Development of 2D Local Searching Algorithms for Surface Determination of X-ray Computed Tomography Measurement

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Outline

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1. Introduction
2. Simulation procedure
3. 2D Local Searching Algorithm
4. Initial results
5. Summary & future work

1. Introduction

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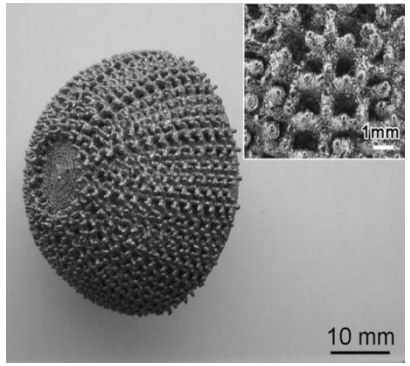
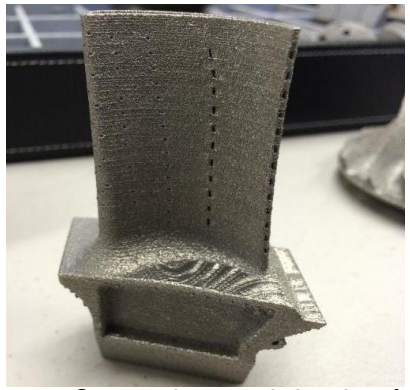
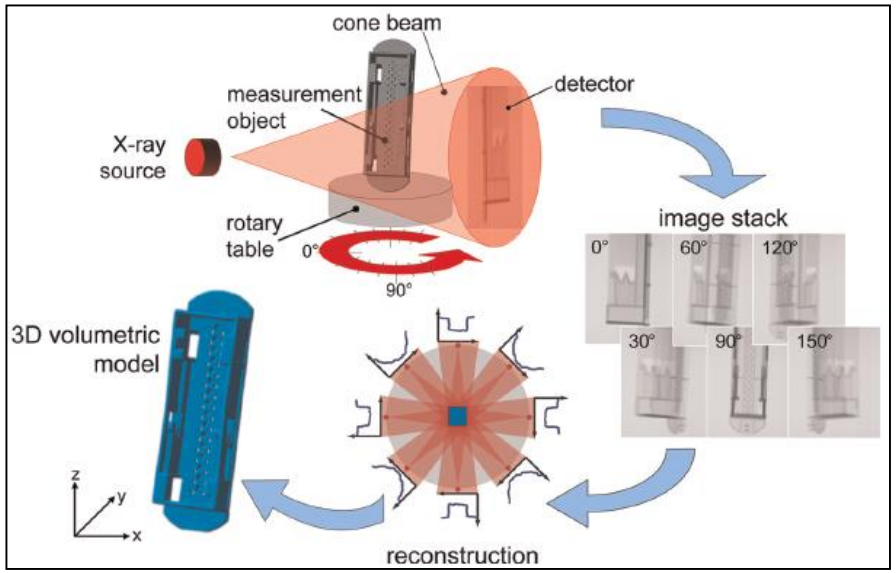
- XCT for geometrical measurement



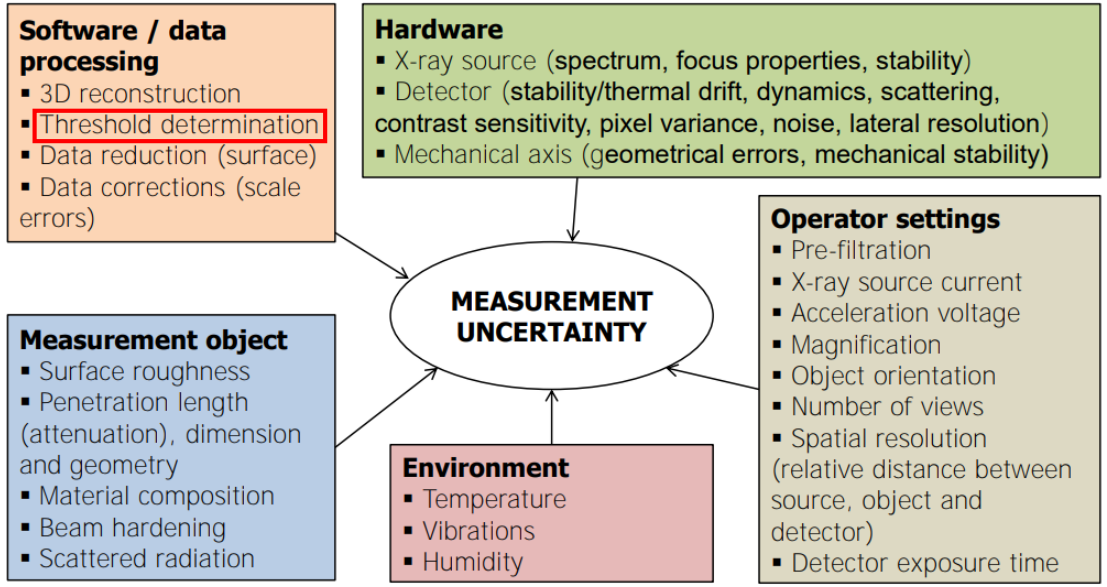
Acetabular cup with a porous structure (SLM)



Aircraft turbine blade (EBM)



Working Principle of XCT
[A. Weckenmann et al. 2012]



XCT measurement uncertainty [Pavel et al. 2013]

Ref 1: Weckenmann A. et al. 2012 Computed tomography in quality control: chances and challenges *Proc ImechE Part B*)
Ref 2: Pavel M. et al. 2013 Coordinate Metrology by Traceable Computed Tomography

2. Simulation procedure

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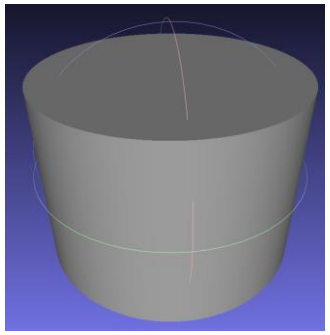
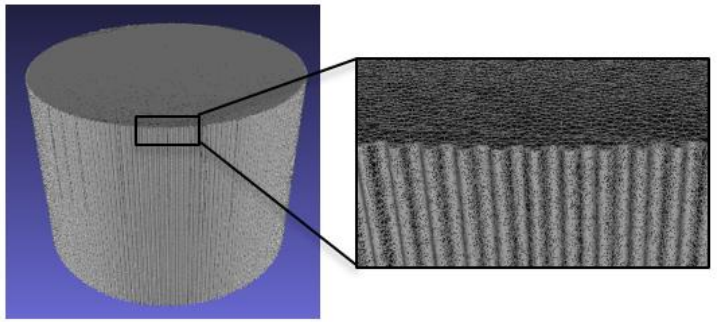


Smooth cylinder (radius: 7 mm)

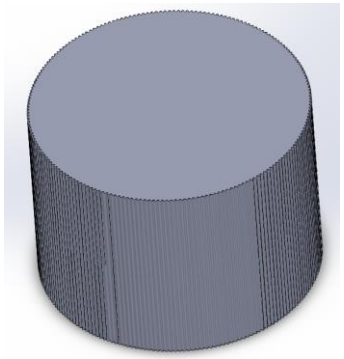


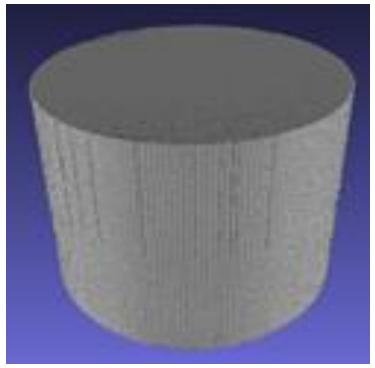
Rough cylinder (radius: 7 mm)

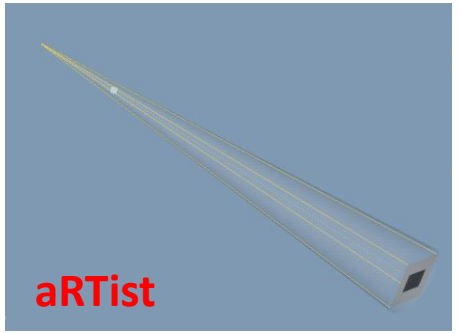
$$\begin{cases} x = (7 + 0.05\sin(200t)) \cdot \sin(t) \\ y = (7 + 0.05\sin(200t)) \cdot \cos(t) \end{cases} \quad t \in [0, 2\pi]$$

Amplitude: 50 µm, Period π/100

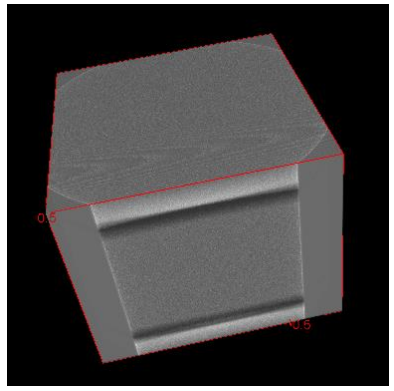
CAD design → Convert to mesh → XCT scanning simulation

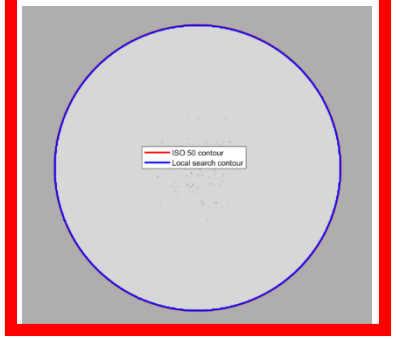






Volumetric reconstruction → Cross-sectioning → Surface determination





3. 2D Local Searching Algorithms

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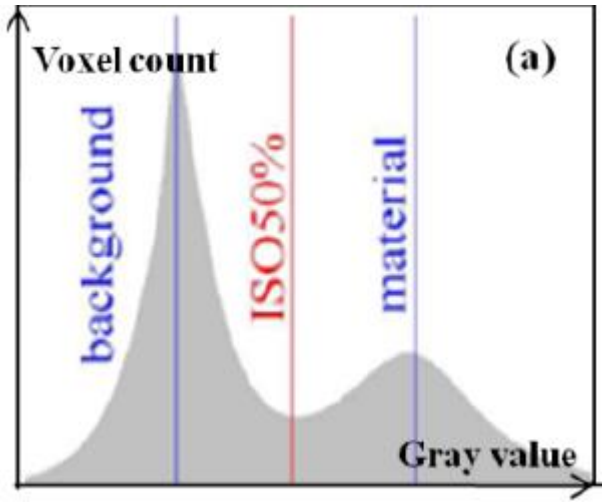
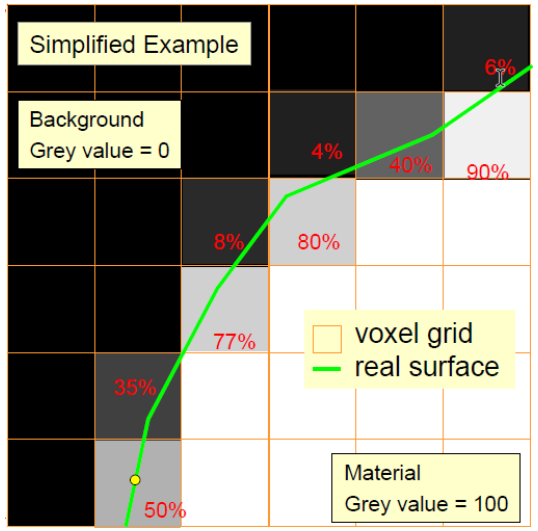
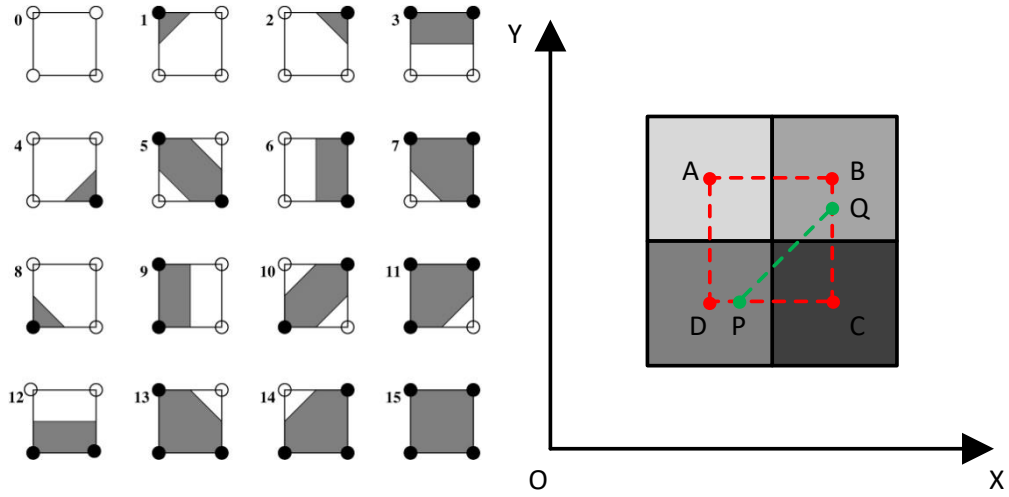
- Initial contour: ISO 50 + Marching square



ISO 50 threshold [Tan et al. 2011]



Partial volume effect [Reinhart 2011]



Marching square [Mantz 2008]

$$\frac{Q_y - B_y}{D_y - B_y} = \frac{ISO50 - I(B)}{I(D) - I(B)} \Rightarrow Q_y = B_y + \frac{ISO50 - I(B)}{I(D) - I(B)}$$

Ref 1: Tan Y, et al. Material Dependent Thresholding for Dimensional X-ray Computed Tomography, 2011.
Ref 2: Reinhart C Industrial CT & Precision, Volume Graphics GmbH, 2011.
Ref 3: Mantz et al. Utilizing Minkowski functionals for image analysis: a marching square algorithm, 2008

3. 2D Local Searching Algorithms

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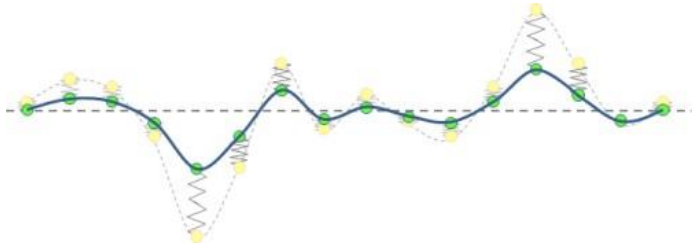
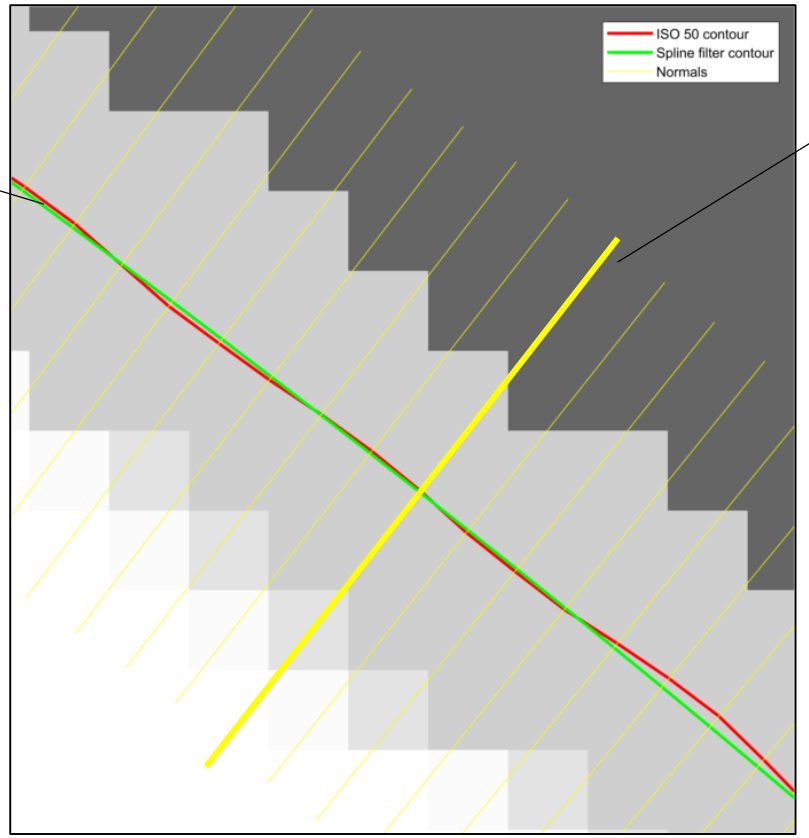
- Searching maximum gradient along the normal vectors of the initial contour

Spline filter is used to smooth the initial contour and thus generates more stable contour normal.

Optimisation problem:
Find the spline minimizing the **square** of the **residual errors** under the conditioning of minimizing the **bending energy** of the spline.

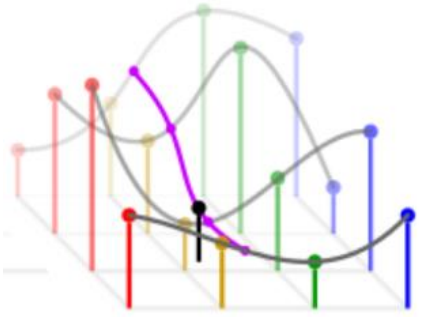


[Image source: Digital Surf]



Extract the grey value profile: the pixels where the searching path pass through within the specified distance

Bicubic interpolation is used to locate the maximum gradient position more accurately



[Image source: Wikipedia]

3. 2D Local Searching Algorithms

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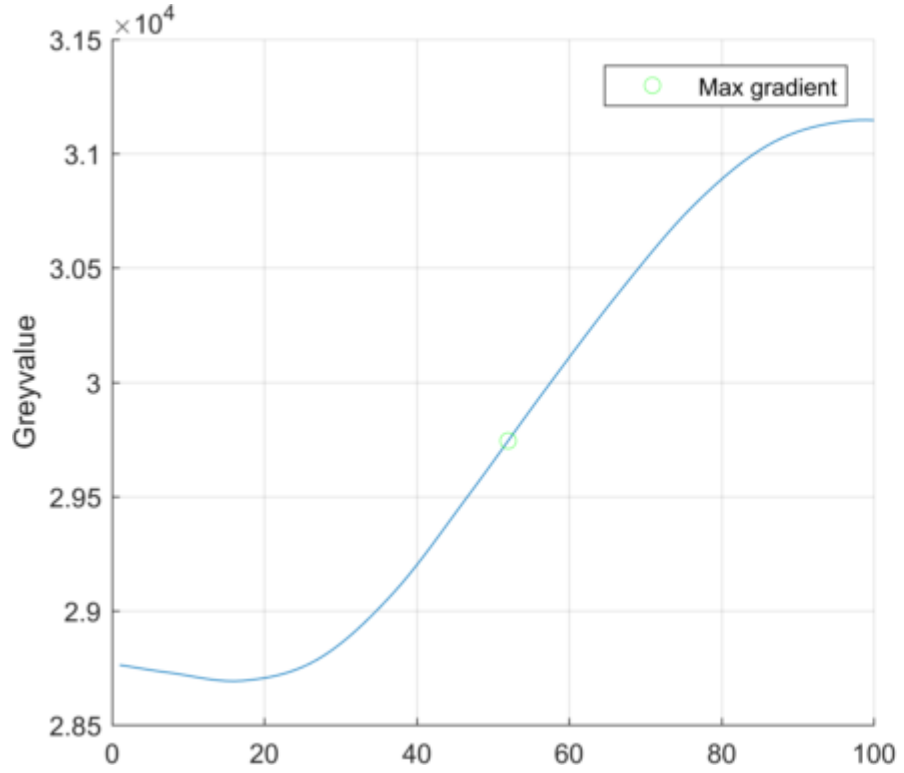
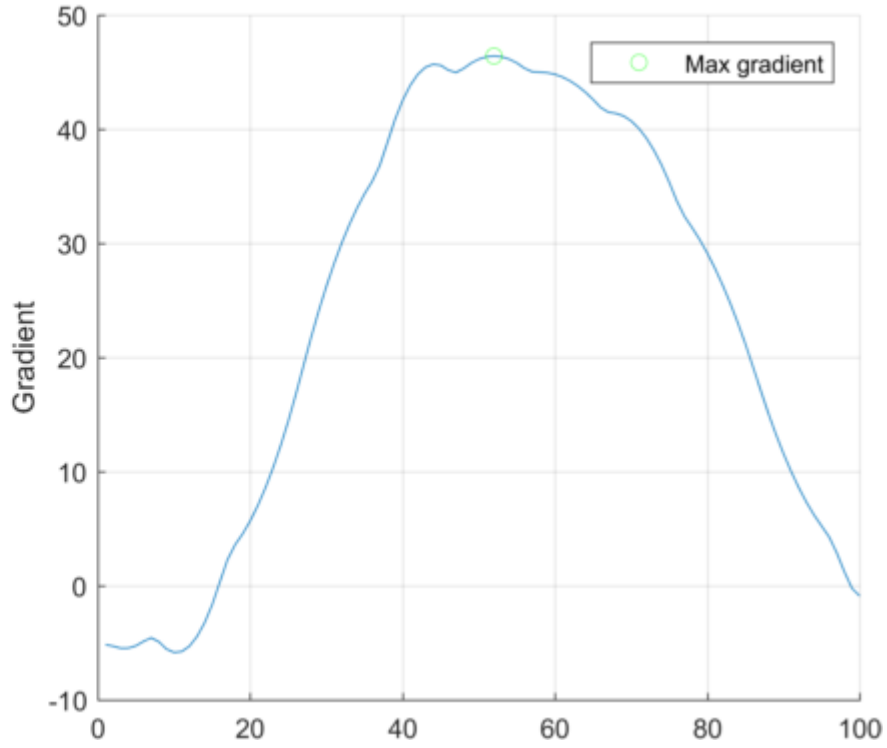
- Determine the position of maximum gradient: interpolation distance is set to the tenth of pixel size.



(a) the grey value profile along the search path



(b) the resulted gradient profile

4. Initial results

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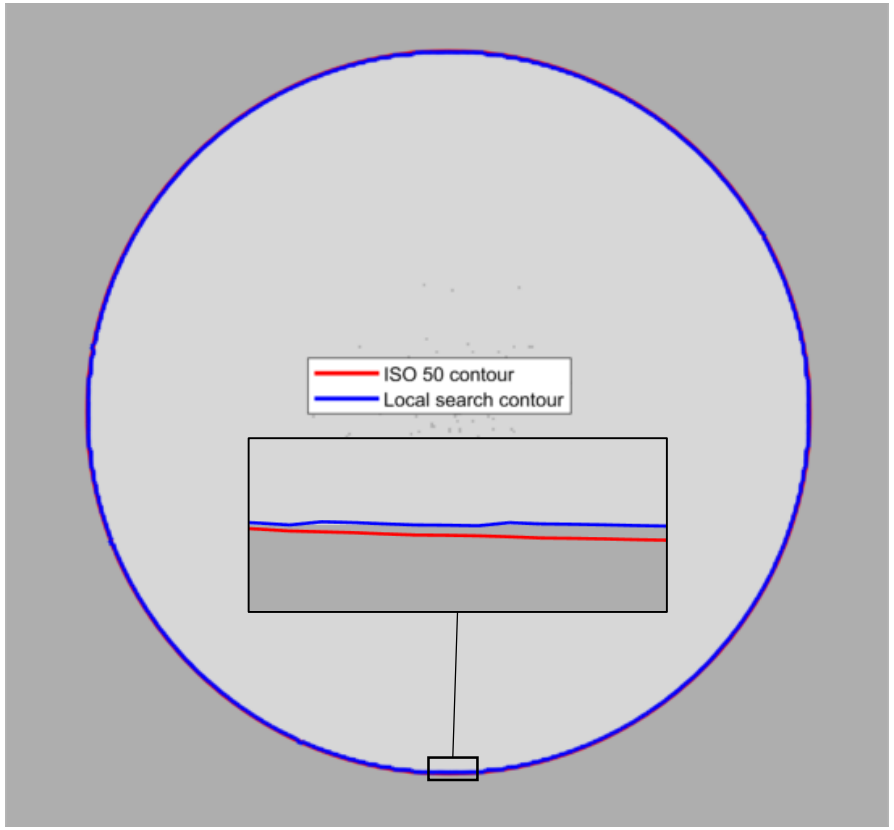
- Smooth cylinder



Voxel size (unit: µm)	Cylinder radius (Nominal: 7 mm)			
	ISO 50 (mm)	Deviation (µm)	Local searching (mm)	Deviation (µm)
50	7.0229	22.9	7.0087	8.7

4. Initial results

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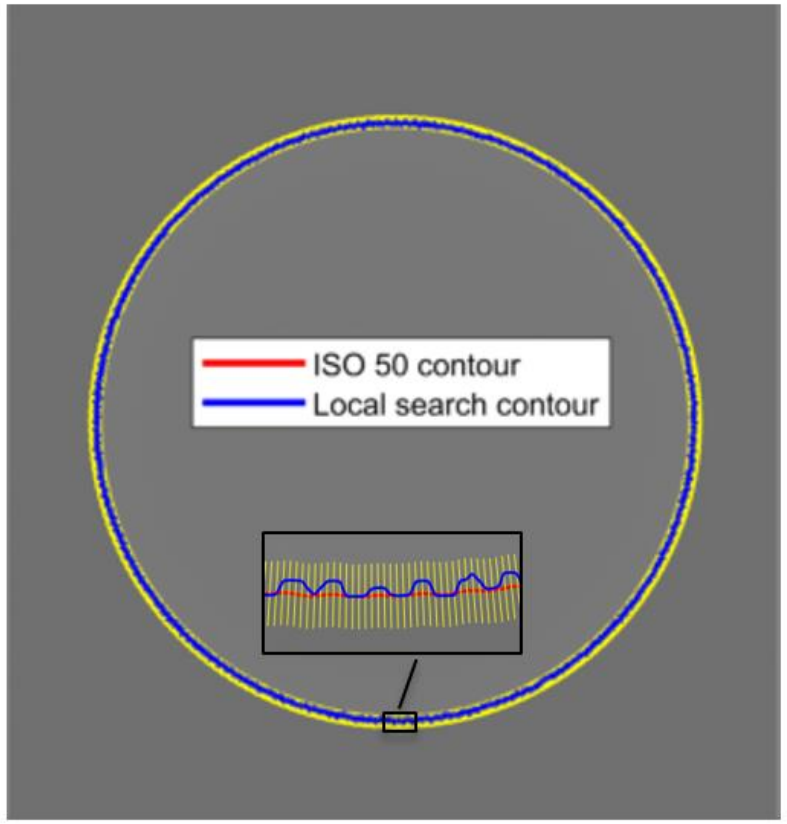
- Rough cylinder



Voxel size (unit: µm)	Cylinder radius (Nominal: 7 mm)			
	ISO 50 (mm)	Deviation (µm)	Local searching (mm)	Deviation (µm)
40	7.0398	39.8	7.0130	13.0

Voxel size (unit: µm)	Ra (Nominal: 31.8 µm)			
	ISO 50 (mm)	Deviation (µm)	Local searching (mm)	Deviation (µm)
40	3.96	-27.84	28.94	-2.86

5. Summary and future work

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- Summary
  1) A simulation procedure is proposed to investigate the impact of partial volume effect of XCT to dimensional and surface measurement.
  2) A 2D local searching algorithm is developed for XCT surface determination.
  3) Both dimensional and surface texture results show that the local searching algorithm is more accurate than the ISO 50 method.

- Future work
  1) Subpixel watershed.
  2) Extend the 2D algorithm to 3D.
  3) Compare the partial volume effect of XCT to the mechanical filtering effect of CMM measurement for rough surfaces.

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Thank You

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