Layered Surface Detection in Micro-CT Tetra Pak Data

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Focus on. . .

- Geometry based image analysis: principles, challenges, opportunities
- Layered surface detection algorithm
- Application: Micro-CT data of Tetra Pak packages with straw opening

Tetra Pak packages with drinking straw

The membrane covering the pre-punched straw hole has to

- hold the liquid content inside the package
- allow for easy opening
- allow for good flow of the liquid product (requires wider straw)
- meet requirements for production cost, converting production speed, package filling machine speed

Straw hole opening

- circular hole in carton packaging
- laminated membrane: aluminium foil (6 μm thick) between layers of polymer

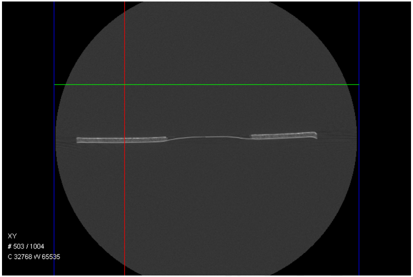
Exact geometry

- important for product development and quality control
- can be used directly as an input to the virtual simulation models for product development

Micro-CT Tetra Pak data

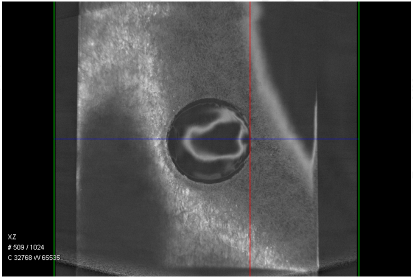
DTU Imaging Industry Portal

- assists companies in using 3D imaging in research, development and production
- expertise in CT, materials science, instrumentation and data analysis



Data acquisition

- Three resolutions
  - Objective: LFOW, Pixel size: 21.2 μm
  - Objective: 4X Pixel size: 4.7 μm
  - Objective: 10X Pixel size: 1.9 μm
- Other settings
  - Voltage 40 kV
  - Power 10 W
  - Filter AIR
  - Exposure: 5 s, 5s, 25 s



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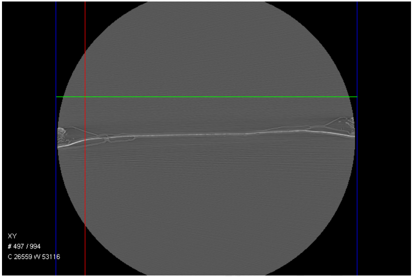

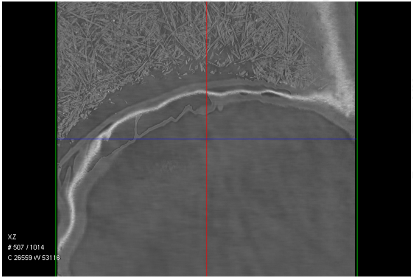

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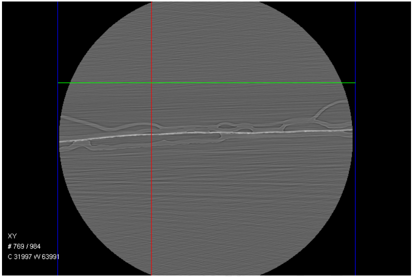

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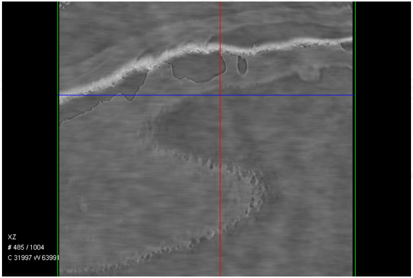
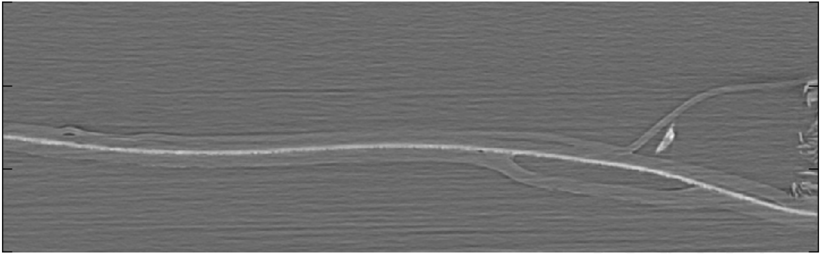


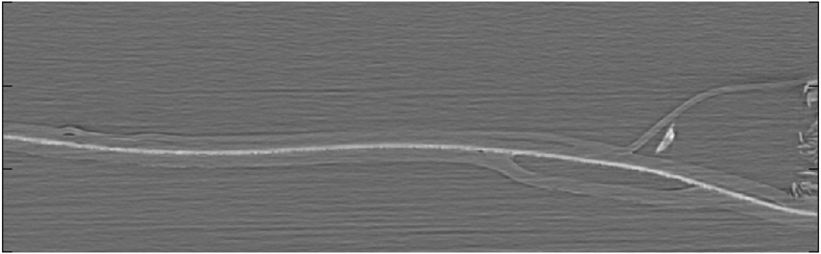
Extracting the exact geometry, initial analysis

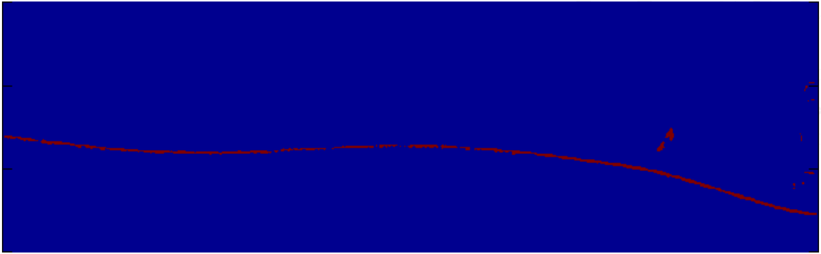
Part of a slice from a volume with dimensions 980 $\times$ 984 $\times$ 1004 voxels



Extracting the exact geometry, initial analysis

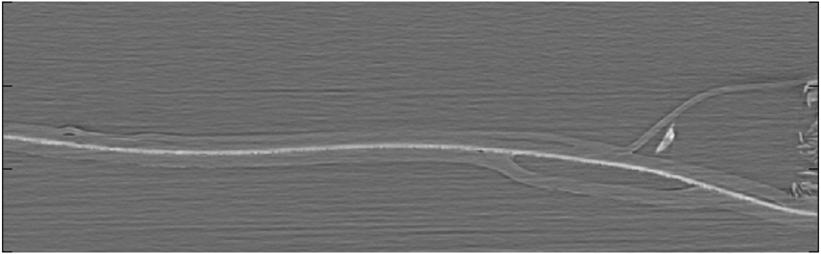
Thresholding aluminium foil – ok

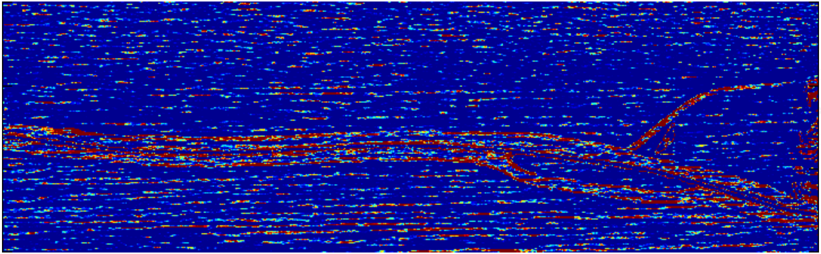




Extracting the exact geometry, initial analysis

Thresholding plastic membrane – noisy

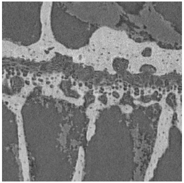
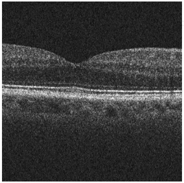
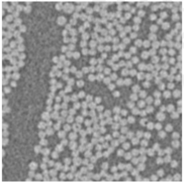
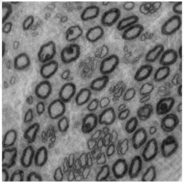




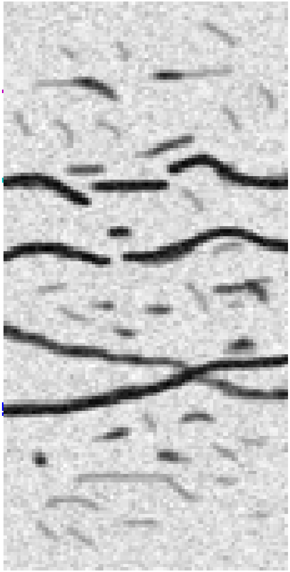
Image/volume segmentation: principles, challenges

Geometry based segmentation

- Local methods (thresholding, filtering, morphology) may be sufficient for segmentation and quantification, but often need to be combined with global methods, e.g. geometrical models.
- Our interpretation of data depends on assumptions made under analysis.
- All image/volume segmentation is based on assumptions, sometimes implicit.
- Size of the data is an extra challenge. Especially while developing a model!
- Tetra Pak data: combining an appearance model with a geometric model.

Surface detection, suggested geometric model



- Terrain-like surfaces

$$z = f(x, y)$$

- Smoothness

$$|f(x+n, y) - f(x, y)| < \Delta$$

$$|f(x, y+n) - f(x, y)| < \Delta$$

- Optimality (surface cost)

$$\min \sum_{x,y} c(x, y, f(x, y))$$

- Geometric constraints reduce the number of acceptable outcomes
- Optimal solution can be found using a graph-cut based search
- Additional modelling options: layered surfaces, region based cost

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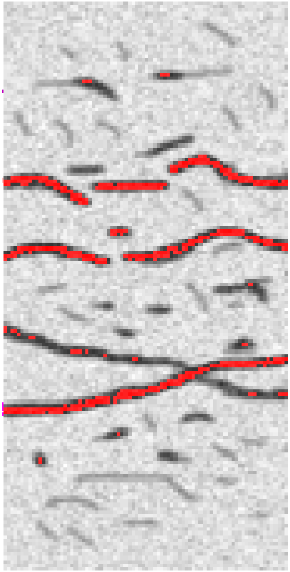

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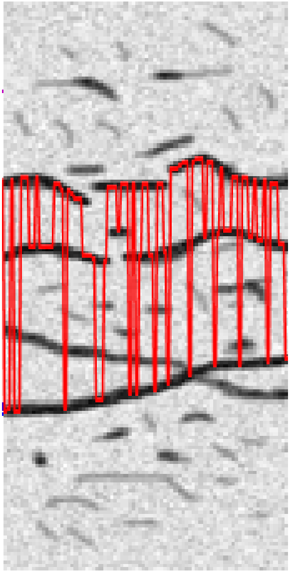

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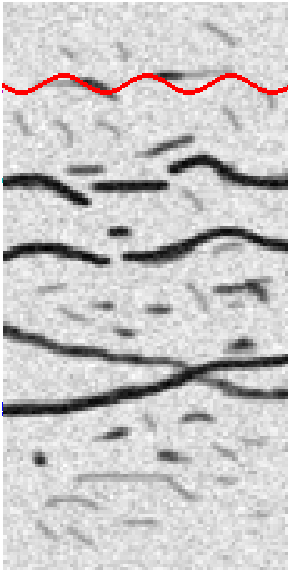

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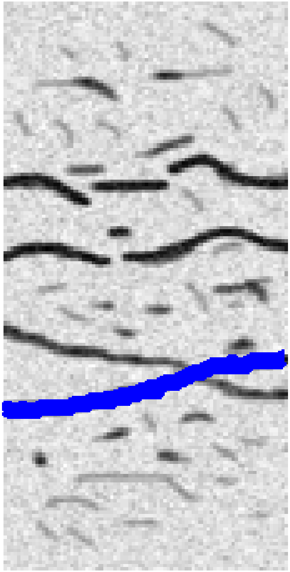

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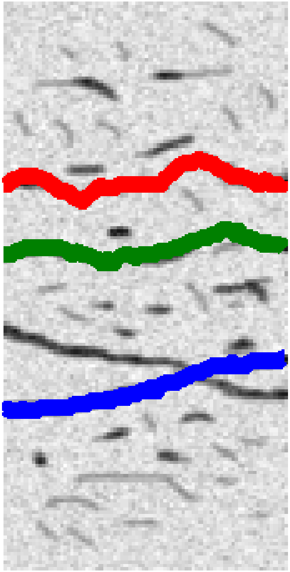

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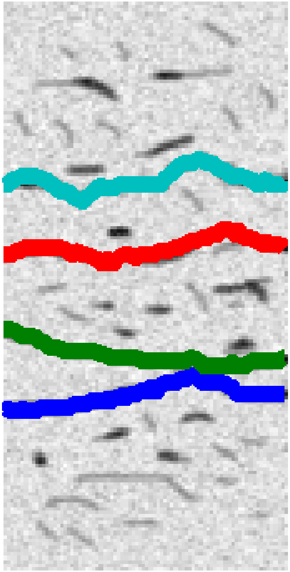

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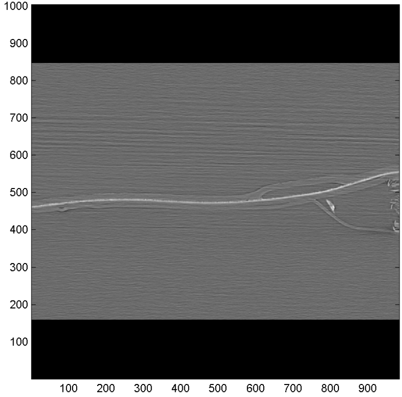
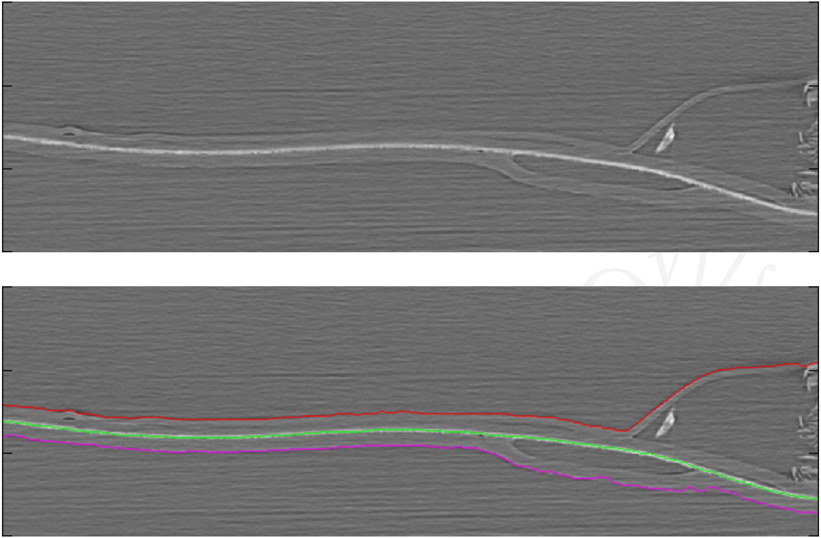
Surface detection, suggested appearance model

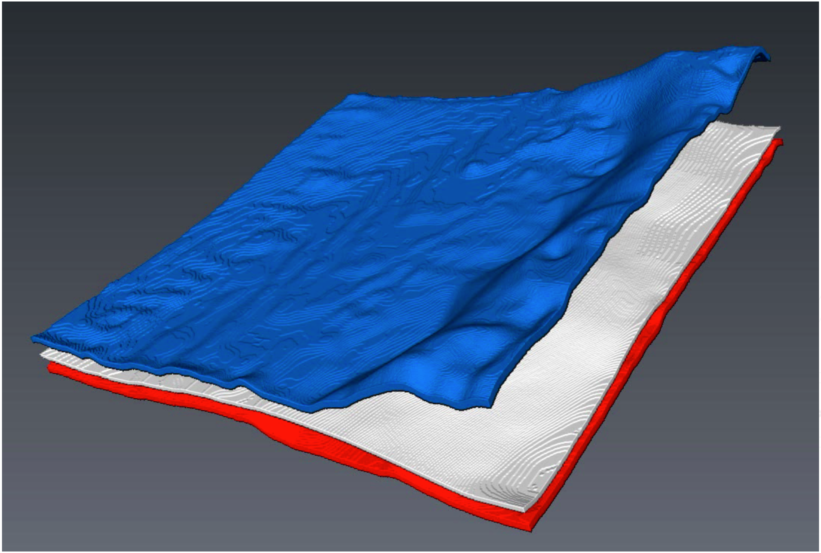


- Surfaces
  - aluminium foil
  - lower edge of the lower polymer layer
  - upper edge of the upper polymer layer
- Aluminium foil:
  - binary aluminium foil response
- Lowest and highest edge, a weighted sum of four contributions:
  - relaxed plastic membrane response
  - edge response
  - repulsion from aluminium foil (limited range)
  - cumulative term (first strong occurrence)

Visualized on a slice



Volumetric results



Discussion

Possible improvements

- Improvements: accuracy, efficiency (hierarchical approach)
- Extensions: multiple layers, inside regions

Interpretation

- Geometric constraints will always be met.
- Should be coupled with the assessment of the quality of the fit.

Thank you!