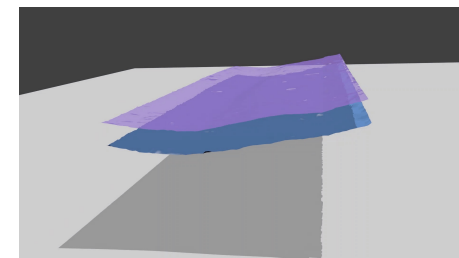
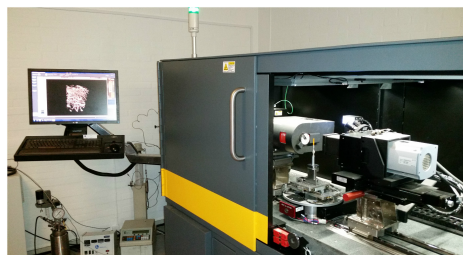
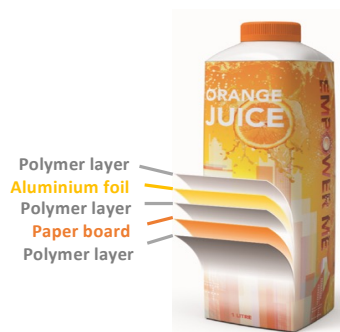


# Study on Bending of Laminar Packaging Material from Tetra Pak

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# Collaborators:

## QIM



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## 3D Imaging Centre at DTU



Sina B.-S. Carsten G.

## Tetra Pak



Christel A. Erik B.



# Motivation

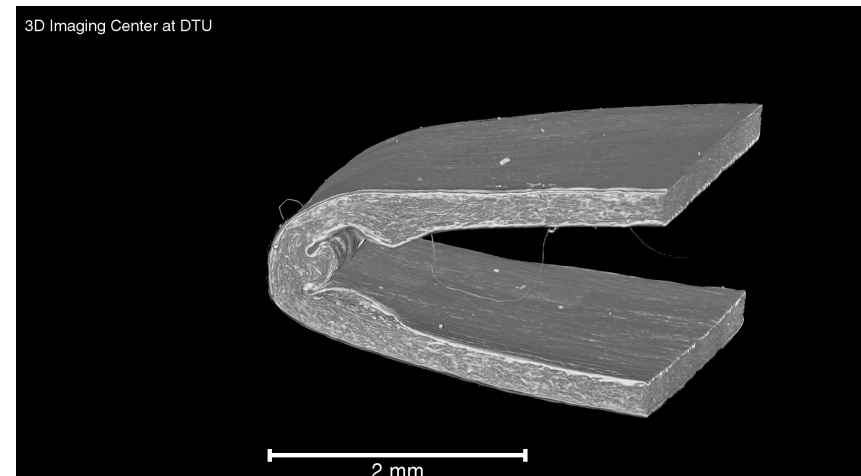
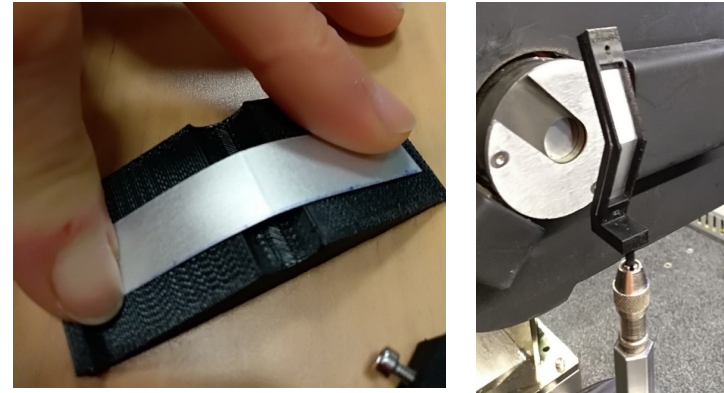
- Increase capacity and quality of packaging process
- To obtain reliable virtual model it is important to know:
  - Exact geometry of the products and
  - Geometrical changes the products undergo during production
- In this study we have developed a pipeline to deduce information on how the packing material behaves when being bent at different angles
- In-depth study of the bent laminar helps Tetra Pak verify the simulation models of machine/material interaction



# Data

- X-ray micro computed tomography (CT)
- 3D images
- 4 samples
  - Based on the direction of crease line: CD or MD
  - Bend inward (in\_in) or outward (out\_out)
- 4 angles:  $0^\circ$ ,  $45^\circ$ ,  $90^\circ$ ,  $180^\circ$
- Pixel size:  $4.2 \mu\text{m}$

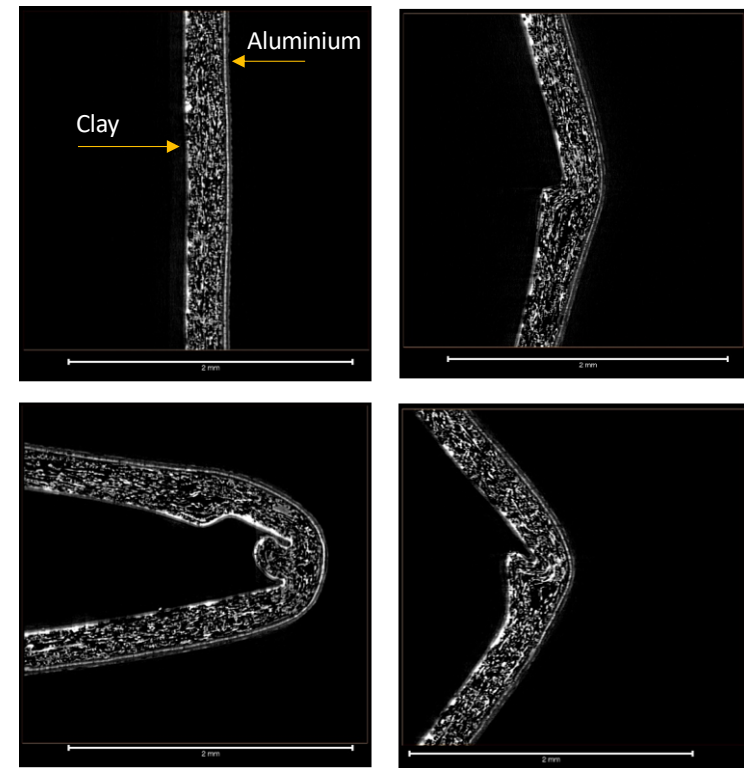
\*Image courtesy of Sina Baier-Stegmaier



# Goal

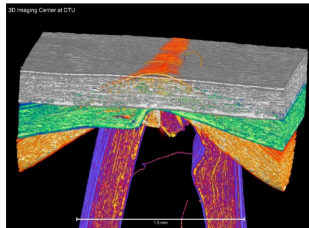
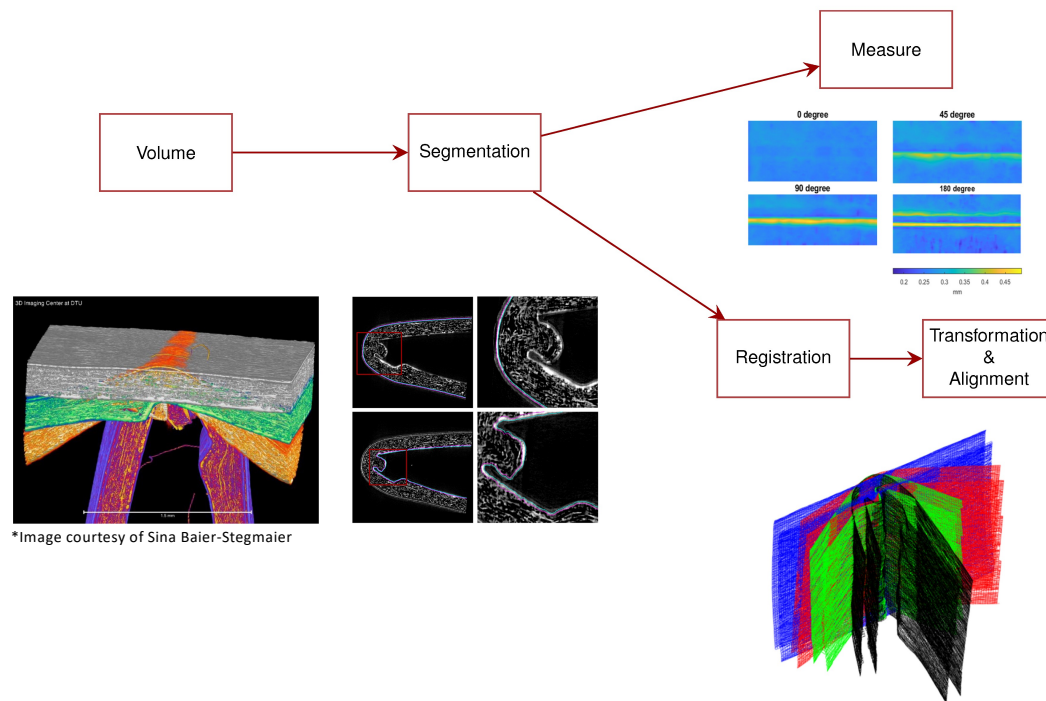
- Identifying the layers
- Obtaining quantitative measures describing the delamination
- Investigating the deformation process

\*Image courtesy of Sina Baier-Stegmaier

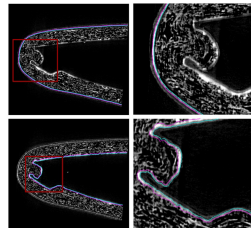


CD\_out\_out: 4.2  $\mu$ m pixel size

# Pipeline



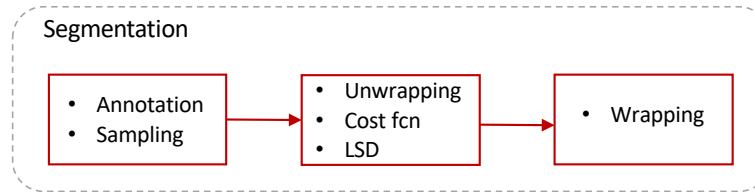
\*Image courtesy of Sina Baier-Stegmaier



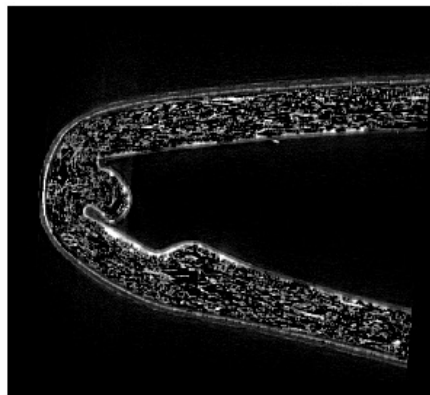
## Pipeline:

- Segment the layers in laminar:
  - Aluminium
  - Clay
- Measure the bent characteristic
- Register the layers (meshes)
- Bijection transformation between the different bending degrees
- Alignment of the meshes

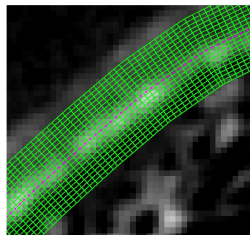
# Segmentation



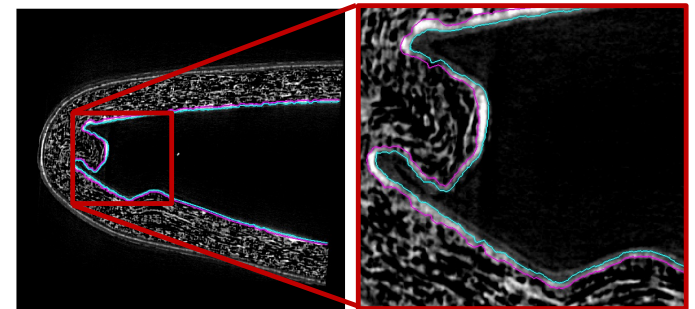
- Why not thresholding?
  - Uneven contrast



- Annotation and sampling
  - create a mesh

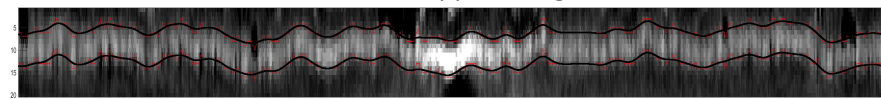


Segmentation results in 2D

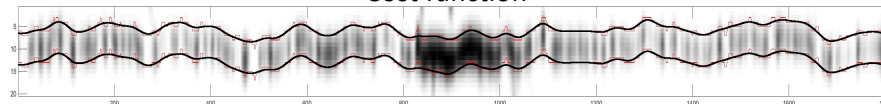


- Layer surface detection (LSD)

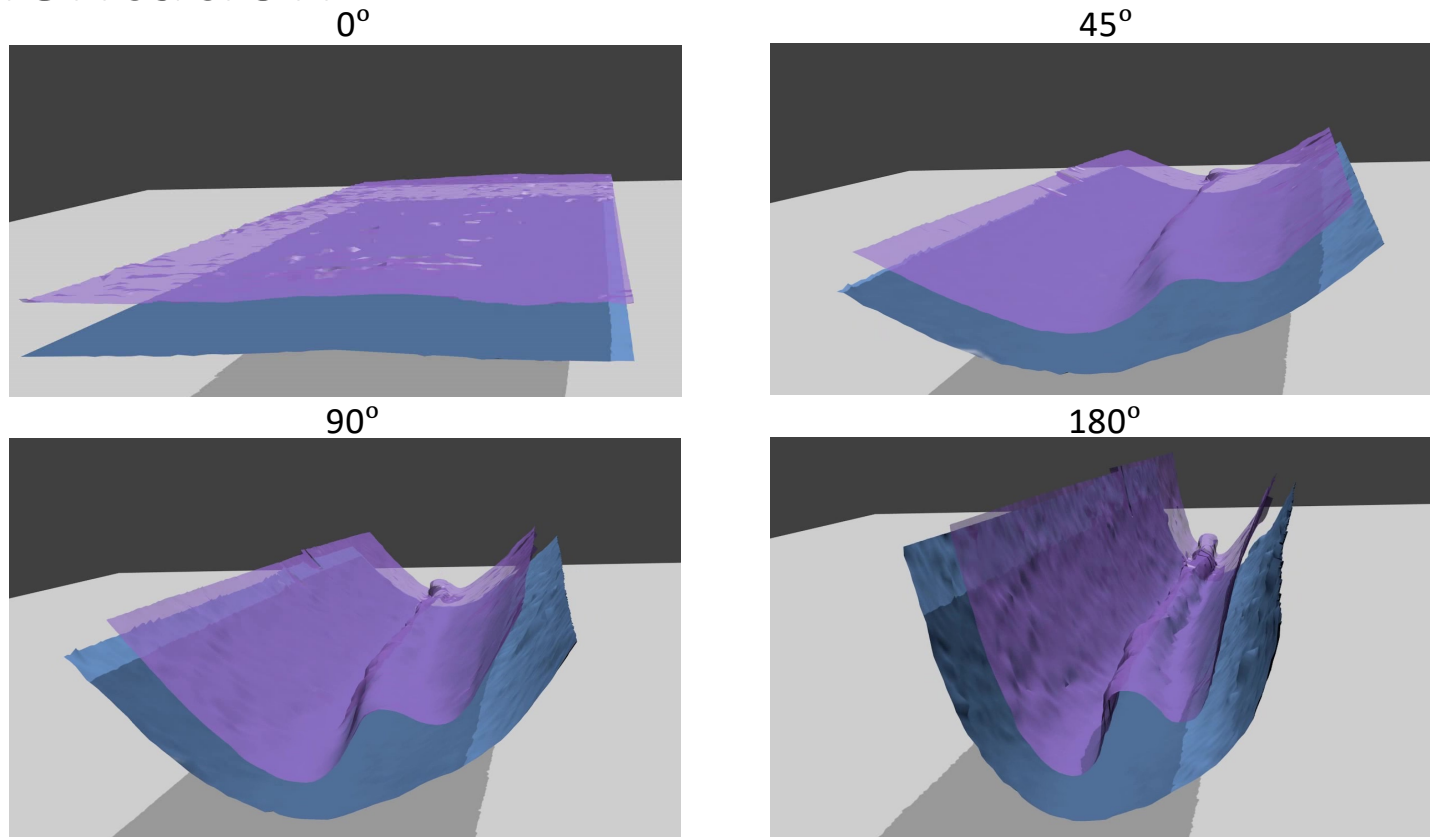
Unwrapped image



Cost function



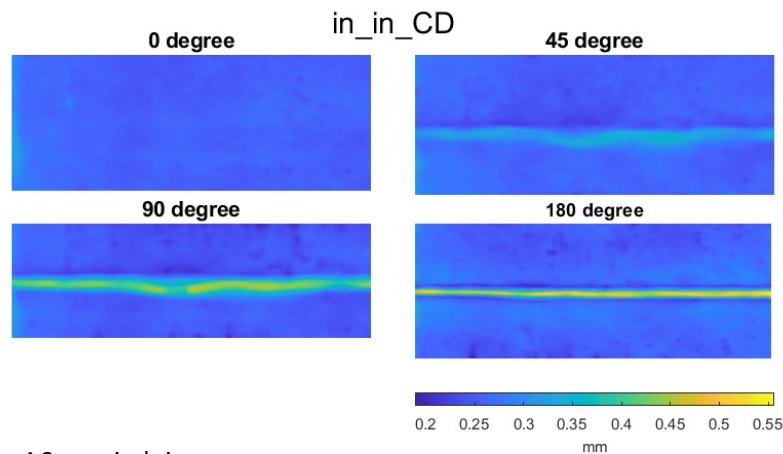
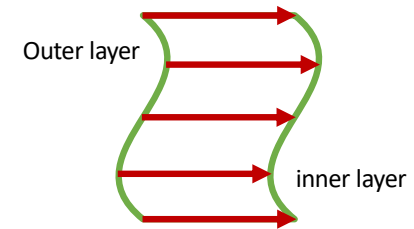
# Segmentation



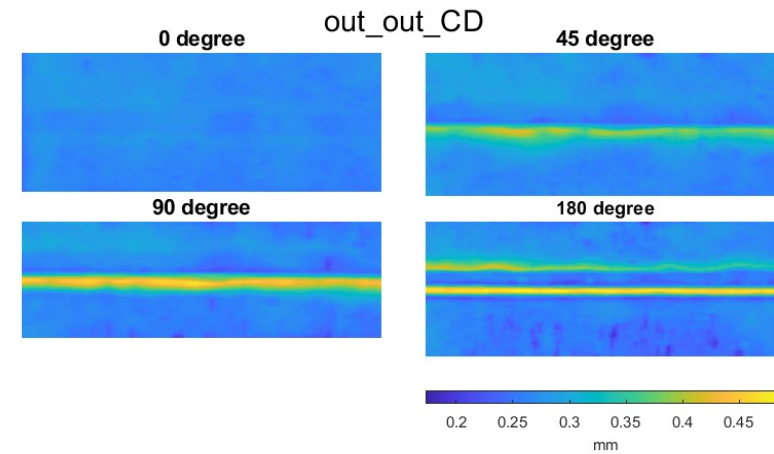
Purple: Aluminium, Blue: Clay

# Measures

- Euclidean distance between inner and outer layers
- X-axis is the direction of the slices
- Each column represent the distance



4.2  $\mu\text{m}$  pixel size

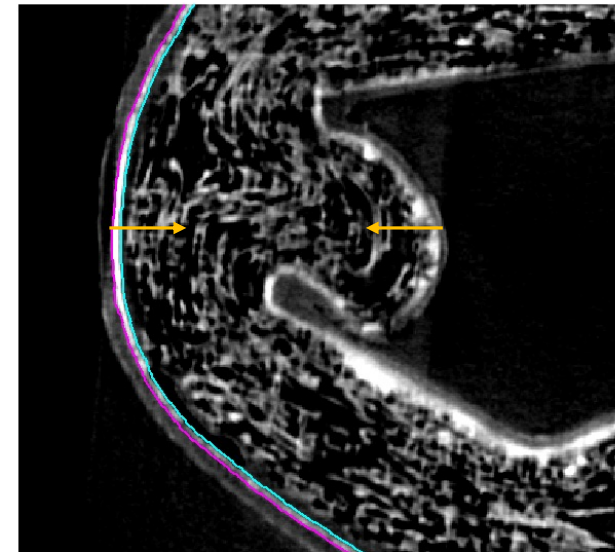


# Registration

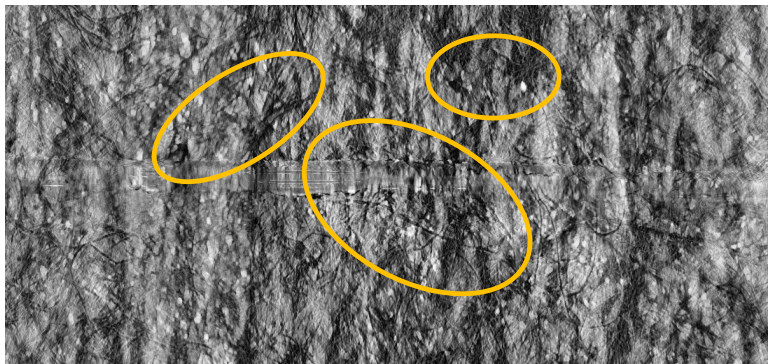
- Using the paper fibres to find the similarity pattern among the different degrees
- Sample from inner and outer layer toward the material
- Using the 180° as reference

## Registration method:

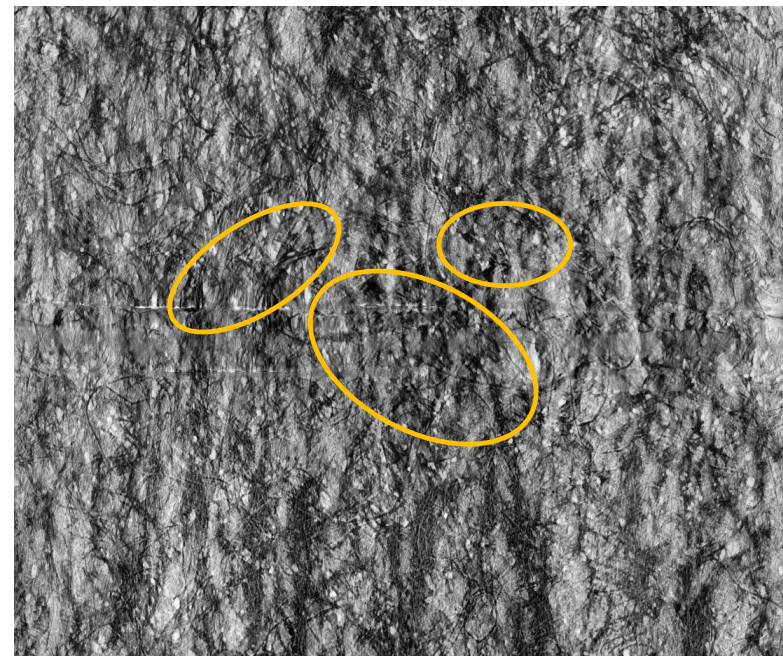
- SURF (Speeded-Up Robust Features)
  - Feature-based registration techniques
  - Sharp corners, blobs
  - Support scale and rotation



# Registration



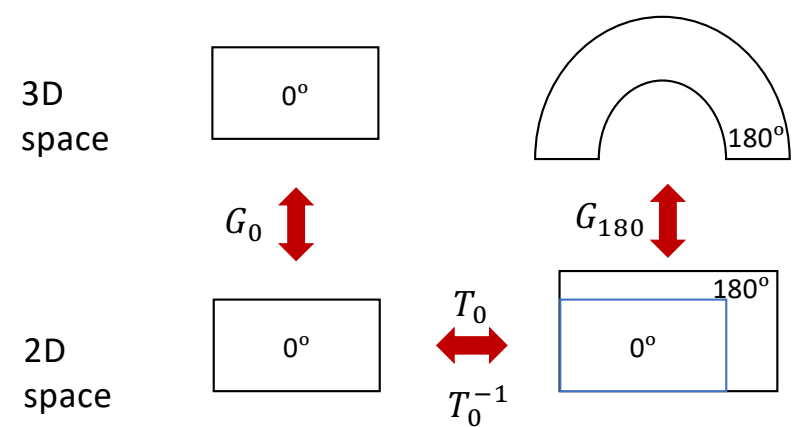
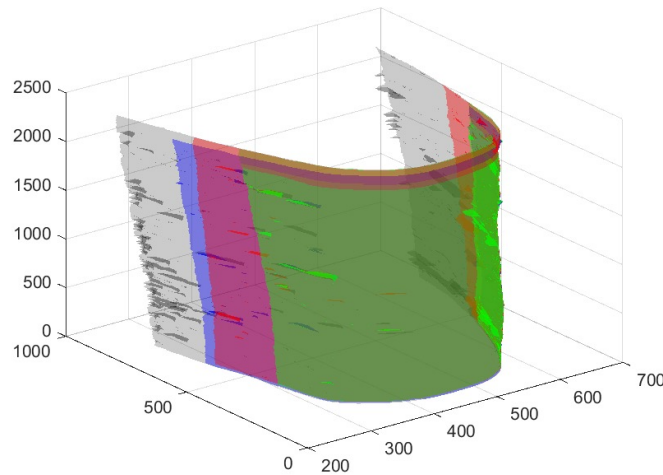
Out\_out\_CD 90 degree



Out\_out\_CD 180 degree

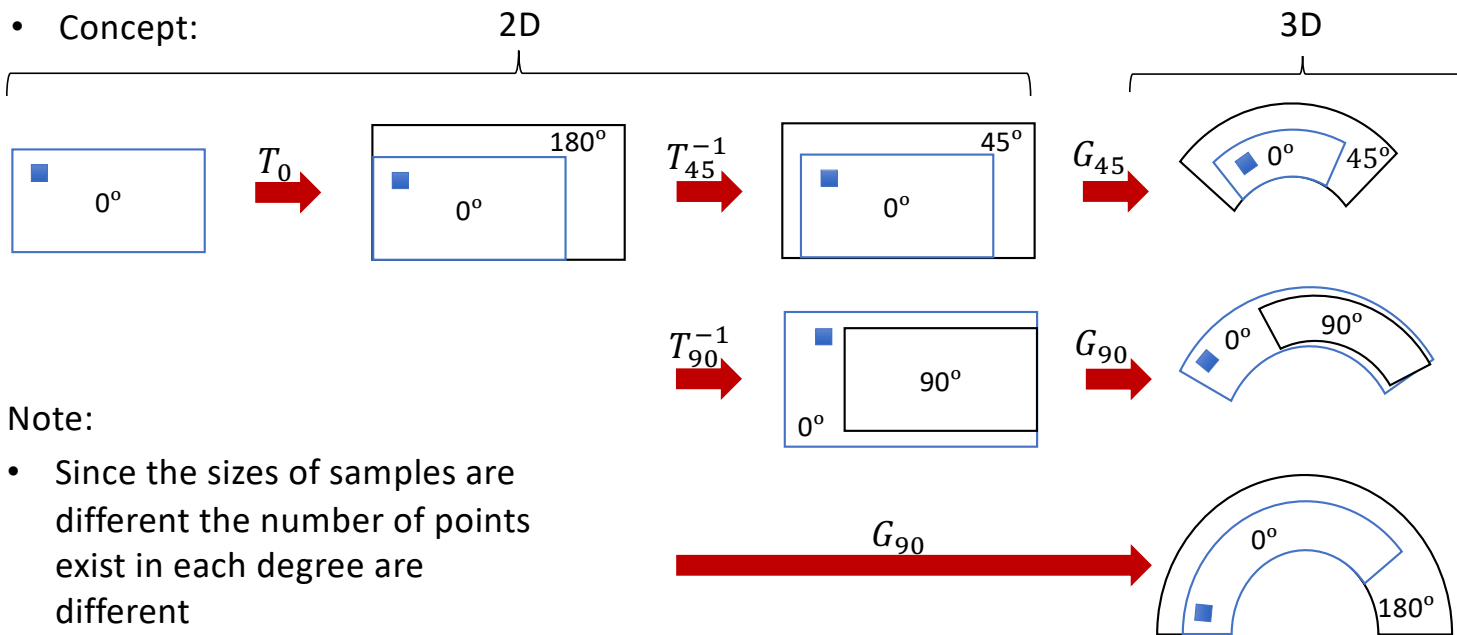
# Transformation

- Using the registration to transform between the bending in 2D space (T)
- Using the geometry transformation to transform between 2D and 3D space (G)
  - Extrapolate the 2D image into 3D mesh



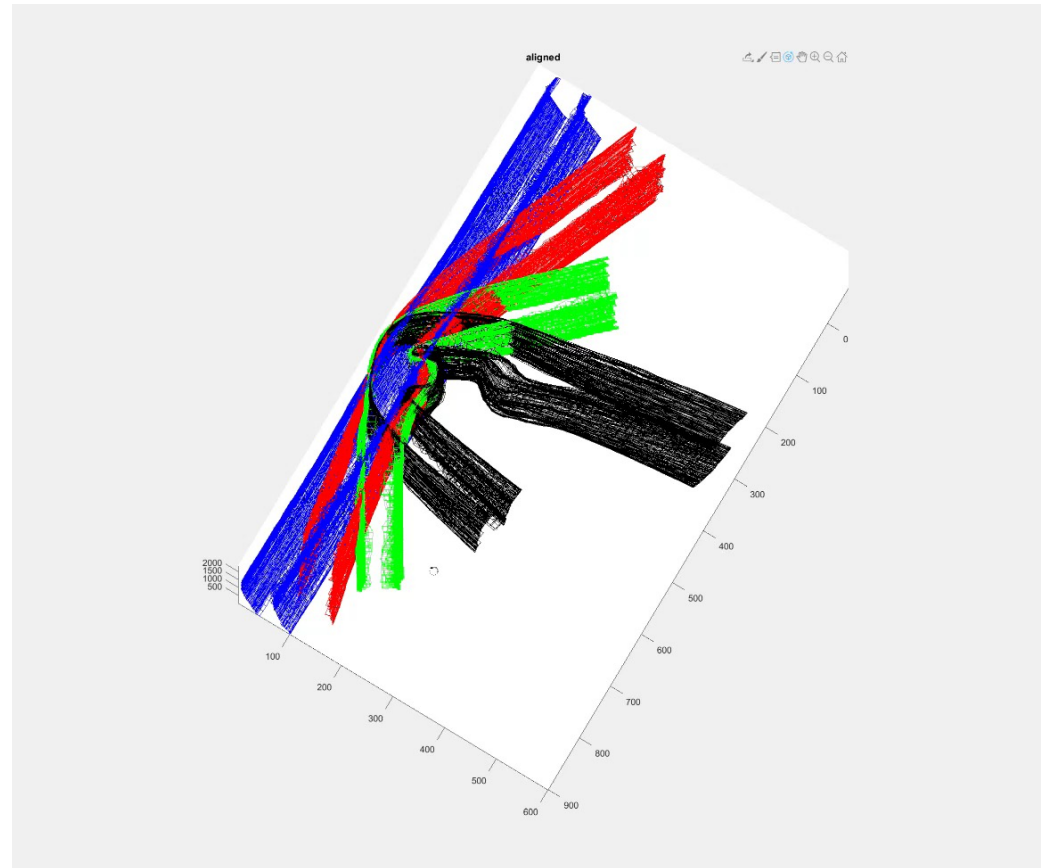
- 0° (blue), 45° (red), 90° (green), 180° (black)

# Transformation

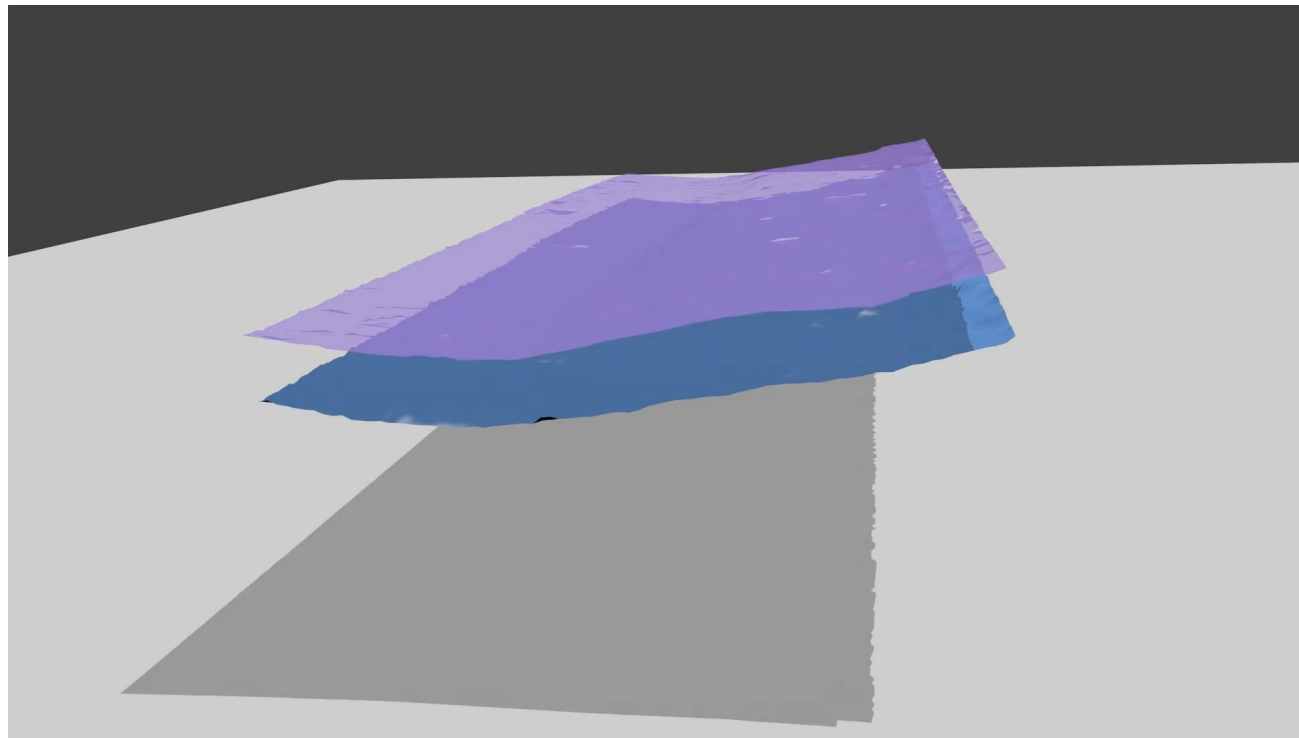


# Alignment

- Subtract the translation among the samples by aligning the concave point of outer  $180^\circ$



# Interpolated bending laminar



# Thanks – Questions?

- QIM: the Centre for Quantification of Imaging Data from MAX IV
  - funded by Capital Region of Denmark.
  - <http://qim.dk/>
- 3D Imaging Centre at DTU
  - <https://3dim.dtu.dk/>
- Tetra Pak
  - <https://www.tetrapak.com/>
- LINX project: Linking Industry to Neutrons & X-rays
  - <https://linxassociation.com/>

