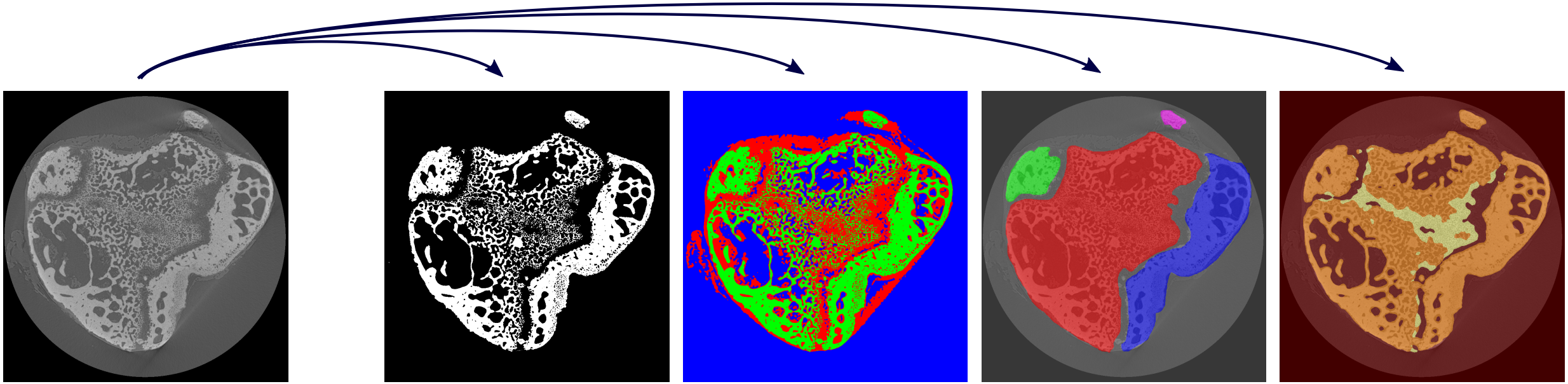
- Pixel-wise labels – is that the only way to represent a segmentation?
- Boundary-based
- Mesh-based
- Function-based, i.e. directly modeling: $g(\mathbf{x}) \rightarrow l$

How to go from image to segmentation

1. Individual pixels -> threshold
2. Include neighborhood -> smooth -> threshold
3. Segmentation models – region growing, watershed, blob detection, merging, splitting, etc.
4. Manual annotation
5. Machine learning!

Simple segmentation – let’s try it together

Segmentation difficulty



Background
Bone

Background
Bone
Cartilage

Background
Region 1
Region 2
Region 3
Region 4

Background
Large trabecular bone
Small trabecular bone

Fiber detection via learning-based segmentation

Deep Learning for Image Analysis

Deep learning model

$$y = f(x)$$

Image

Output:

- Segmented image
- Classify image
- Detectoin of feature
- other

Universal function approximator

- No physical understanding
- Only predicting in the domain where it has been trained

Imaging modalities

- 3D tomography
- X-ray scattering
- Neutrons
- Optical imaging
- Multi-modal

Deep learning

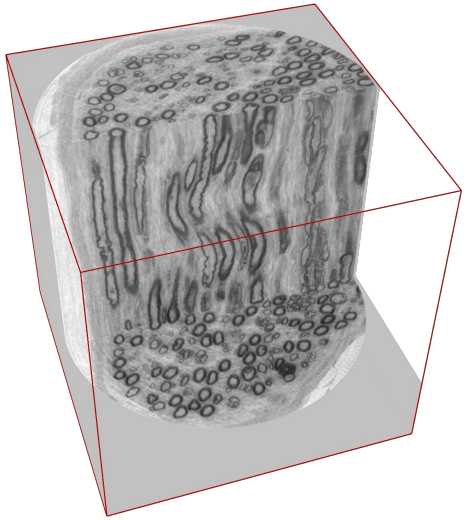
- Detection
- Segmentation
- Classification
- Registration, etc.

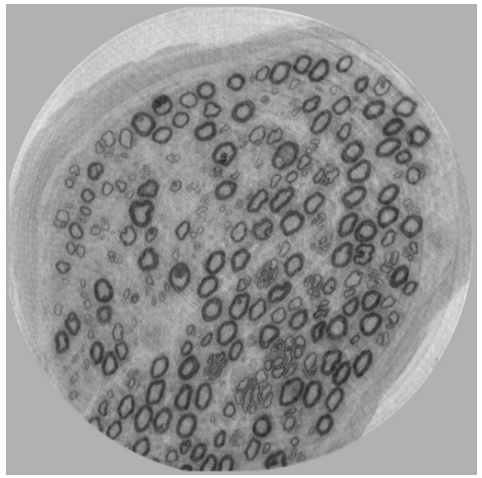
Requires training data, i.e. pairs of

$$(x_i, y_i) \quad \text{where} \quad i = 1, ..., n \quad \text{and } n \text{ is large}$$

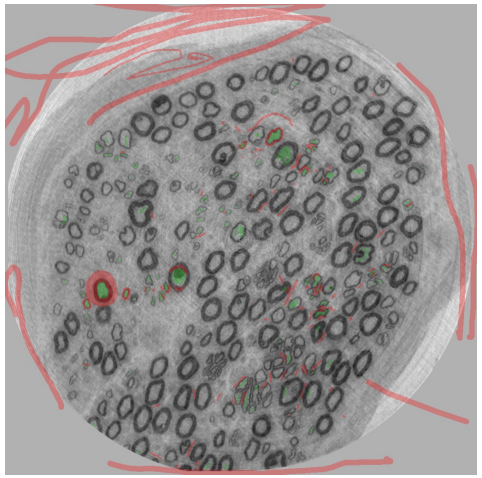
InSegt pipeline

Input volume

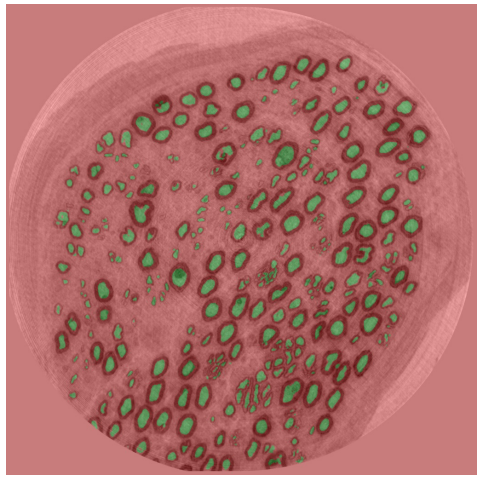




Slice

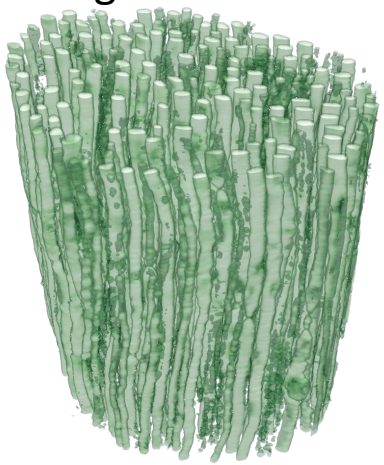


Manual input



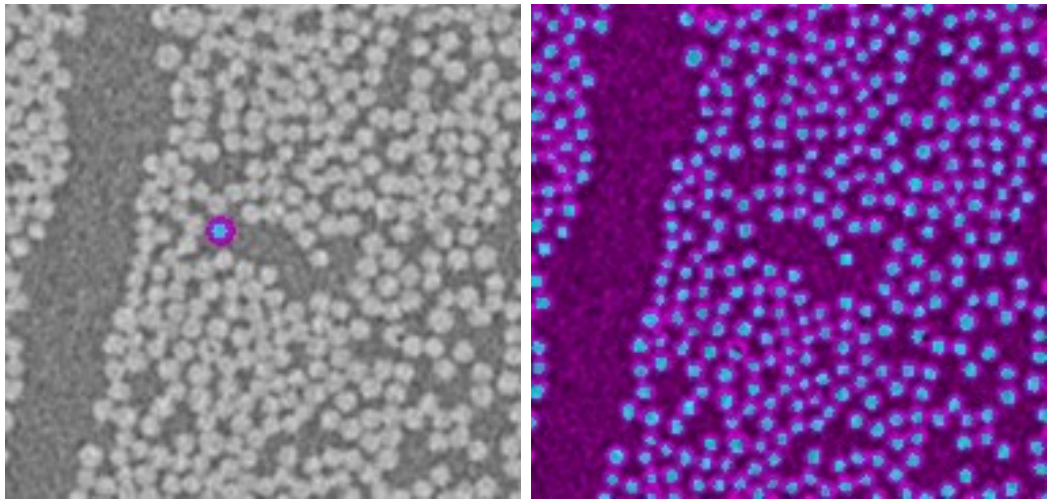
Segmentation

Resulting segmentation

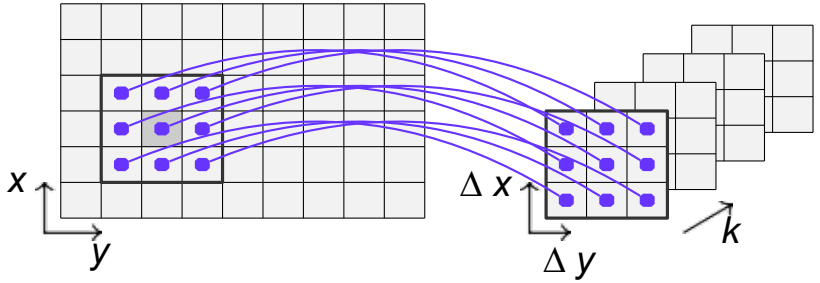


Segmentation – with machine learning

- InSegt[2]
- Tool for interactive segmentation and feature detection
- Real time update of labels
- Easy and intuitive
- Especially useful for repetitive patterns
  - Fiber composite analysis
  - Analysis of insect eyes
  - Analysis of peripheral nerves, etc.



CT-scan of glass fiber composite. The goal is to detect individual fibers. The user marking on the left are propagated to the image on the right.



Analysis method employs a dictionary that links image patches to dictionary patches and allow fast informatino flow.

InSegtpy demo

Fiber detection and tracking

1. Detect individual fibers using InSegtpy
2. Visualize the result
3. Track fibers through the volume
4. Visualize the result

Detect individual fibers using InSegtpy

1. Available on GitHub: https://github.com/vedranaa/insegtpy
2. You will use GIMP – not the cool GUI which is a little tricky to make work
3. Annotate – test segmentation result – annotate more – test again – continue until the result is ok
4. Segment all slices

Visualize the detected fibers

1. Use for example ParaView or TomViz
2. Open file – display volume – choose colormap – adjust colors

Track fibers through the volume

1. Fiber tracking tool available on GitHub: https://github.com/abdahl/3Dtools
2. Run the tool
3. Visualize the result
4. Display the tracked fibers
5. Verify that the tracks are correct

Visualize the track fibers

1. Use for example ParaView or TomViz
2. Open file – display volume – choose colormap – adjust colors

Quantify tracked fibers

1. Use for example ParaView or TomViz
2. Open file – display volume – choose colormap – adjust colors