Weakly Supervised Geodesic Segmentation of Egyptian Mummy CT Scans

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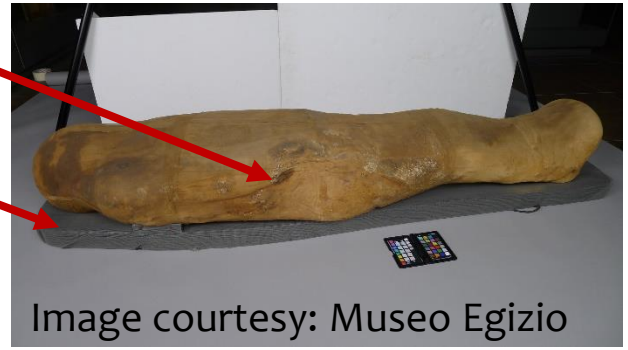
Problem

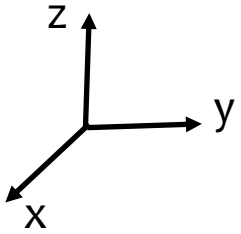
- Mummies from Museo Egizio

Mummy

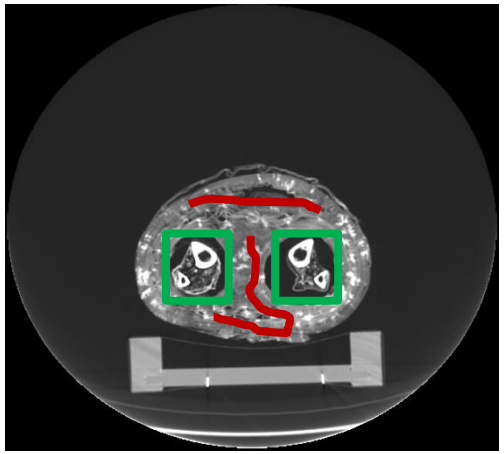
Supporting frame



- 3D volumetric (MxNxH) scans from CT devices



Axial view
XY-plane

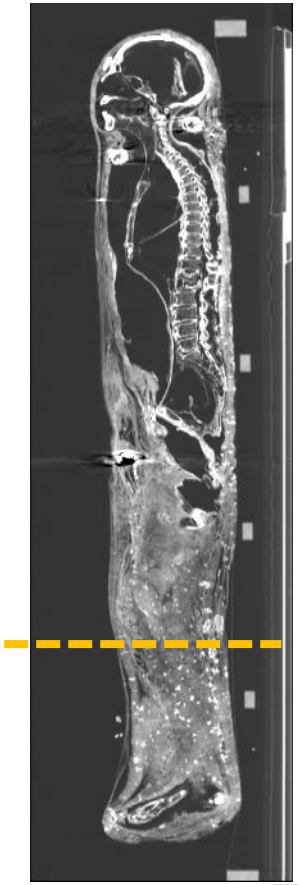


1. Wrap/bandage
2. body

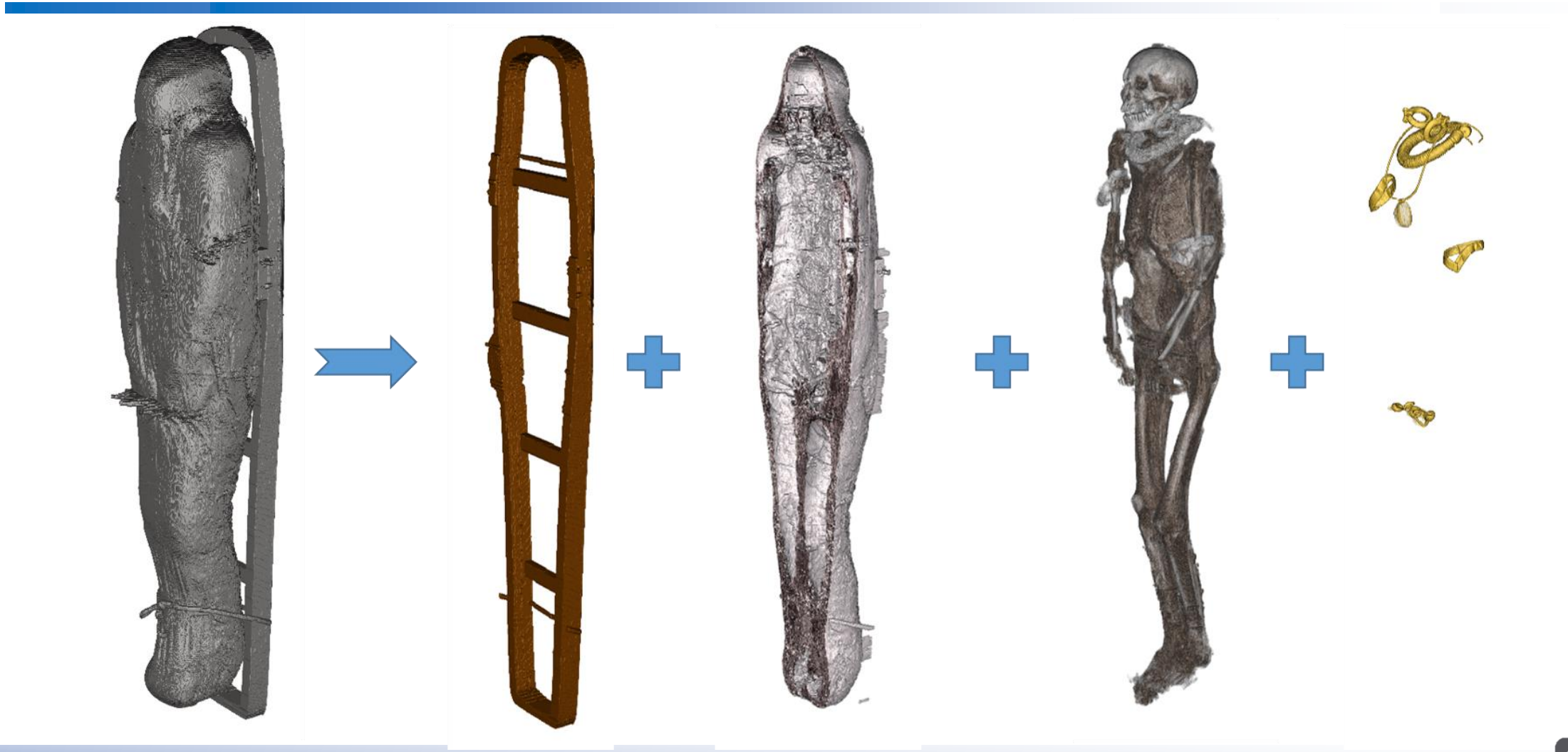
Segment the body

Coronoal view
YZ-plane

Sagittal view
XZ-plane

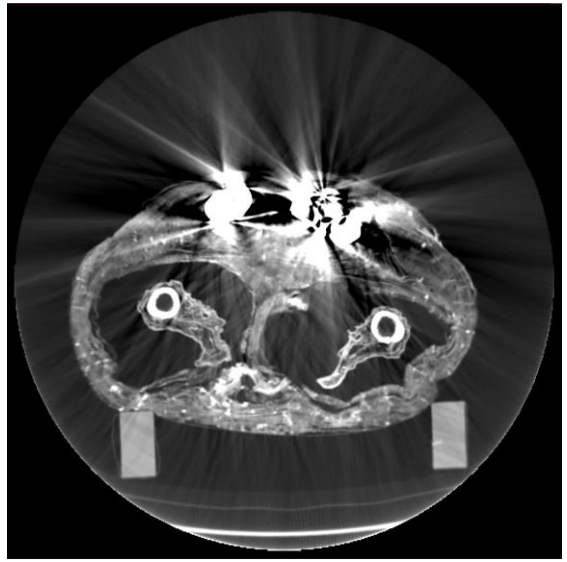


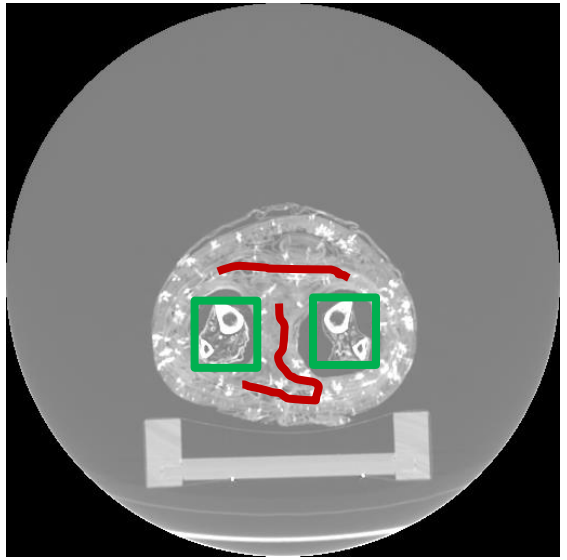
Goal



Challenges

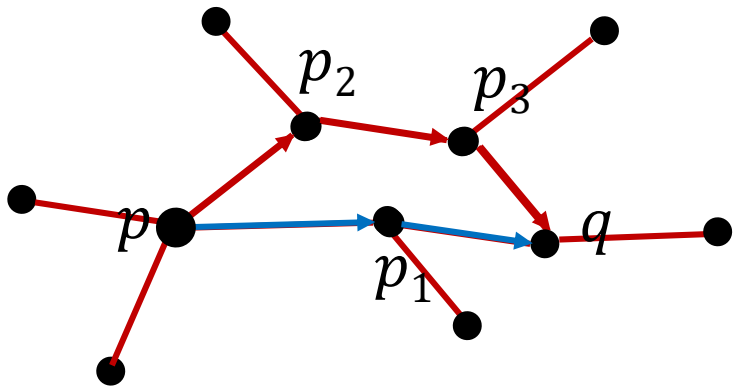
- Scattering due to presence of metal (jewelries)
- Varying structure of supporting frame
- Overlapping voxels intensity ranges in bandage and mummy body





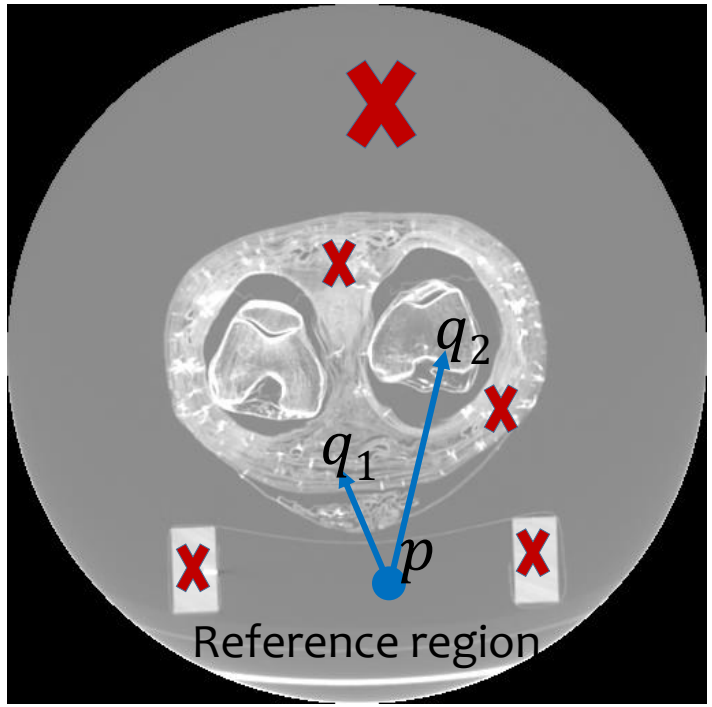
Method

- External space: histogram and connected components
- Wooden frame: template matching and Hough lines
- Bandages: geodesic distance
  - ambiguity using pointwise distance

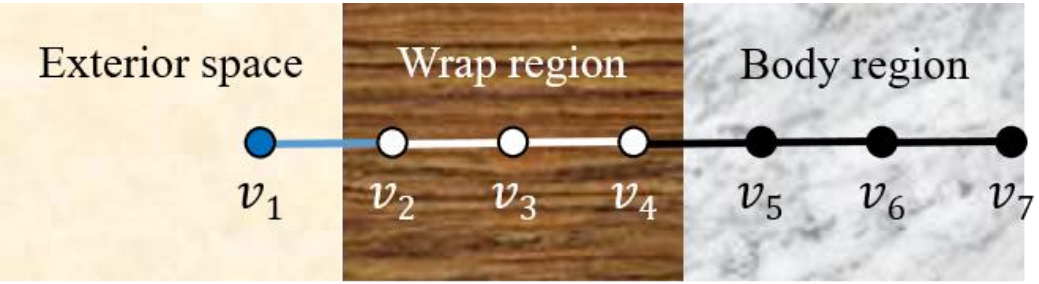


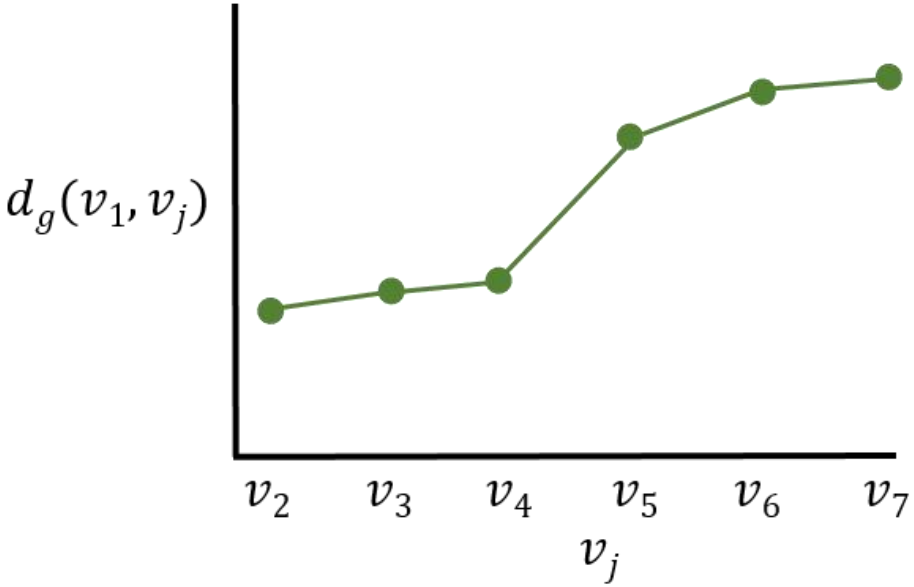
$$d(p, q_1) \approx d(p, q_2)$$

$$d_g(p, q) = \min_{\text{all paths}} \sum_{(p_i, p_j) \in \{p \to q\}} d(p_i, p_j)$$

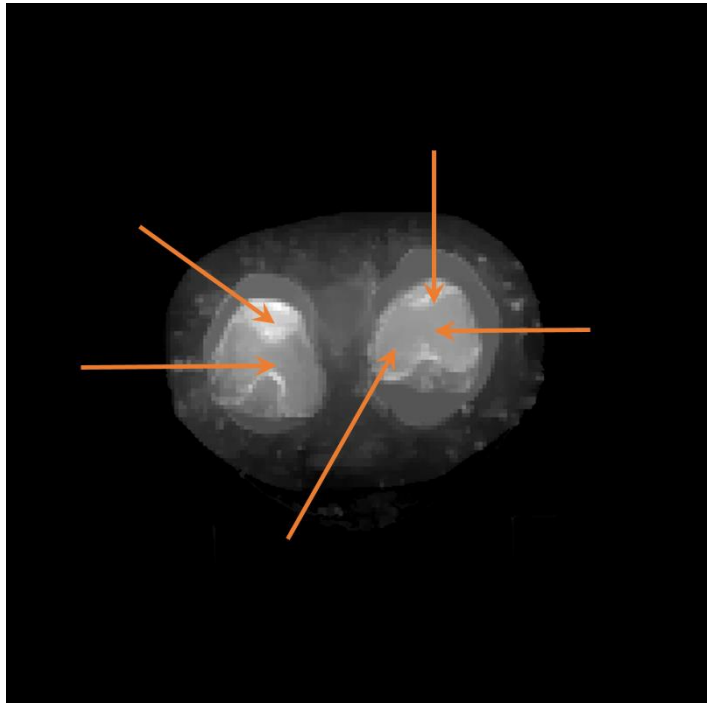


Geodesic distance

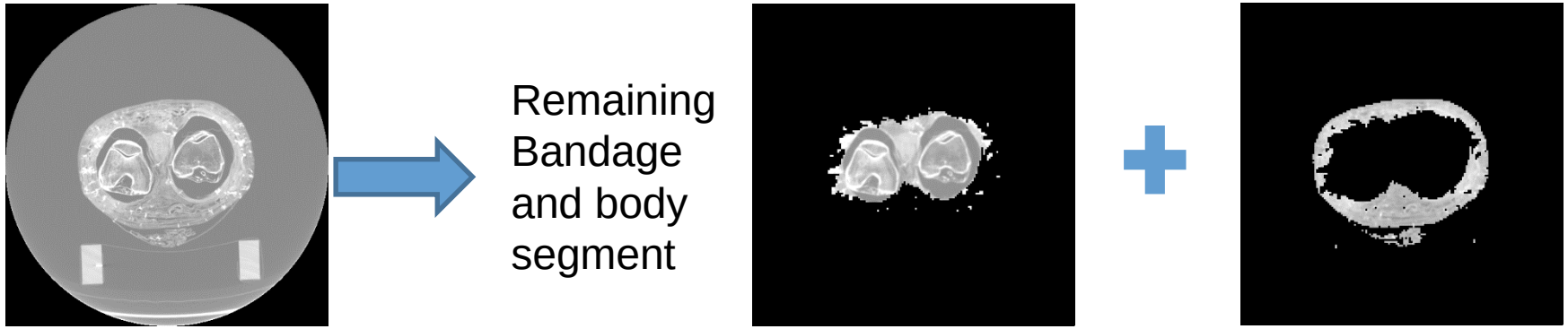




Geodesic distance map

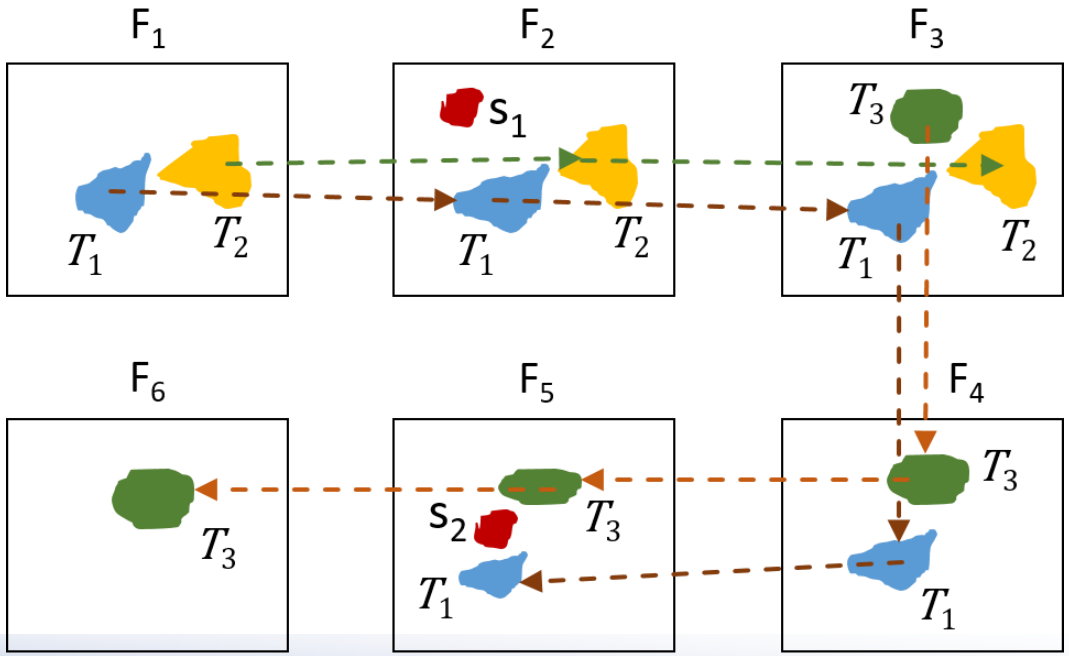


Tracking segments



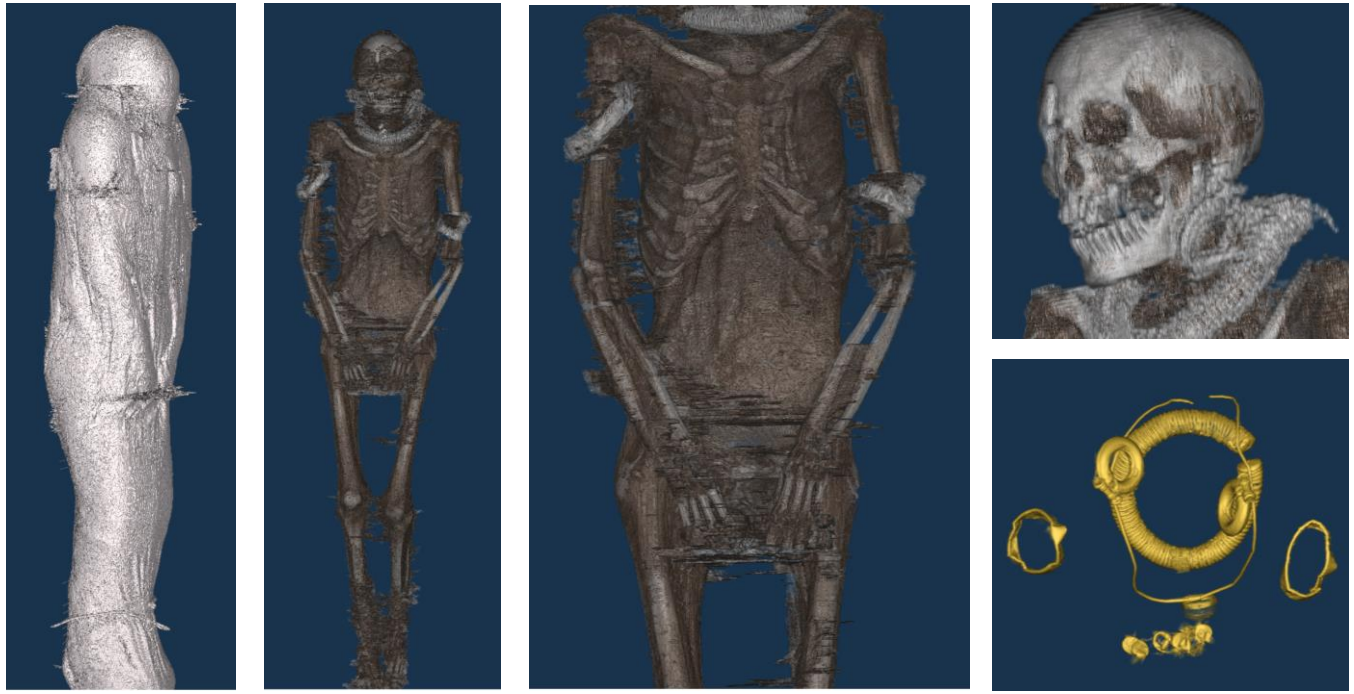
- Apply GrabCut
  - Automatically selected scribble
- Tracking valid segments

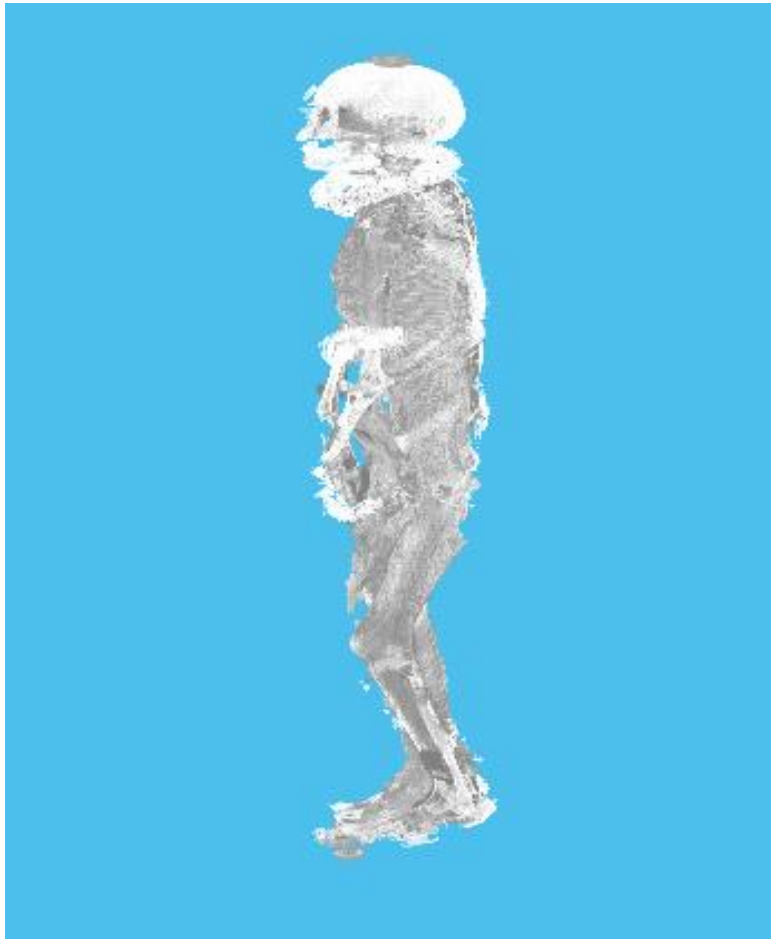
$$T_i^{(k+1)} = \arg \max_{s_j \in R_b^{(k+1)}} \Phi(H_i^{(k)}, s_j)$$



Qualitative results

- Entire mummy wrapped in bandages
- Segmented mummy body, including skin and bones
- Segmented jewels decorating the mummy





Quantitative analysis

- Generate multiple warped data using thin-plate splines [1] for evaluation

Intersection over union (IOU) score and ablation study

IOU \ Data	Original	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6
Without tracking	0.79	0.80	0.81	0.80	0.80	0.80	0.80
With tracking	0.81	0.81	0.81	0.82	0.81	0.82	0.82

Comparison of the proposed method with standard interactive segmentation methods

Proposed method	GrabCut segmentation [2]	Saliency detection [3]	Graph Cut segmentation [4]	Video object segmentation [5]
0.81	0.50	0.46	0.42	0.24

[1] Bookstein, PAMI, 1989. [2] Rother et al., ACM Trans. Graph., 2004. [3] Zhu et al., CVPR 2014.
[4] Borovec et al., Journal of Electron. Imaging, 2017. [5] Griffin et al., WACV 2019.