Weakly Supervised Geodesic Segmentation of Egyptian Mummy CT Scans

Avik Hati, Matteo Bustreo, Diego Sona, Vittorio Murino, Alessio Del Bue

Avik.Hati17@gmail.com, {Matteo.Bustreo, Diego.Sona, Vittorio.Murino, Alessio.DelBue}@iit.it
Problem

- Mummies from Museo Egizio

  - 3D volumetric (MxNxB) scans from CT devices

  - 1. Wrap/bandage
  - 2. body

  - Segment the body

Axial view
  XY-plane

Coronal view
  YZ-plane

Sagittal view
  XZ-plane

Mummy
Supporting frame

Image courtesy: Museo Egizio
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

\[
d(p, q_1) \approx d(p, q_2)
\]

\[
d_g(p, q) = \min_{\text{all paths}} \sum_{(p_i, p_j) \in \{p \rightarrow q\}} d(p_i, p_j)
\]
Geodesic distance

Exterior space

Wrap region

Body region

\[ d_g(v_1, v_j) \]

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

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<th>IOU \ Data</th>
<th>Original</th>
<th>Set 1</th>
<th>Set 2</th>
<th>Set 3</th>
<th>Set 4</th>
<th>Set 5</th>
<th>Set 6</th>
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Comparison of the proposed method with standard interactive segmentation methods

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