



## Layered Surface Detection in Micro-CT Tetra Pak Data

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## Layered Surface Detection in Micro-CT Tetra Pak Data

Vedrana Andersen Dahl, DTU Compute

Industrial CT scanning Erfa-group meeting, 7. October 2014

$$f(x+\Delta x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$$

## Focus on...

- ▶ Image analysis. Principles, challenges, opportunities...
- ▶ One surface detection algorithm

$$f(x+\Delta x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$$

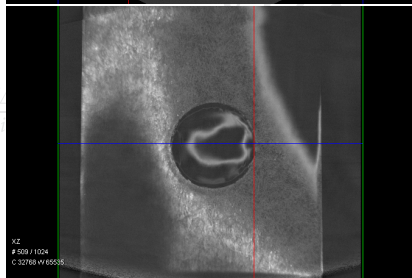
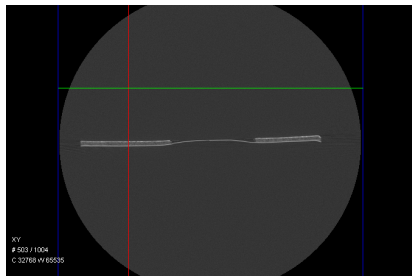
## Data collection

Carsten Gundlach, DTU Physics

### Three settings

- ▶ Objective: LFWO,  
Pixel size: 21.2  $\mu\text{m}$
- ▶ Objective: 4X  
Pixel size: 4.7  $\mu\text{m}$
- ▶ Objective: 10X  
Pixel size: 1.9  $\mu\text{m}$

Voltage 40 kV  
Power 10 W  
Filter AIR  
Exposure: 5 s, 5s, 25 s.



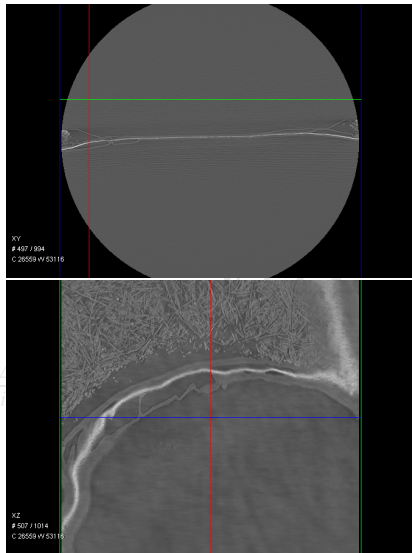
## Data collection

Carsten Gundlach, DTU Physics

### Three settings

- ▶ Objective: LFWO,  
Pixel size: 21.2  $\mu\text{m}$
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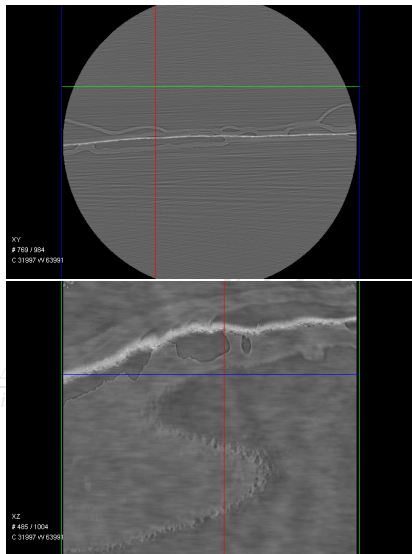
## Data collection

Carsten Gundlach, DTU Physics

### Three settings

- ▶ Objective: LFWO,  
Pixel size:  $21.2 \mu\text{m}$
- ▶ Objective: 4X  
Pixel size:  $4.7 \mu\text{m}$
- ▶ **Objective: 10X**  
**Pixel size:  $1.9 \mu\text{m}$**

Voltage 40 kV  
Power 10 W  
Filter AIR  
Exposure: 5 s, 5s, 25 s.



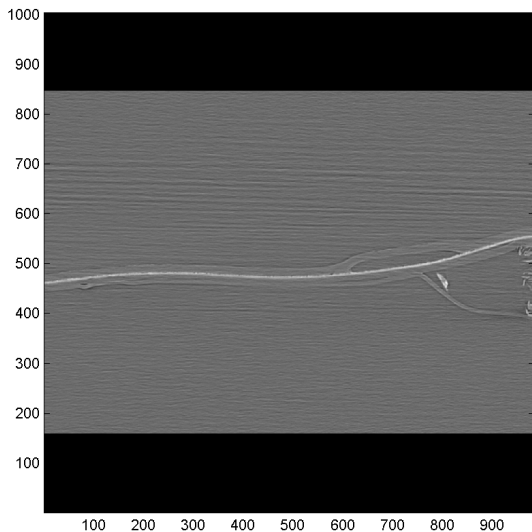
## The nature of data

- ▶ Data is noisy, including projection data. Reconstruction data cannot be less noisy without assumptions.
- ▶ All image/volume segmentation is based on assumptions.
- ▶ Our interpretation of data depends on assumptions made under analysis – also in cases where those assumptions are implicit.

$$f(x+\Delta x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$$

## Surface detection, initial analysis

Example slice, volume dimensions  $980 \times 984 \times 1004$  voxels

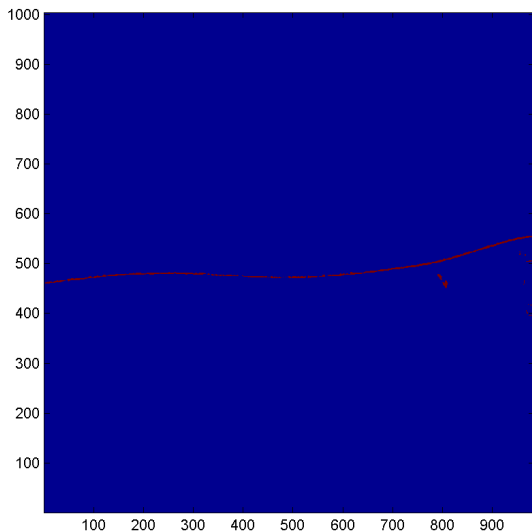


$$7e^{i\pi} = 18284$$



## Surface detection, initial analysis

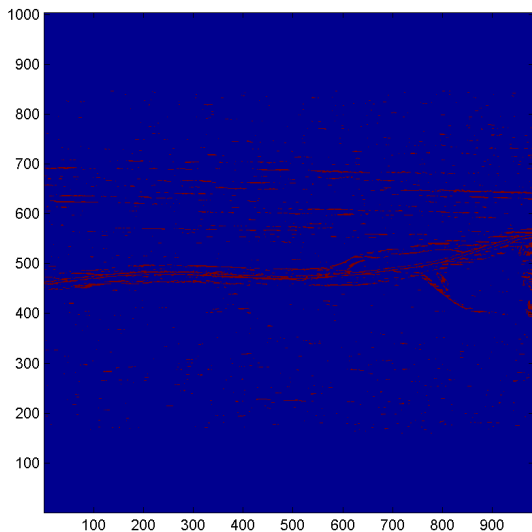
Thresholding aluminium foil – ok



$$7e^{i\pi} = 18284$$

## Surface detection, initial analysis

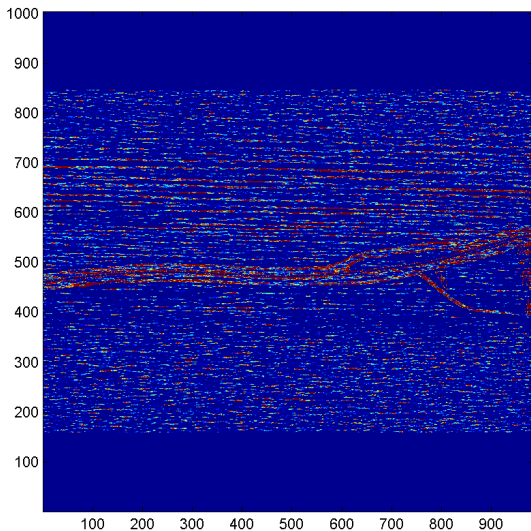
Thresholding plastic membrane – noisy



$$7 e^{i\pi} = 18284$$

## Surface detection, initial analysis

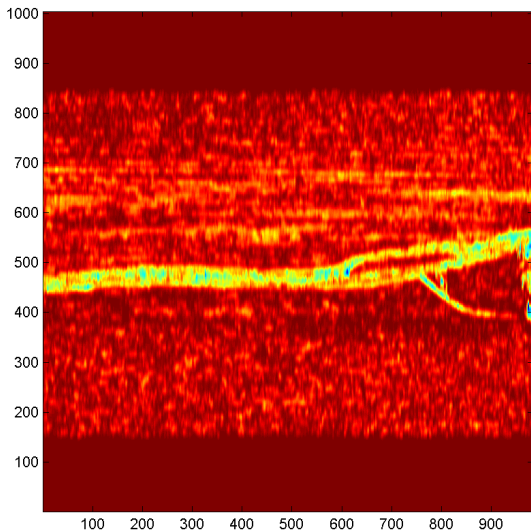
Relaxed plastic membrane response



$7e^{i\pi} = 18284$

## Surface detection, initial analysis

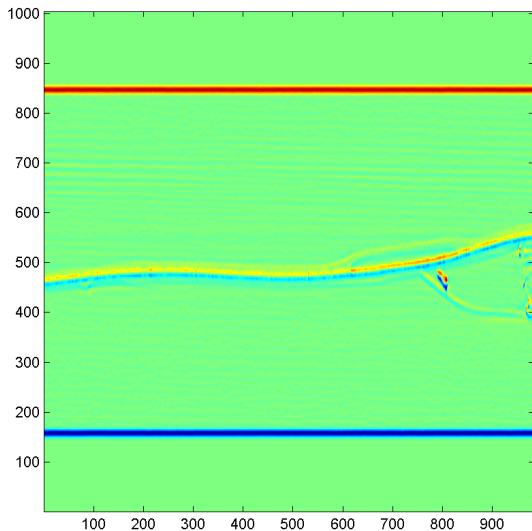
Averaged relaxed plastic membrane response – a useful contribution



$$7 e^{i\pi} = 18284$$

## Surface detection, initial analysis

Edge response – a useful contribution



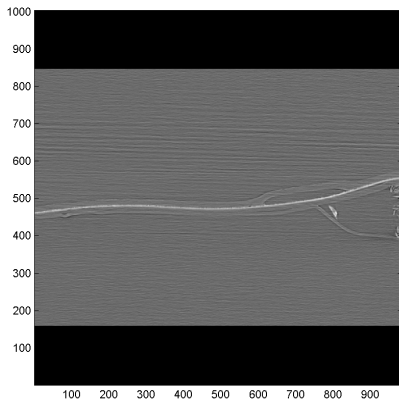
$$7e^{i\pi} = 18284$$

## Surface detection, initial analysis

- ▶ Challenges: data size, presence of noise.
- ▶ Conclusion: We need to choose a model, including an appearance model and a geometric model.

$$f(x+\Delta x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$$

## Surface detection, suggested geometric model



- ▶ Terrain-like surfaces

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

- ▶ Smoothness

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

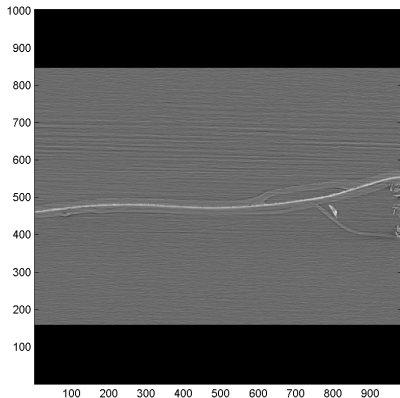
$$|f(x, y + n) - f(x, y)| < \Delta$$

- ▶ Optimality

$$\min_{x, y} \sum c(x, y, f(x, y))$$

- ▶ Initial focus on three surfaces:  
aluminium foil, lowest edge,  
highest edge.

## Surface detection, suggested appearance model

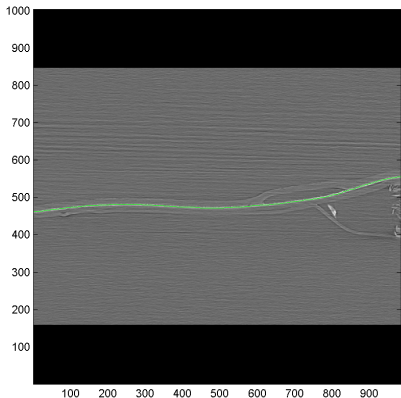


- ▶ Aluminium foil:
  - ▶ binary aluminium foil response
- ▶ Lowest and highest edge, a weighted sum of four contributions:
  - ▶ relaxed plastic membrane response
  - ▶ edge response
  - ▶ repulsion from aluminium foil (limited range)
  - ▶ cumulative term (first strong occurrence)

$$f(x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$$



## Surface detection, pipeline

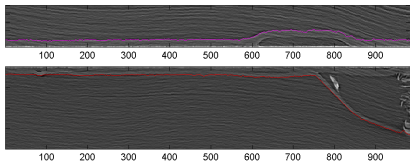


### Ordering

1. aluminium foil
2. lowest plastic edge and highest plastic edge in sampled images
3. plastic edge transformed back

$$f(x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$$

# Surface detection, pipeline

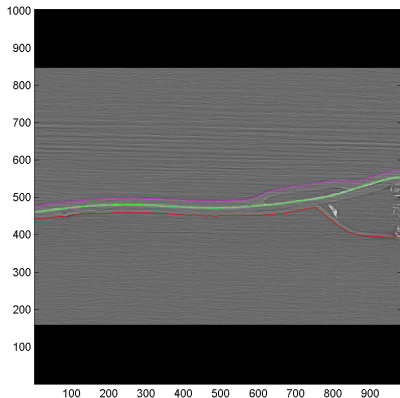


## Ordering

1. aluminium foil
2. lowest plastic edge and highest plastic edge in sampled images
3. plastic edge transformed back

$$f(x+\Delta x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$$

## Surface detection, pipeline

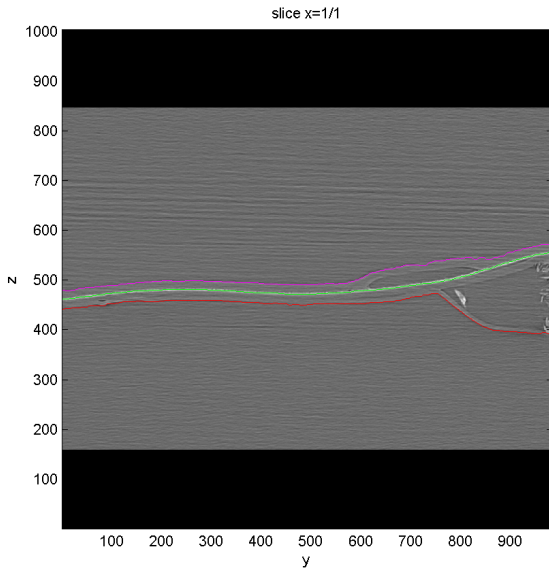


### Ordering

1. aluminium foil
2. lowest plastic edge and highest plastic edge in sampled images
3. plastic edge transformed back

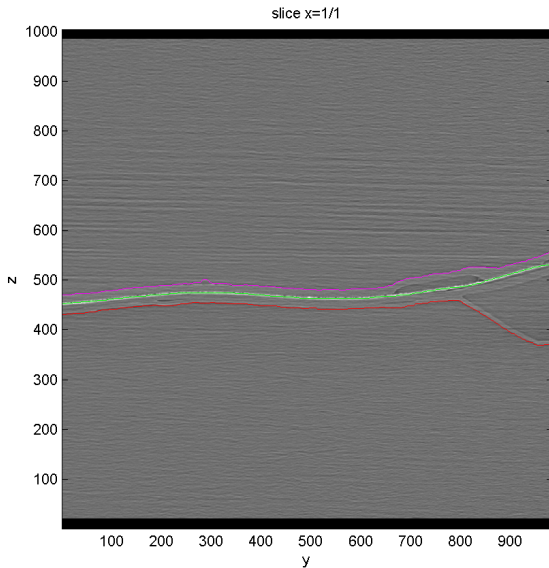
$$f(x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$$

## Surface detection, results



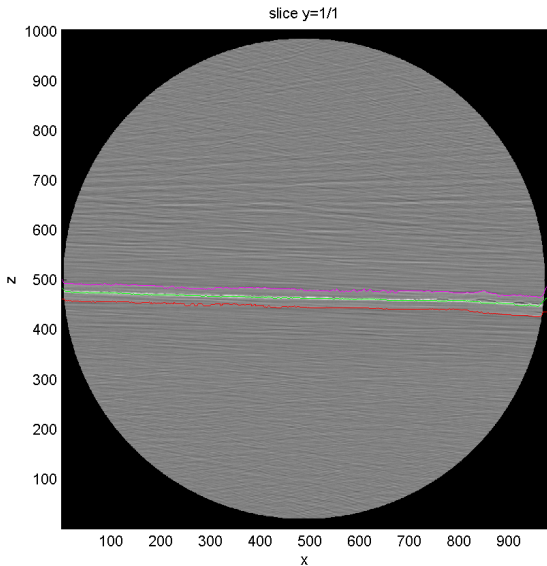
$$7e^{i\pi} = 18284$$

## Surface detection, results



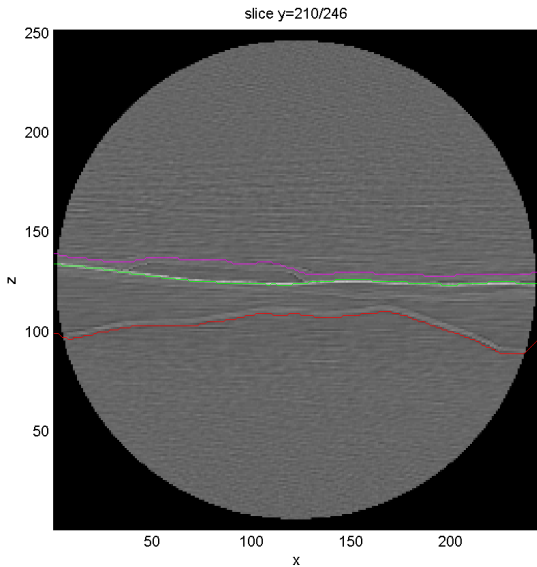
$$7e^{i\pi} = 18284$$

## Surface detection, results



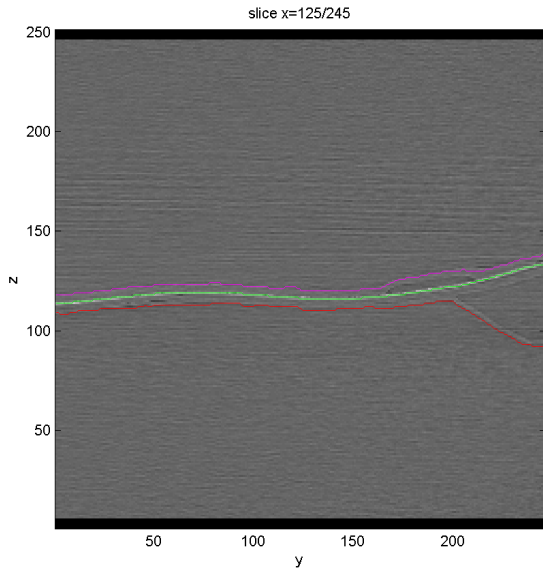
$$7e^{i\pi} = 18284$$

## Surface detection, results



$$7e^{i\pi} = 18284$$

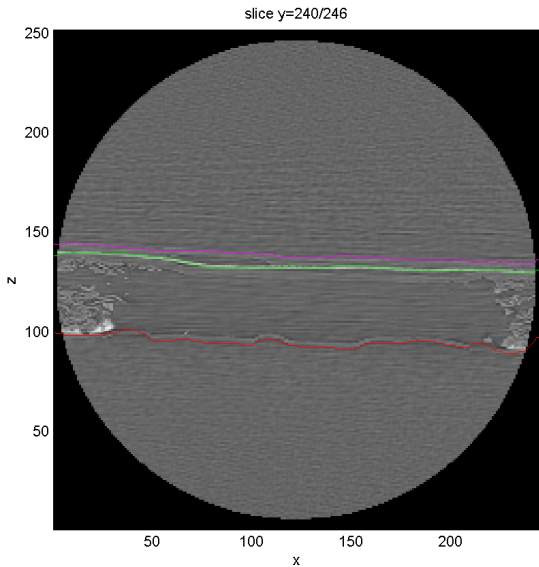
## Surface detection, results



$$7e^{i\pi} = 18284$$

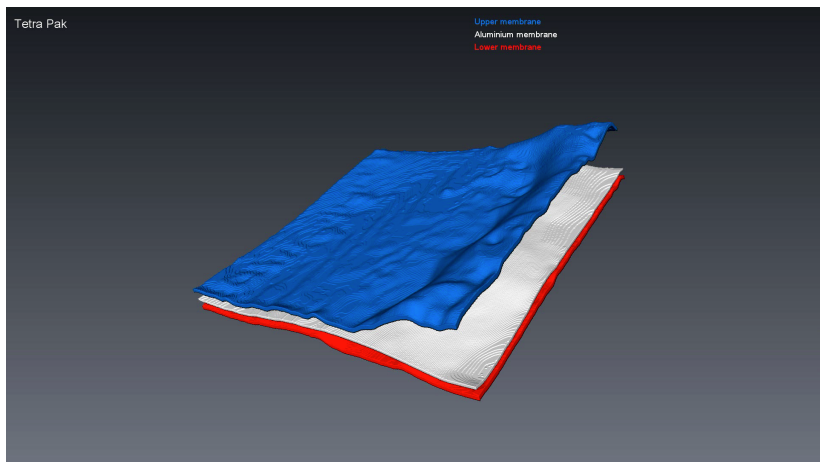


## Surface detection, results



$$7e^{i\pi} = 18284$$

# Results



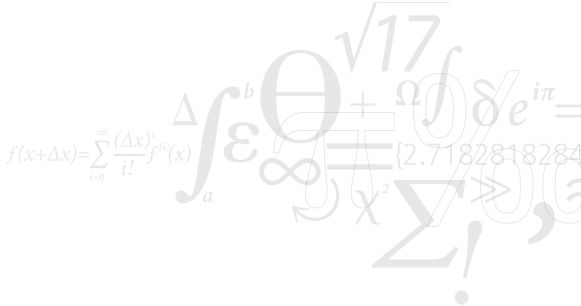
Carsten Gundlach, DTU Physics

## Surface detection, possible improvements

- ▶ Improvements: accuracy, boundary effect
- ▶ Extensions: multiple layers, inside regions

$$f(x+\Delta x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$$

Thank you!


$$f(x+\Delta x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$$
$$\int_a^b \varepsilon \Theta = \Omega \int \delta e^{i\pi} = \{2.7182818284\}$$
$$\chi^2 \Sigma!$$