3D Imaging of Chinese Puzzle Balls

A Case Study in Technical Art History

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Computational Imaging

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Context

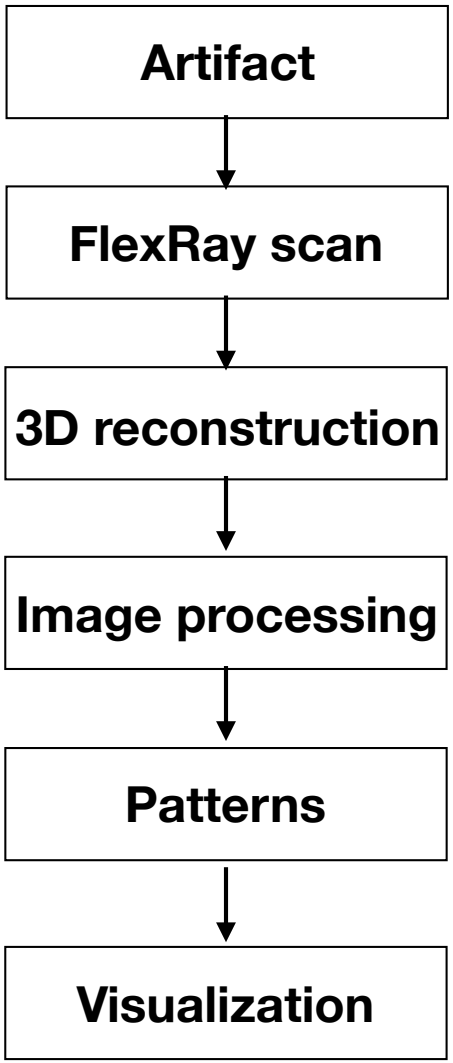
1. NWO JSTP “*See-through museum”* project
    - Partners: CWI, Rijksmuseum, Naturalis, Palace Museum Beijing, Shanghai Natural Museum, DNTA-IHEP
    - Goal: what information can we obtain from ‘*inside*’ a museum artifact, and how can this information be useful for historians and conservators.
2. NWO NICAS “IMPACT*4Art”* project
    - Partners: CWI, Rijksmuseum
    - Goal: Computational Tomography as a hands-on tool for technical art history and conservation diagnostics.

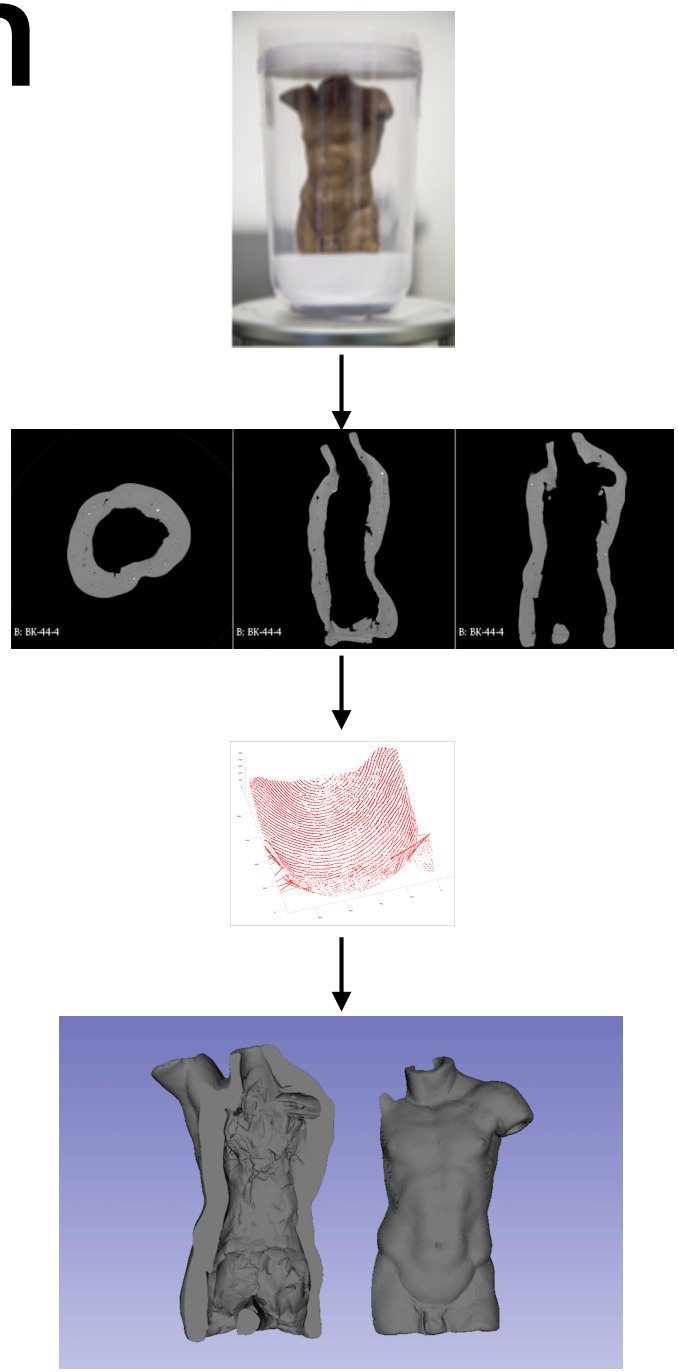
Technical Art History

- TAH is the study of art history through the use of data science and technology.

- Our goal: use CT to gather information in order to deduce the make process of art artifacts. Specifically, we search the data for patterns that indicate ‘tool marks’ and/or ‘material origin’

Approach





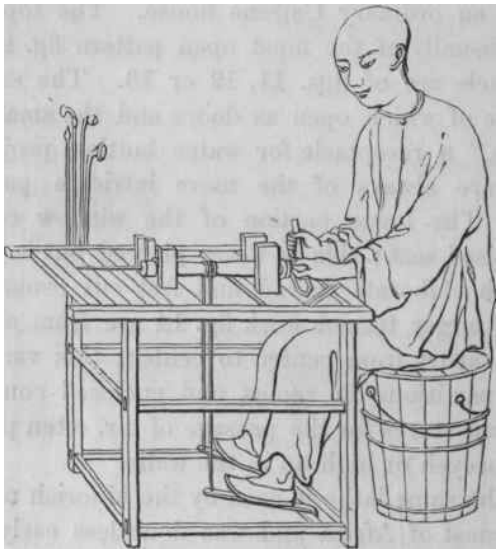
Terracotta statue, Florence, ca 1560
Question: van der Schardt or Michelangelo ?

Chinese puzzle balls ?

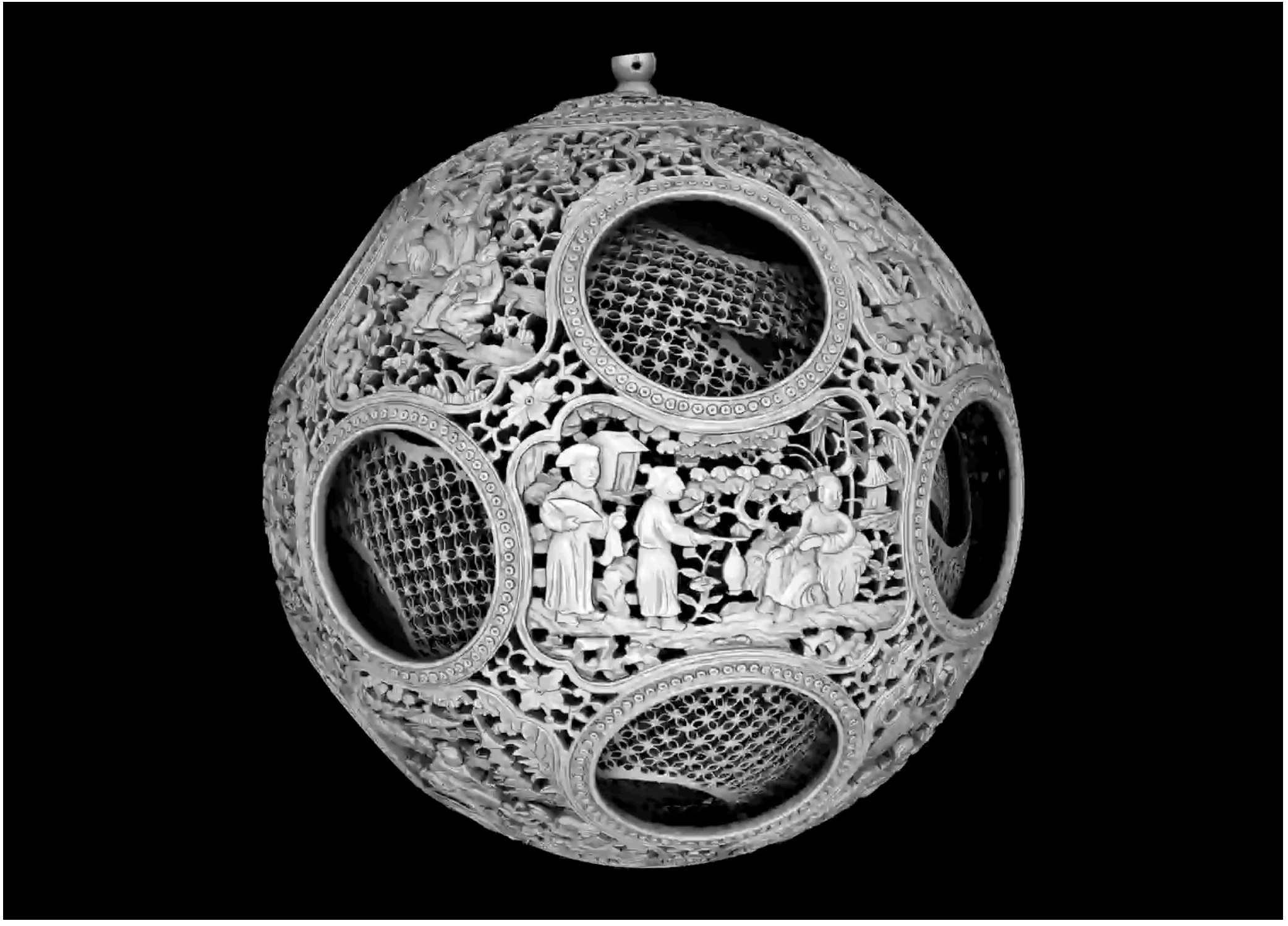
- ca.1750, 4.15cm radius, 9 spheres

- ca. 1790, 8.1cm radius, 12 spheres

- Crafted in Canton early 18th century
- Puzzle ball :
  1. N concentric ivory spheres rotate freely
  2. A geometric pattern on each sphere
  3. Chain and (optional) small foot.
- Crafted using only a lathe and various carving tools. The literature calls this process "*turning*".



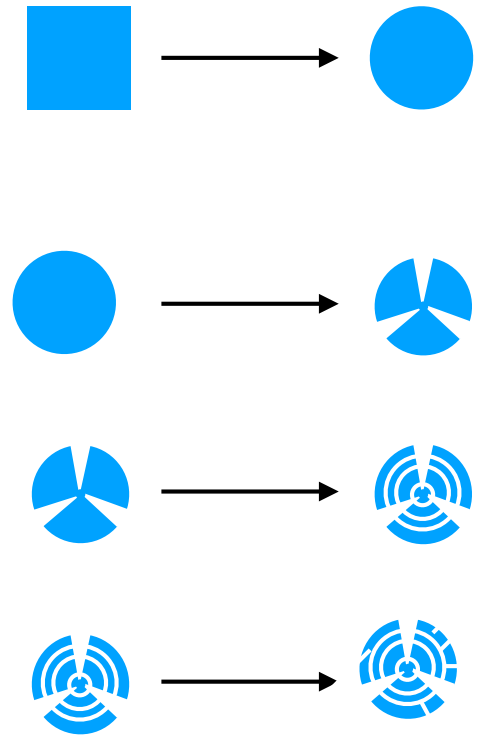
…….. lets now pause and think how this ball was made …….



Make process

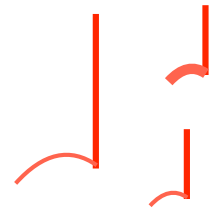
- Using a lathe :

1. With a cup-shaped tool, turn an ivory solid cylinder into a solid sphere
2. With a cone-shaped tool, turn conic sections from surface to center; “*peepholes*”
3. With L-shaped knives, turn concentric spheres
4. With sharp knives, carve a geometric pattern on each sphere



Specific case study questions

- From the data, can we deduce
  - How many L-shaped tools are required?
  - What are L-shape tool sizes and shapes ?



  - What can the craftsman see during carving ?

Scanning & Reconstruction

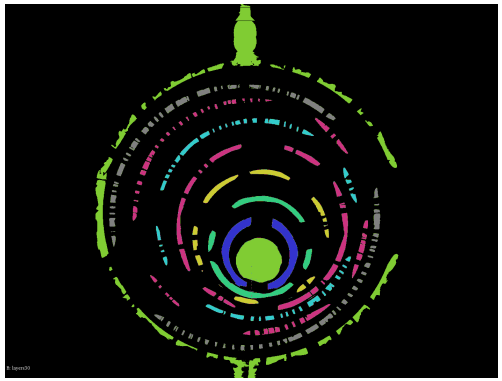
- CWI Flex-Ray setup
- 3x2 tiled acquisition
- Resolution 0.05 mm/voxel
- Volume 4K x 4K x 4K voxels = 64 GB

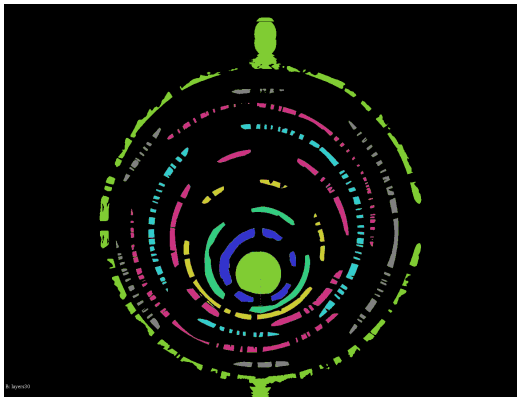
- XY, YZ, XZ cross sections

Segmentation

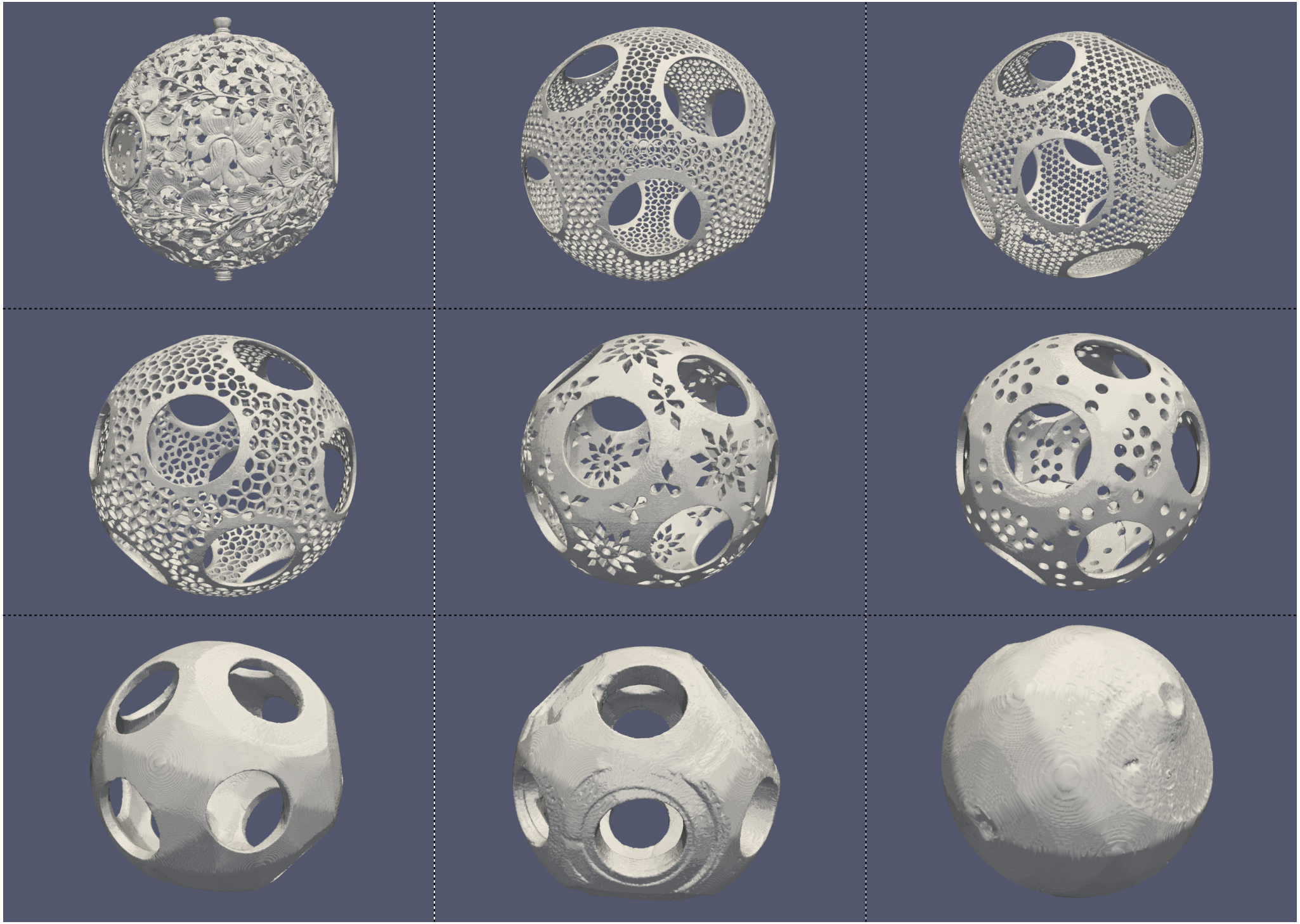
- Standard segmentation methods do not suffice
  - Complex contact regions
  - Ambiguous voxel classification

- Novel method based on ray tracing and high level wall classification was developed



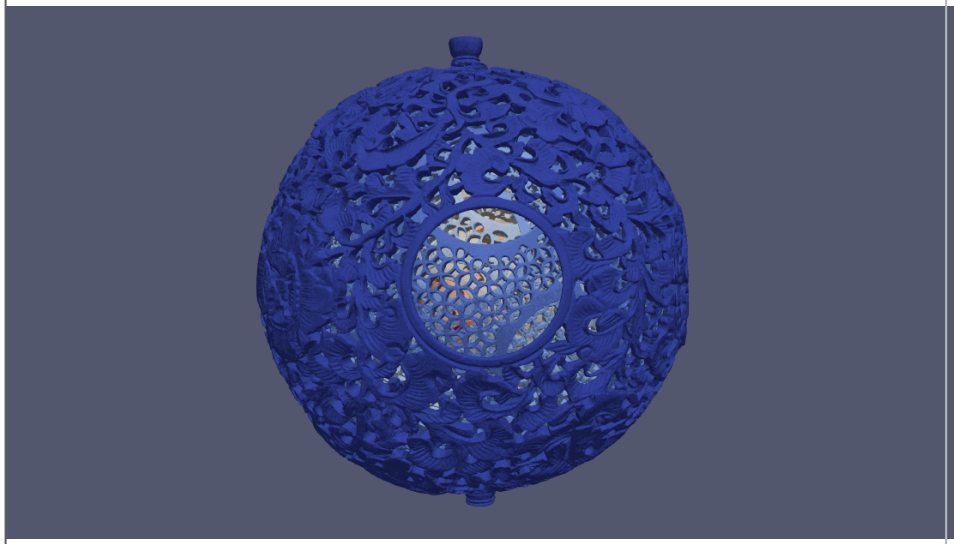


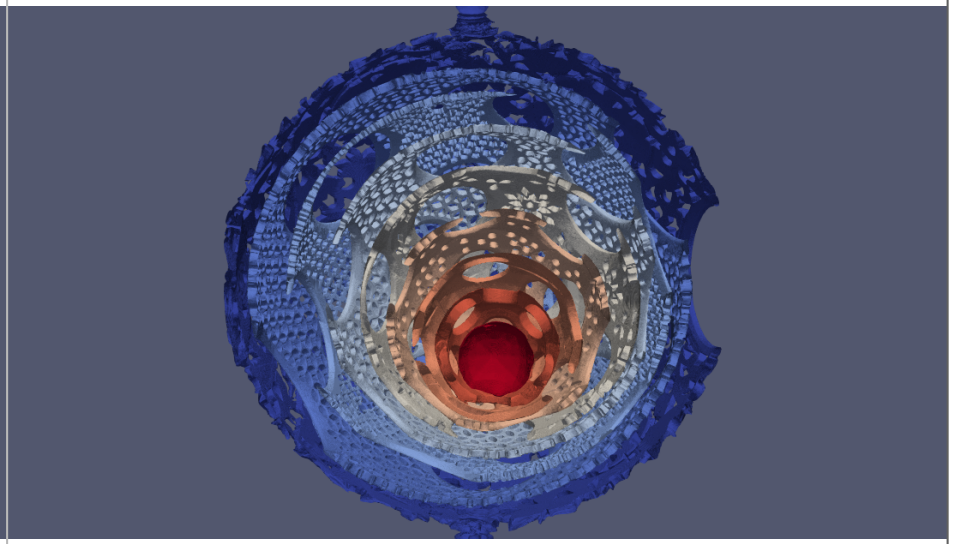
- Labeled XY, YZ, XZ cross sections

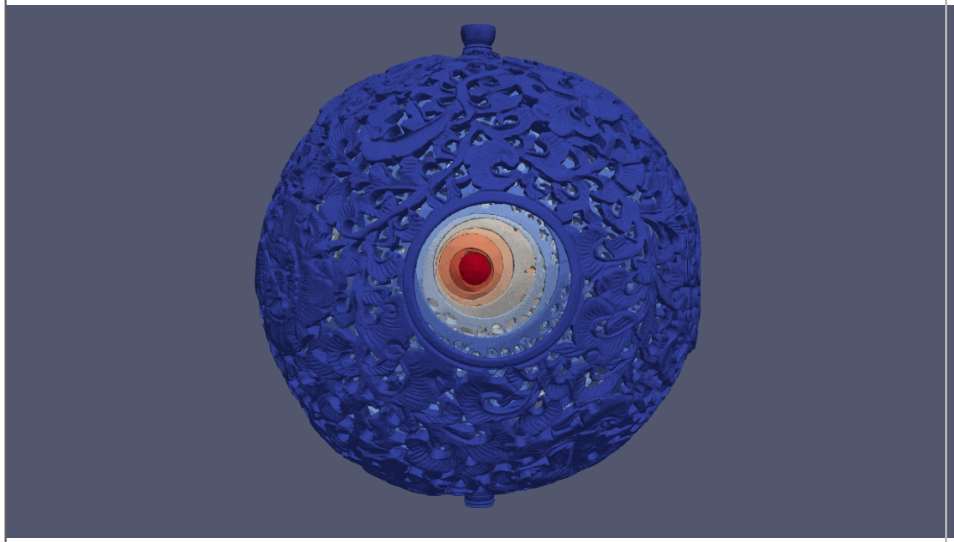


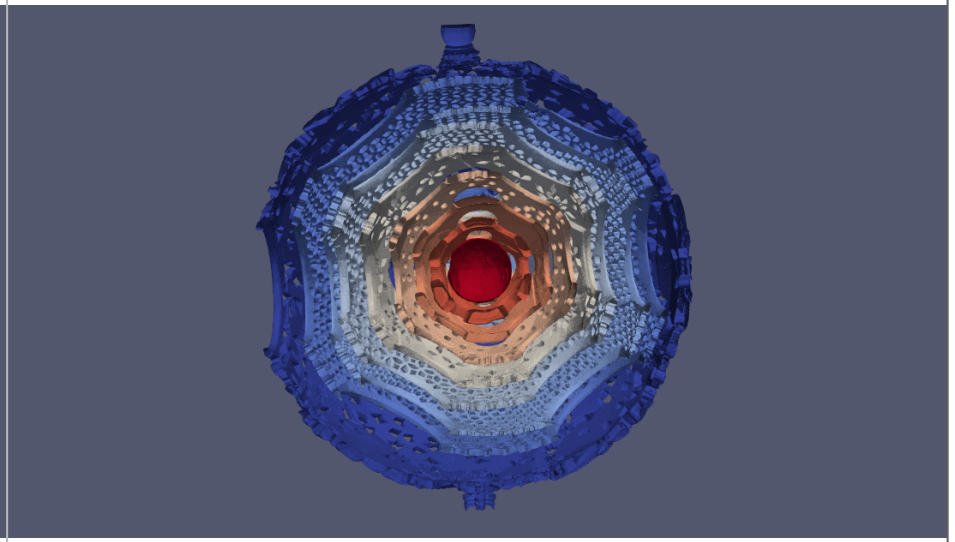
Clipping

Align







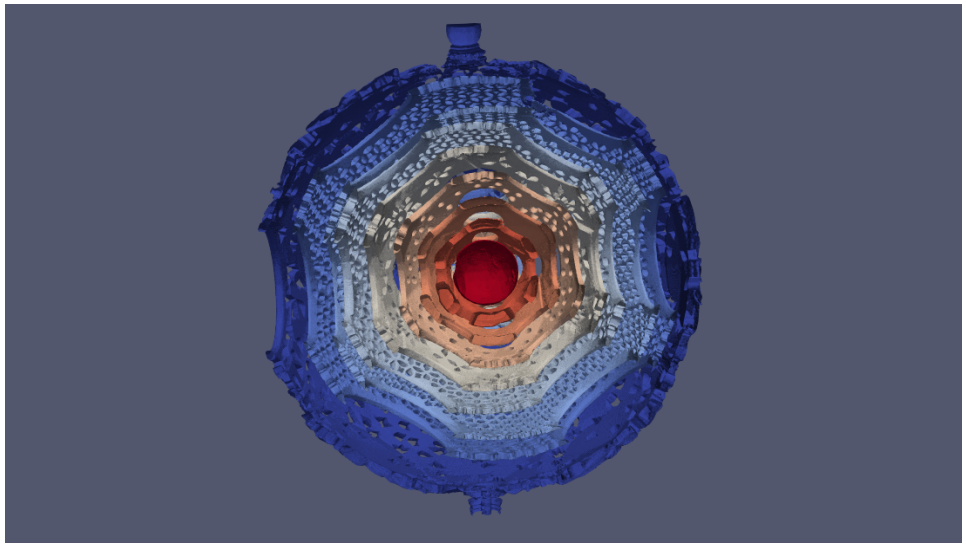


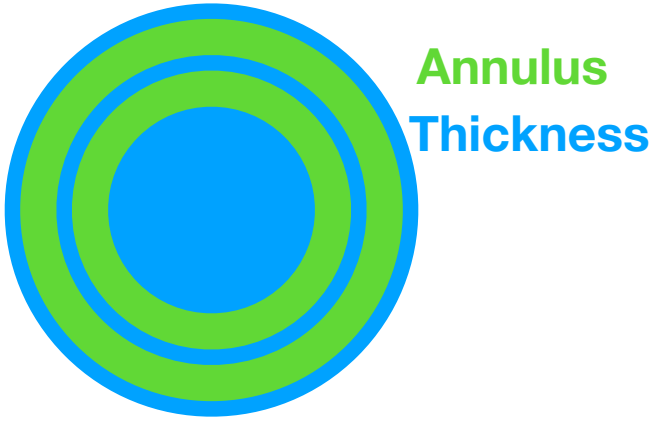
Spatial measurements

- Annulus: the region bounded by two concentric circles

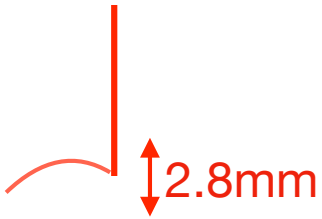
Si-Sj	Annulus mm
1-2	2.8
2-3	2.9
3-4	2.7
4-5	2.8
5-6	2.8
6-7	2.9
7-8	2.7
8-9	2.7
	2.3 cm

Si	T mm
1	3.5
2	1.6
3	1.6
4	1.6
5	1.7
6	1.7
7	1.8
8	1.8
9	5.0
	2.0cm



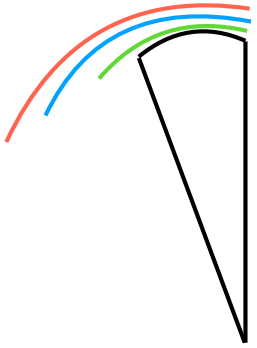


- Height of *L-shaped tool* is bounded by the annulus;

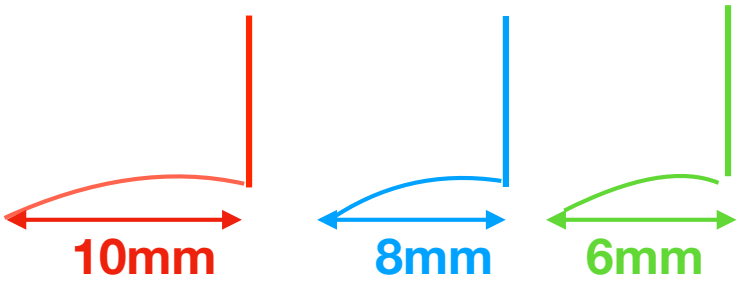


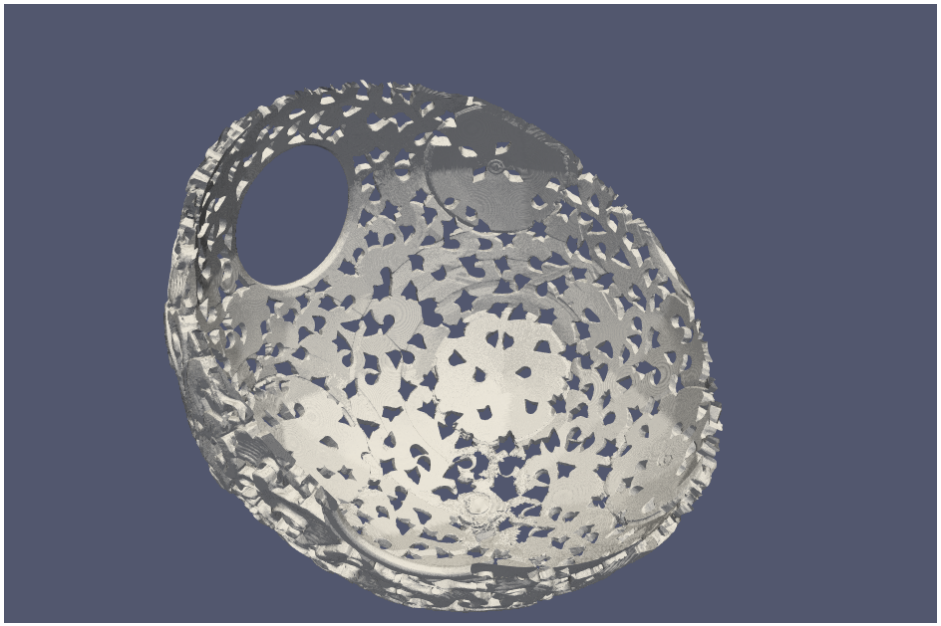
Patterns on spheres

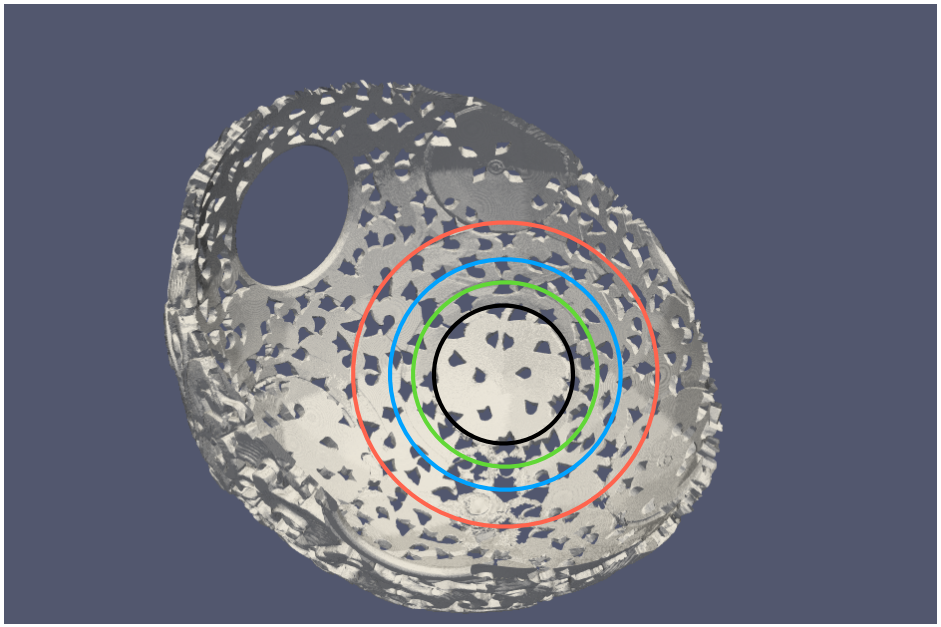
- Three concentric circles with center at the center of each peephole



- Width of largest L-shaped tool is distance to midpoint of adjacent peephole.







What does the craftsman see?

- Light only travels through peepholes and geometric patterns

- Light simulation:
  - ambient lighting
  - no external occlusion

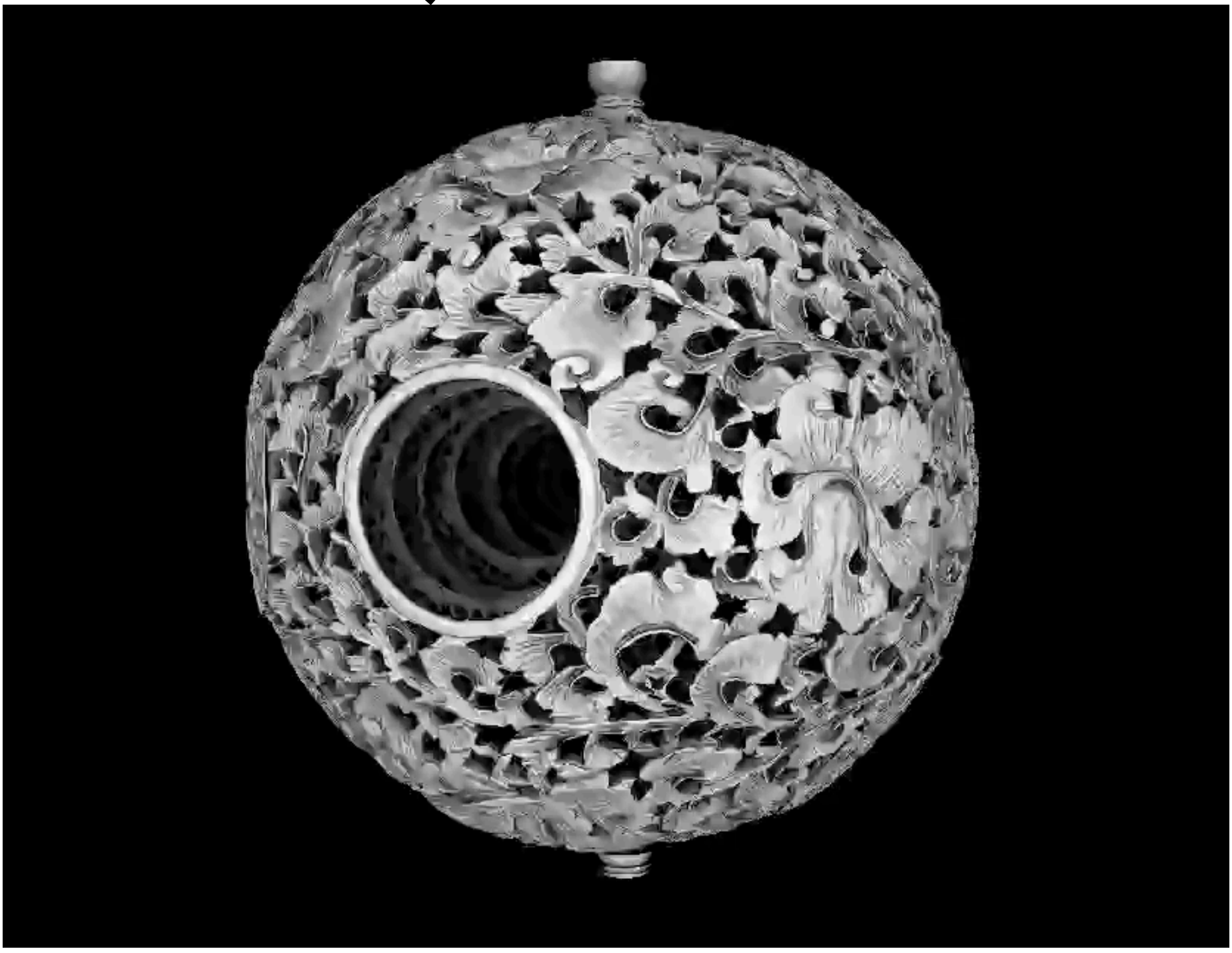
- Result:
  - layers 1, 2, 3, 4, 5 are clearly visible
  - layers 6, 7, 8 and 9 are carved ‘blindly’.

Conclusions

- Computational Tomography is a useful tool for Technical Art History

- Ivory puzzle balls are intriguing :
  - It is unbelievable that these balls are +/- 300 years old
  - CT imaging reveals the morphological properties of the puzzle balls

- Many secrets can be deduced from patterns in the data :
  - Tool shapes and sizes can be computed
  - It is very dark deep down in the ball !

- Governing art historical question: how much did the craftsman know before starting the make process ?

Questions?