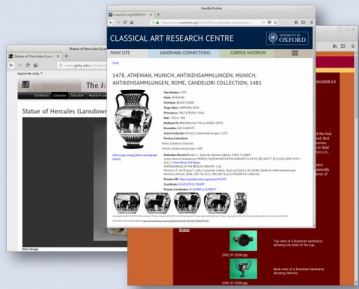
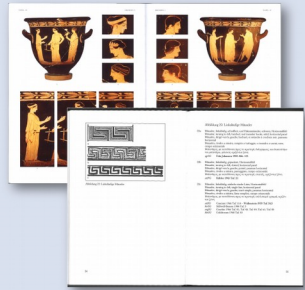


Sources



Repositories

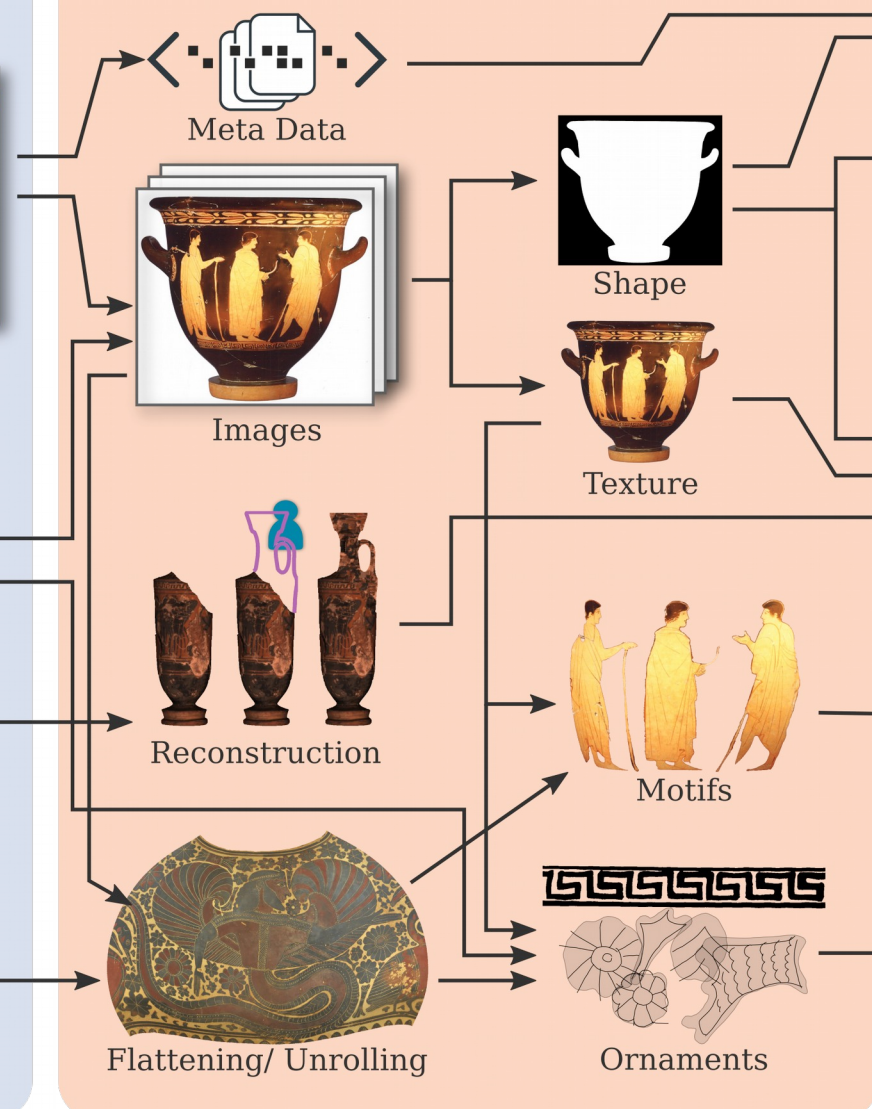


Volumes



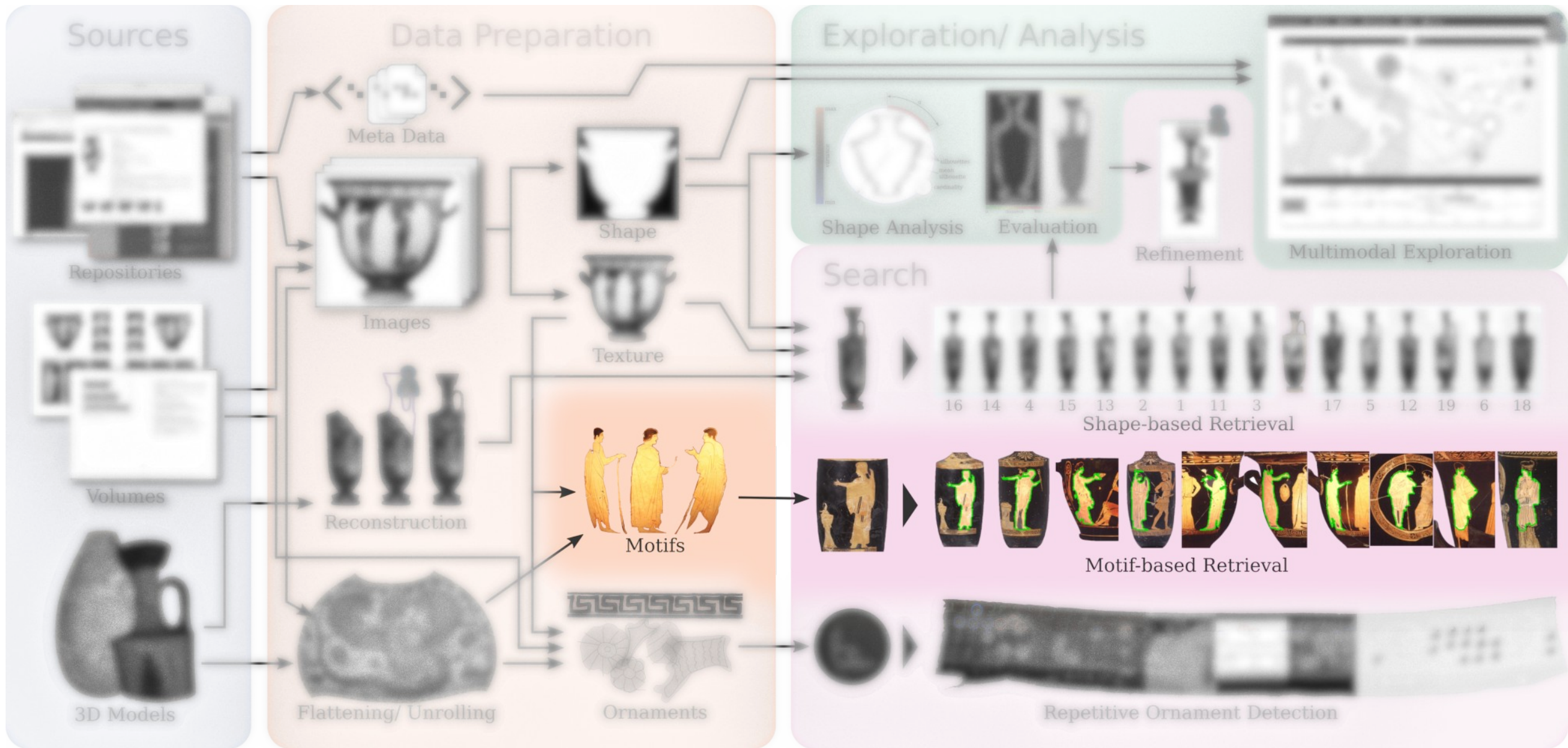
3D Models

Data Preparation



Exploration/ Analysis

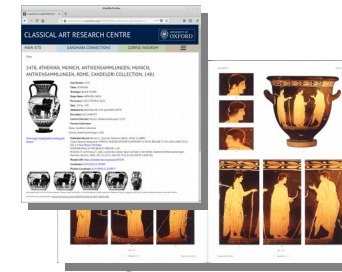




Concept

Preparation: Database creation

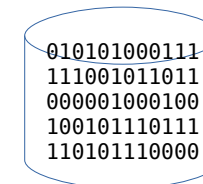
- 1) Segmentation
- 2) Feature Extraction
- 3) Insertion into database



Sources



Preprocessing
Feature Extraction



Search space

Concept

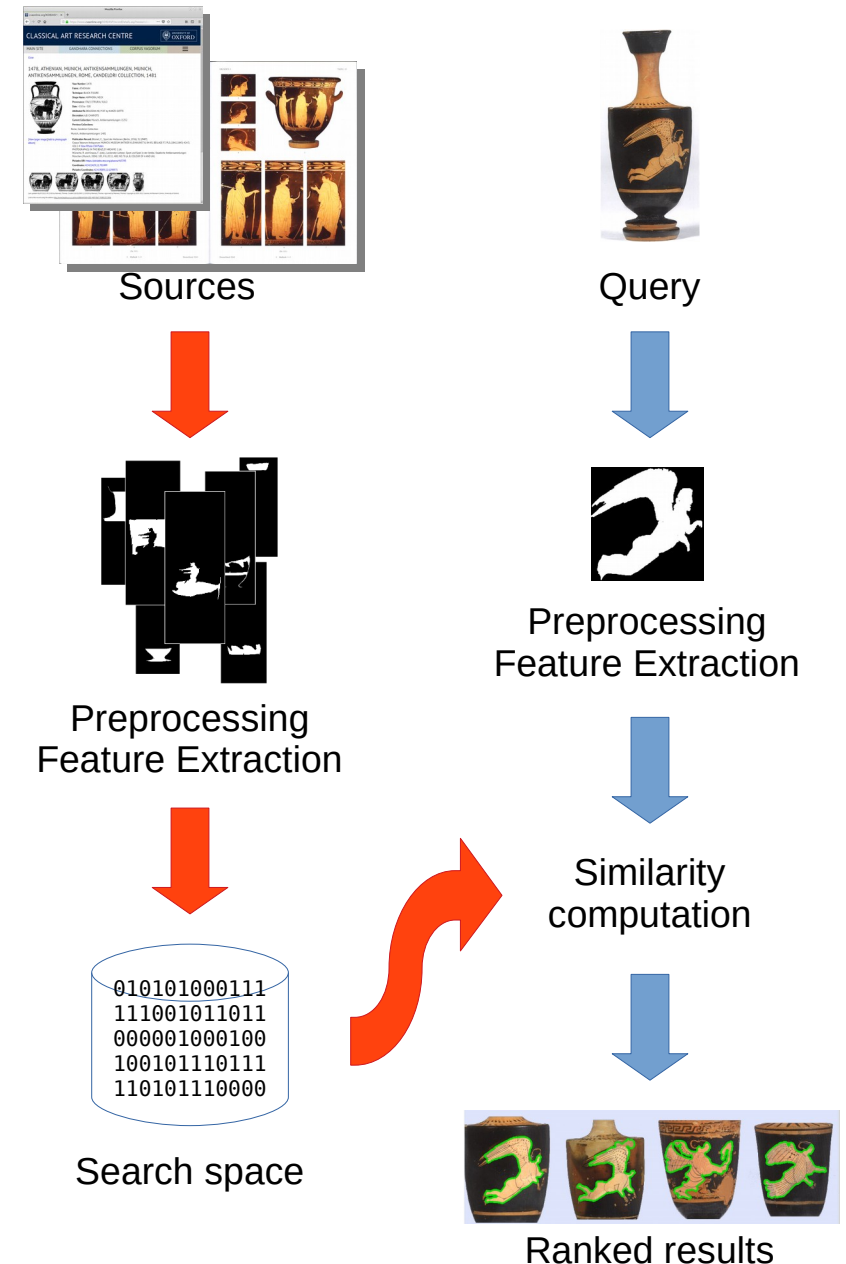
Preparation: Database creation

- 1) Segmentation
- 2) Feature Extraction
- 3) Insertion into database

Input: Selected reference image

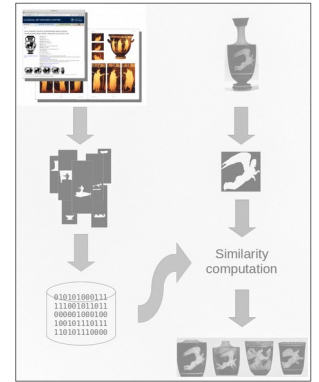
- 1) Preprocessing
- 2) Feature Extraction
- 3) Similarity computation

Output: Ranked list of results



Sources

- Sources
 - Corpus Vasorum Antiquorum Berlin 13^[0]
 - Corpus Vasorum Antiquorum Dresden 3^[1]
- Search space
 - Different vessel shapes (lekythoi, crates, cups, plates, etc.)
 - Numerous motifs of various types
 - 99 images → **937** (152 + 785) silhouettes

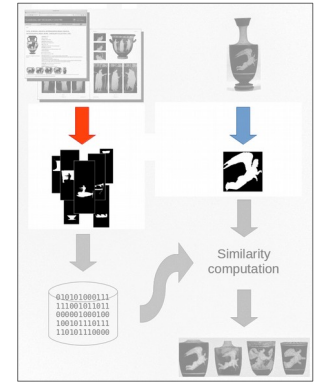
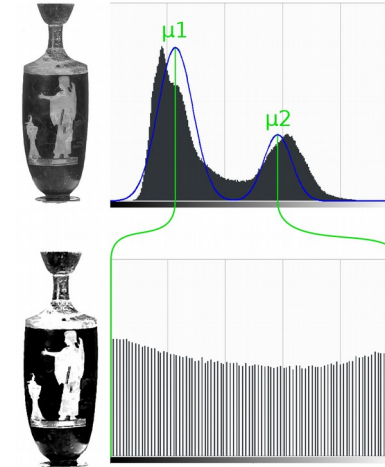


^[0]Zimmermann-Elseify, N., CVA Berlin 13: Attisch rotfigurige Lekythen. C.H. Beck, 2013.

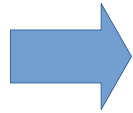
^[1]Eschbach, N., CVA Dresden 3: Attisch rotfigurige Keramik, C.H. Beck, 2018.

Motif Preserving Segmentation

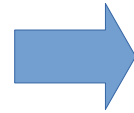
- Contrast enhancement and binarization
 - 1) Find *fg* and *bg* peaks in the grayscale histogram
 - 2) Map the colors in-between to the whole range
 - 3) Binary image from thresholding



Original



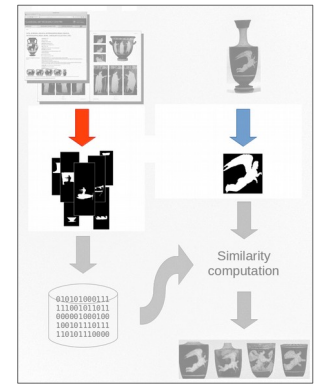
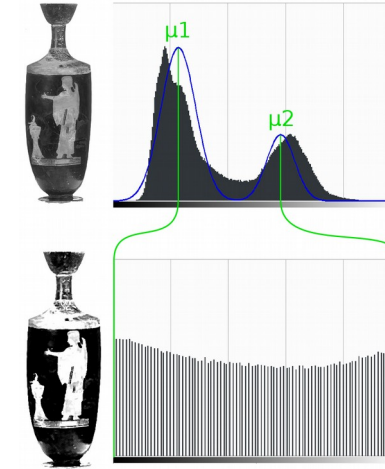
Contrast enhancement



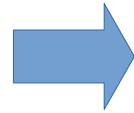
Thresholding

Motif Preserving Segmentation

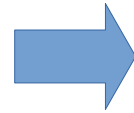
- Contrast enhancement and binarization
 - 1) Find *fg* and *bg* peaks in the grayscale histogram
 - 2) Map the colors in-between to the whole range
 - 3) Binary image from tresholding
- Segmentation^[2]
 - Labels are assigned to coherent image areas



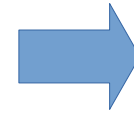
Original



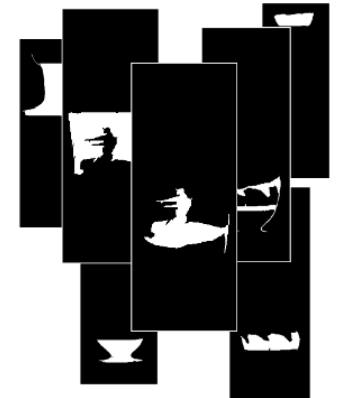
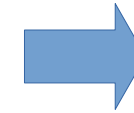
Contrast enhancement



Thresholding



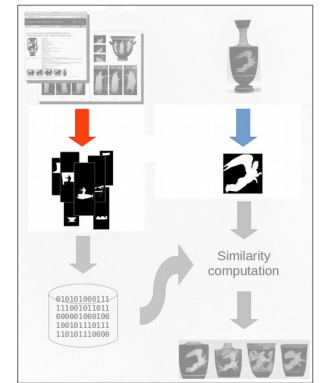
Segmentation



Export

^[2]Felzenszwalb, Pedro F., and Daniel P. Huttenlocher. "Efficient graph-based image segmentation." *International journal of computer vision* 59.2 (2004): 167-181.

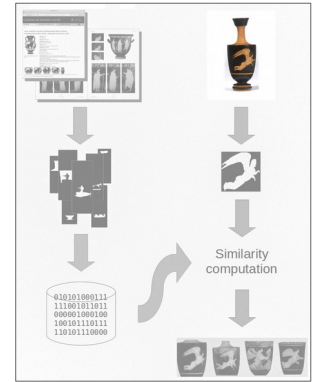
Motif Preserving Segmentation



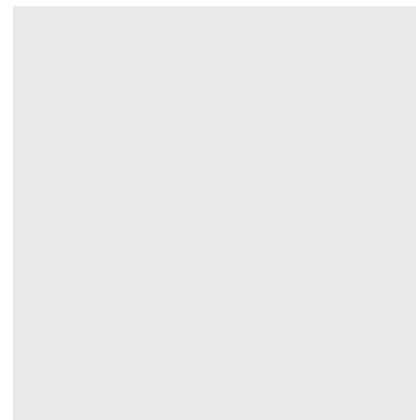
Segmentations obtained from two different approaches

Query Specification

- Loading reference image
- Rough selection of motif with brush tool
- Real-time silhouette extraction in the background
- Same feature extraction as with the search space objects



Brush Selection



Query Segmentation



Extracted Silhouette

Silhouette Descriptor

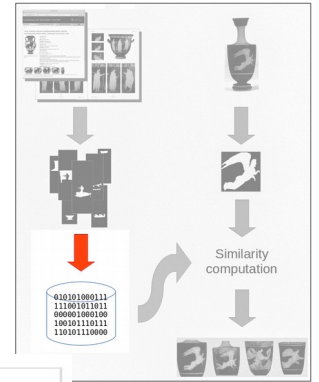
Shape Contexts Descriptor^[3]

1. Silhouette sampling

- Silhouette approximation with a fixed number of points N

2. Histogram computation

- For each point:
 1. Determine direction and distance to all other points
 2. Sort into radial and angular bins
 3. Normalize



^[3]Belongie, Serge, Jitendra Malik, and Jan Puzicha. "Shape matching and object recognition using shape contexts." *IEEE transactions on pattern analysis and machine intelligence* 24.4 (2002): 509-522.

Silhouette Descriptor

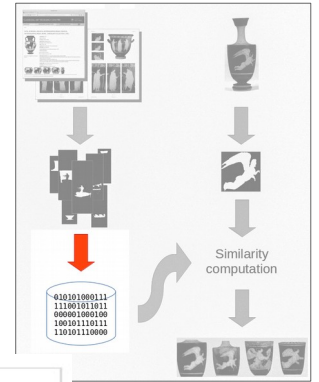
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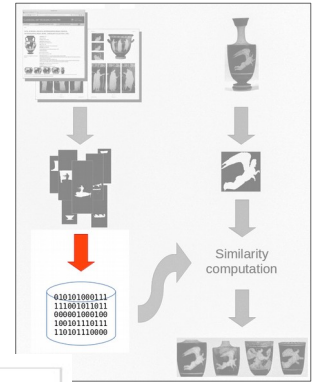
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Silhouette Descriptor

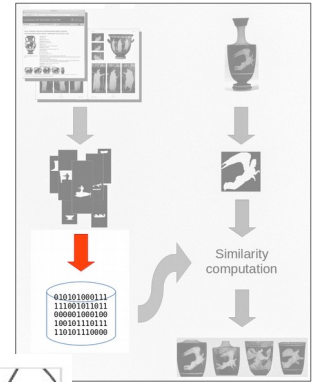
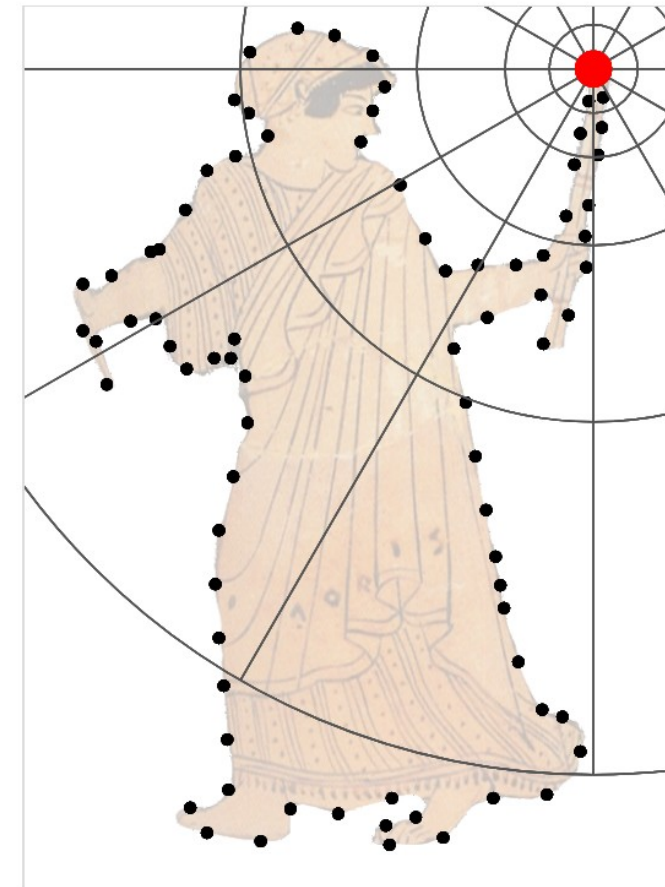
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Silhouette Descriptor

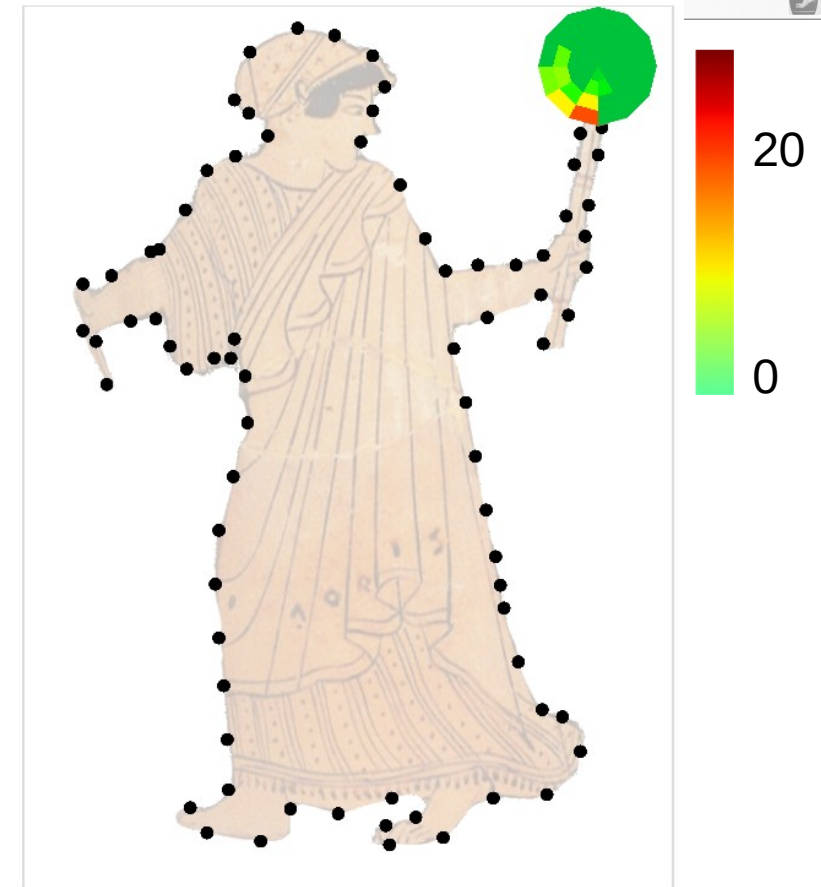
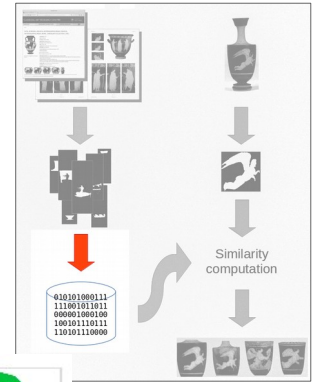
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^[3]Belongie, Serge, Jitendra Malik, and Jan Puzicha. "Shape matching and object recognition using shape contexts." *IEEE transactions on pattern analysis and machine intelligence* 24.4 (2002): 509-522.

Silhouette Descriptor

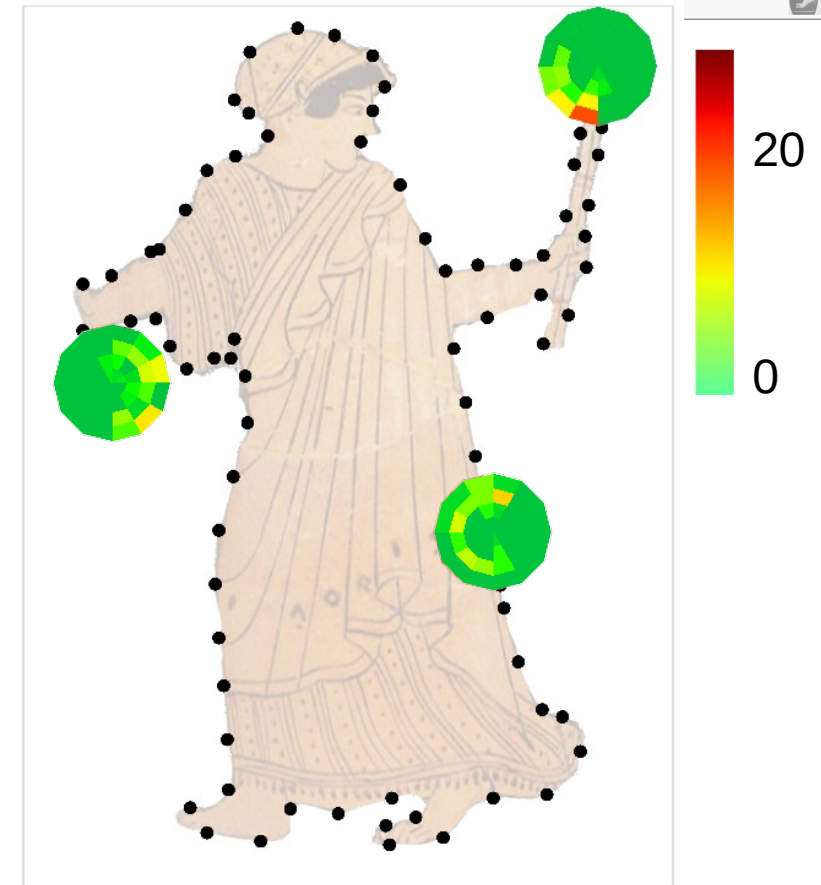
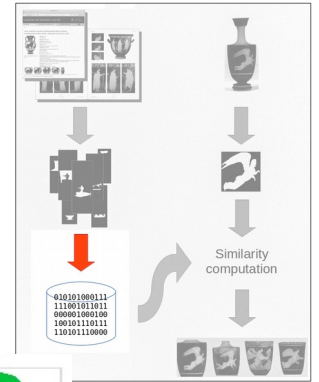
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1. Silhouette sampling

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- For each point:
 1. Determine direction and distance to all other points
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 3. Normalize



Silhouette Descriptor

Shape Contexts Descriptor^[3]

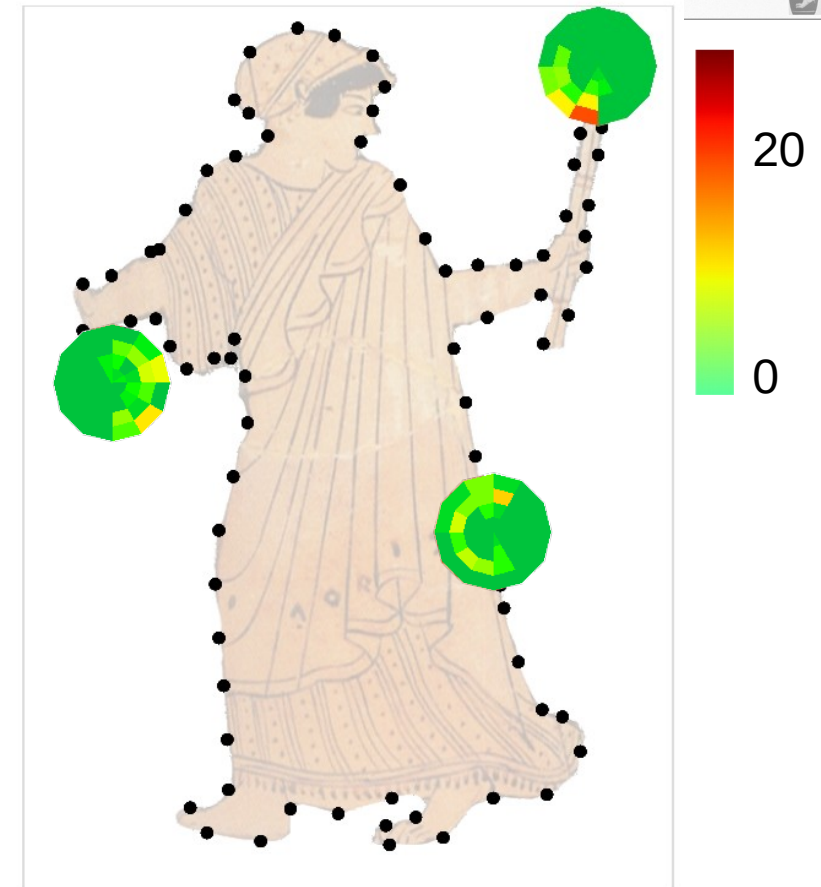
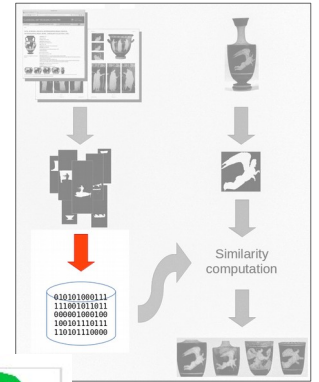
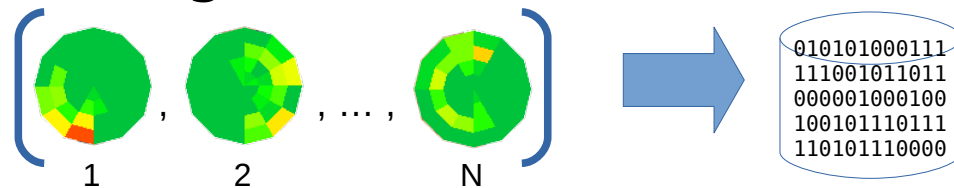
1. Silhouette sampling

- Silhouette approximation with a fixed number of points N

2. Histogram computation

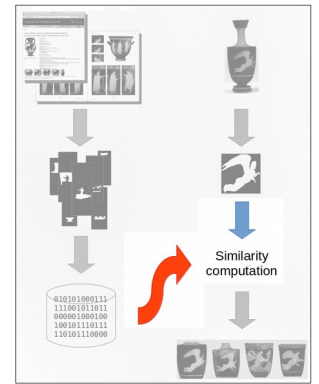
- For each point:
 1. Determine direction and distance to all other points
 2. Sort into radial and angular bins
 3. Normalize

3. Insert histograms vector into database

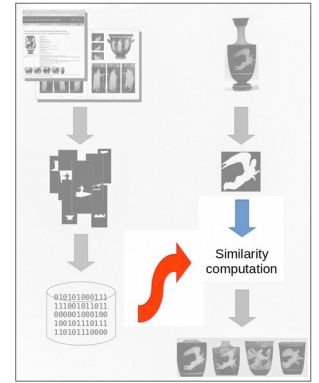


Similarity Computation

- Compare of every silhouette of the search space to the query silhouette given by the histograms $\{q_i\}$
- For each target silhouette, given by the histograms $\{t_j\}$:
 - 1) Find optimal assignment^[3] π of all q_i to t_j



Similarity Computation



- Compare of every silhouette of the search space to the query silhouette given by the histograms $\{q_i\}$
- For each target silhouette, given by the histograms $\{t_j\}$:
 - Find optimal assignment^[3] π of all q_i to t_j
 - Compute overall assignment costs

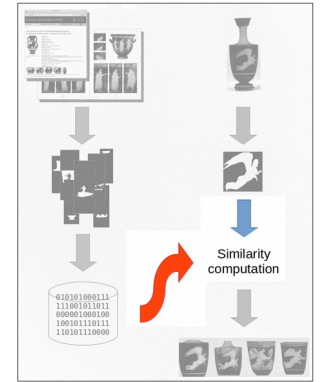
$$H(\pi) = \sum_i C(q_i, t_{\pi(i)})$$

$$H\left(\begin{array}{c} \text{Running silhouette} \end{array}, \begin{array}{c} \text{Running silhouette} \end{array}\right) \approx 0$$

$$H\left(\begin{array}{c} \text{Running silhouette} \end{array}, \begin{array}{c} \text{Running silhouette (rotated)} \end{array}\right) > 0$$

$$H\left(\begin{array}{c} \text{Running silhouette} \end{array}, \begin{array}{c} \text{Standing silhouette} \end{array}\right) \gg 0$$

Similarity Computation



- Compare of every silhouette of the search space to the query silhouette given by the histograms $\{q_i\}$
- For each target silhouette, given by the histograms $\{t_j\}$:

- Find optimal assignment^[3] π of all q_i to t_j
- Compute overall assignment costs

$$H(\pi) = \sum_i C(q_i, t_{\pi(i)})$$

- Similarity of query and target $\propto H^{-1}$
- Ranking of search space silhouettes according to similarity

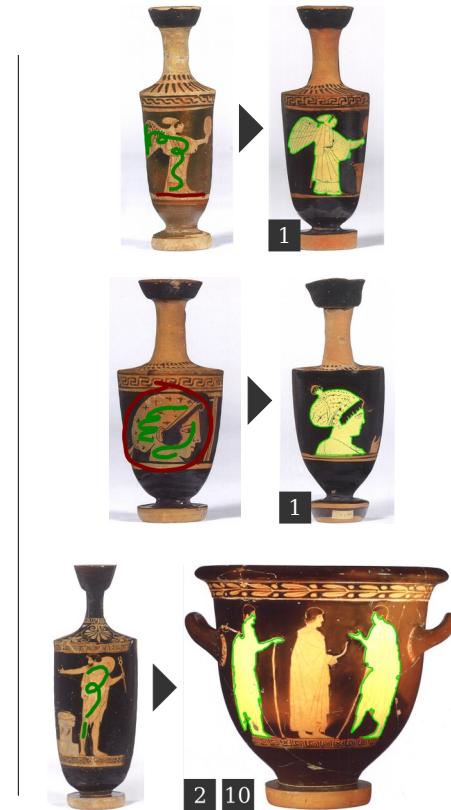
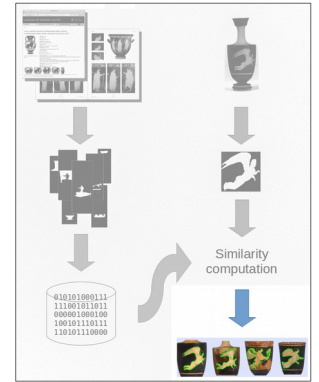
$$H\left(\begin{array}{c} \text{Query Silhouette} \\ \text{(Person Running)} \end{array}, \begin{array}{c} \text{Target Silhouette} \\ \text{(Person Running)} \end{array}\right) \approx 0$$

$$H\left(\begin{array}{c} \text{Query Silhouette} \\ \text{(Person Running)} \end{array}, \begin{array}{c} \text{Target Silhouette} \\ \text{(Person Running, Different Pose)} \end{array}\right) > 0$$

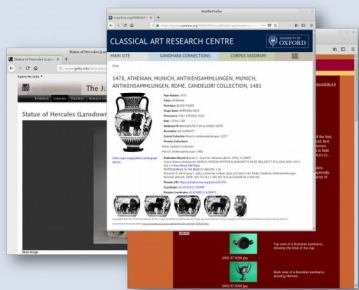
$$H\left(\begin{array}{c} \text{Query Silhouette} \\ \text{(Person Running)} \end{array}, \begin{array}{c} \text{Target Silhouette} \\ \text{(Person with Sword)} \end{array}\right) \gg 0$$

Experimental Evaluation

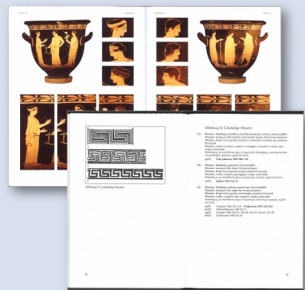
Proof of concept with queries taken from the search space



Sources



Repositories

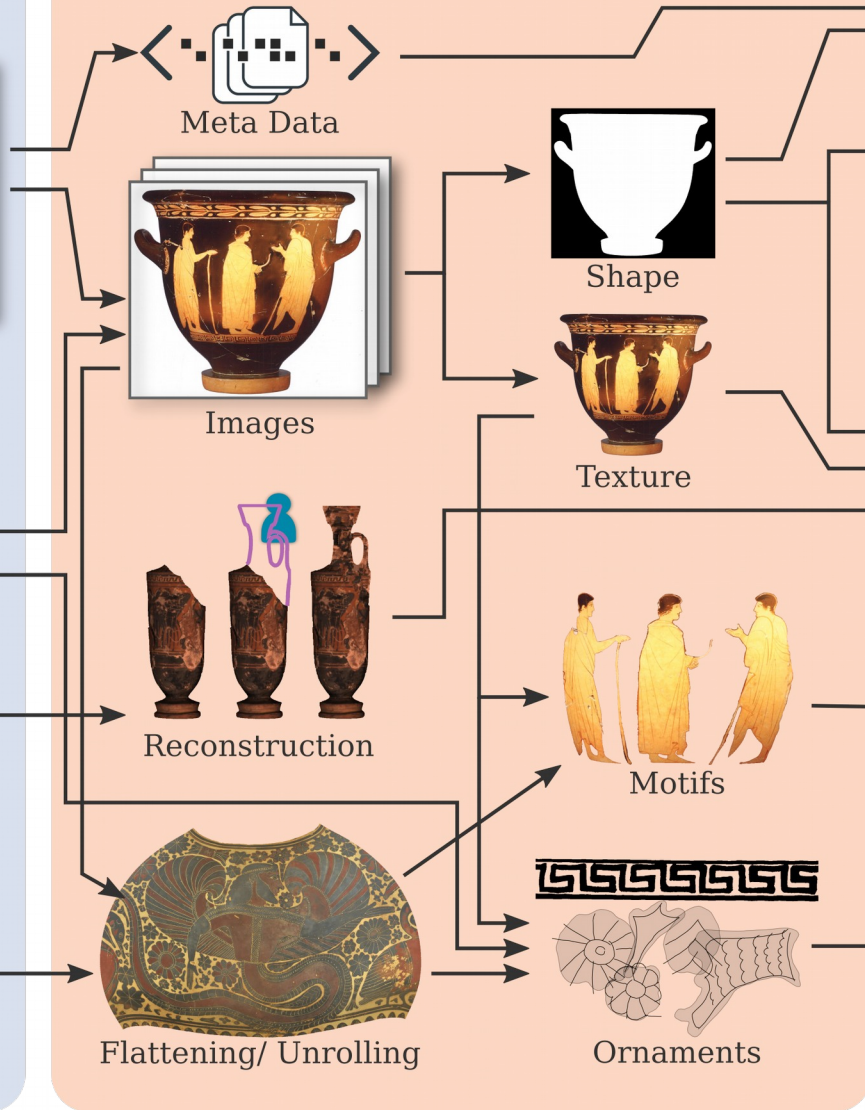


Volumes



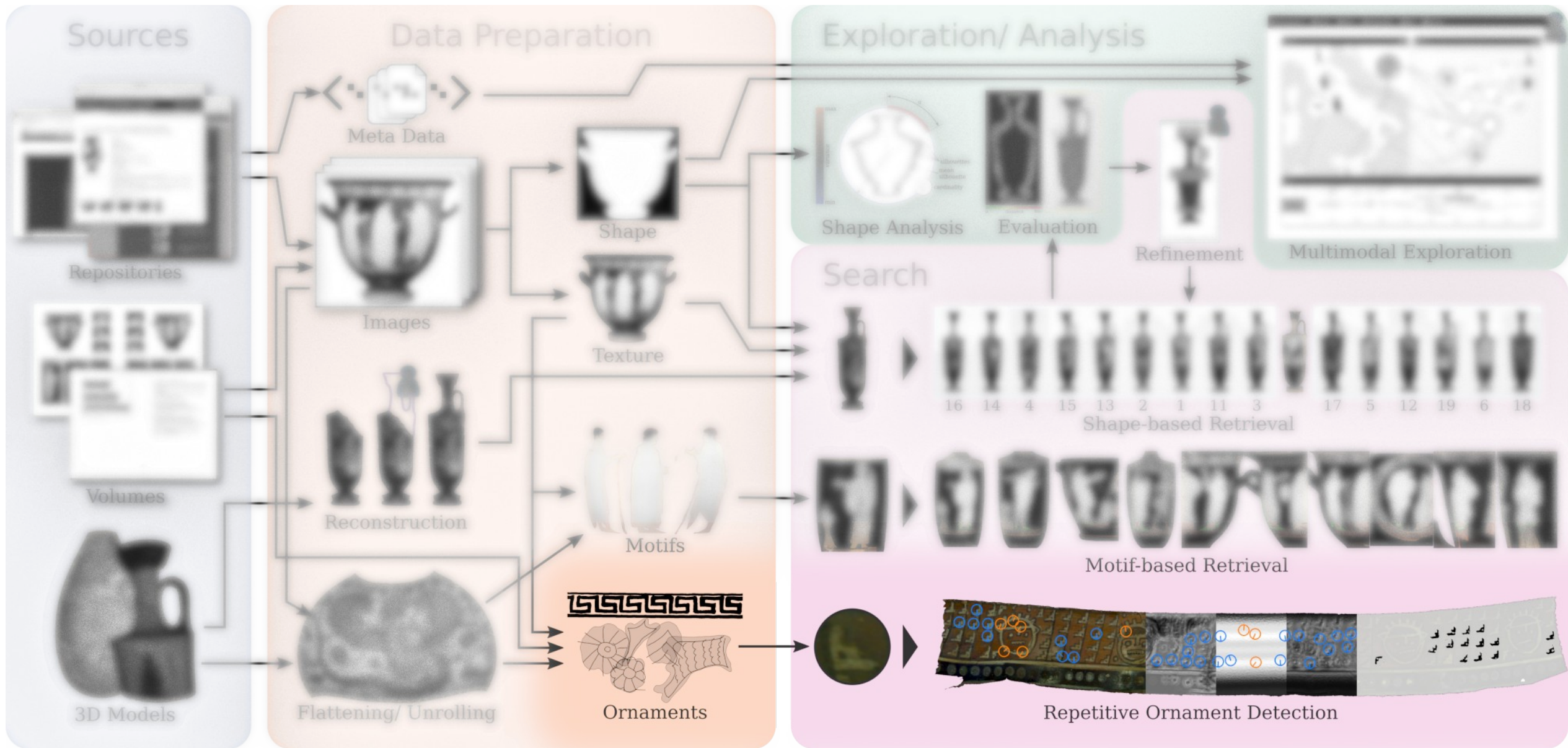
3D Models

Data Preparation



Exploration/ Analysis





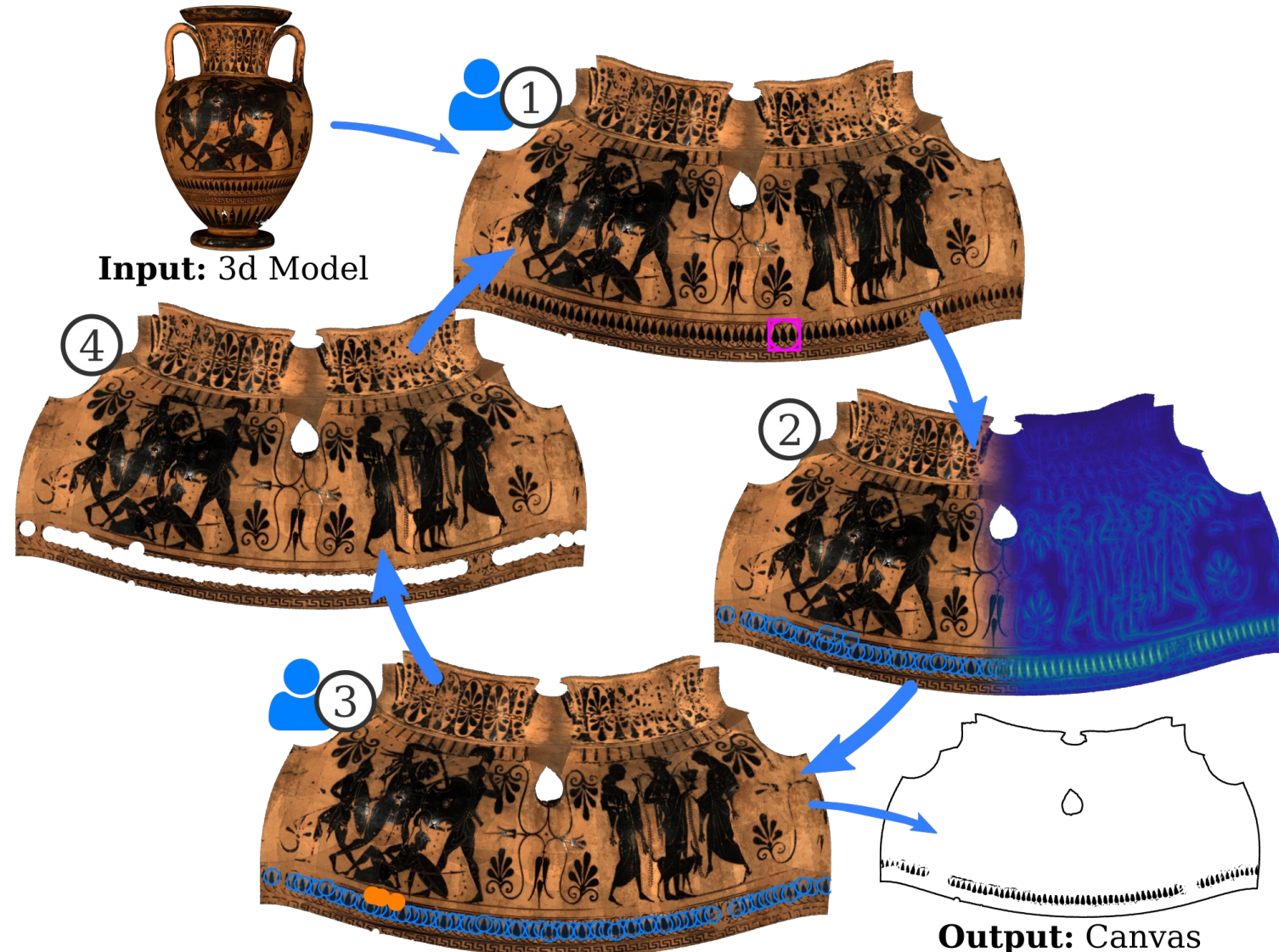
Workflow

Input: 3d model

Iterative dissection of the flattened^[1] surface:

- 1) Query selection
- 2) Self-similarity detection
- 3) Results refinement
- 4) Surface subtraction

Output: 'Canvas' with detected and extracted ornaments



Self-similarity Detection



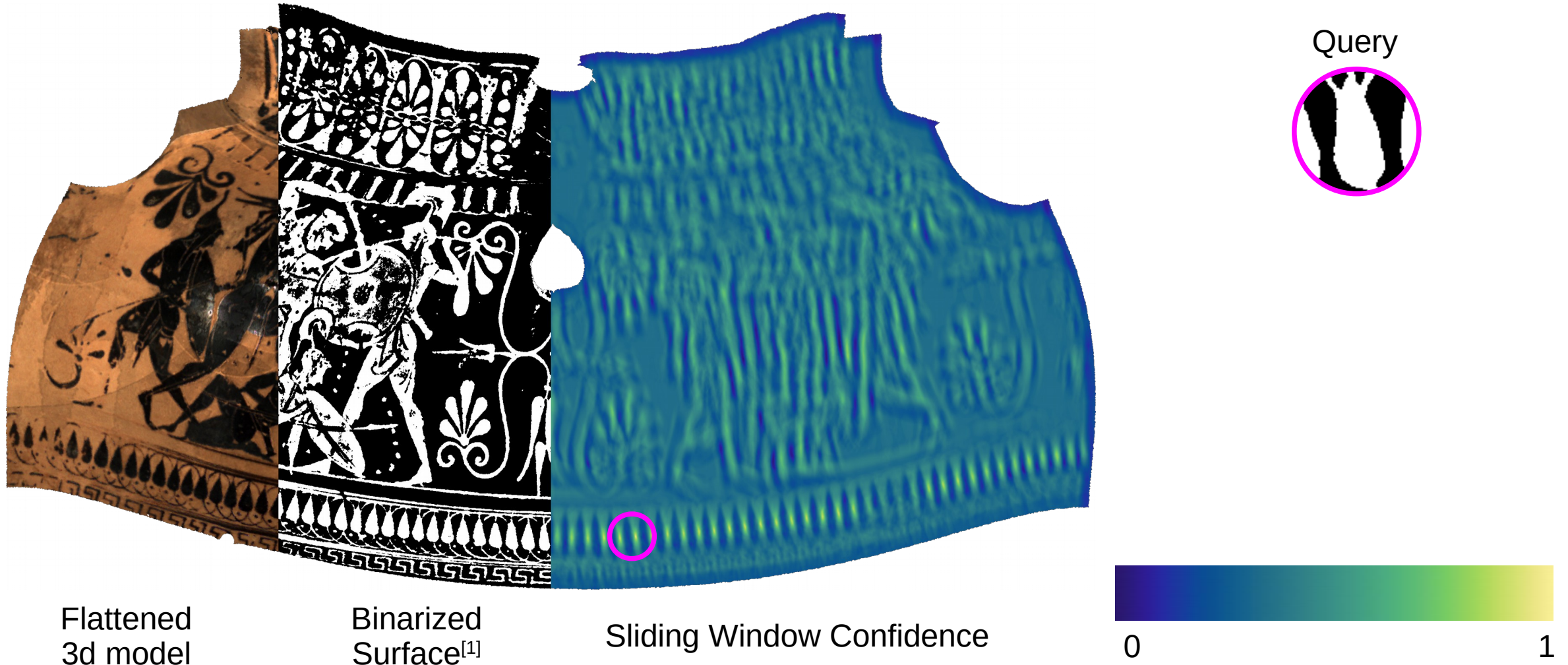
Flattened
3d model

Self-similarity Detection



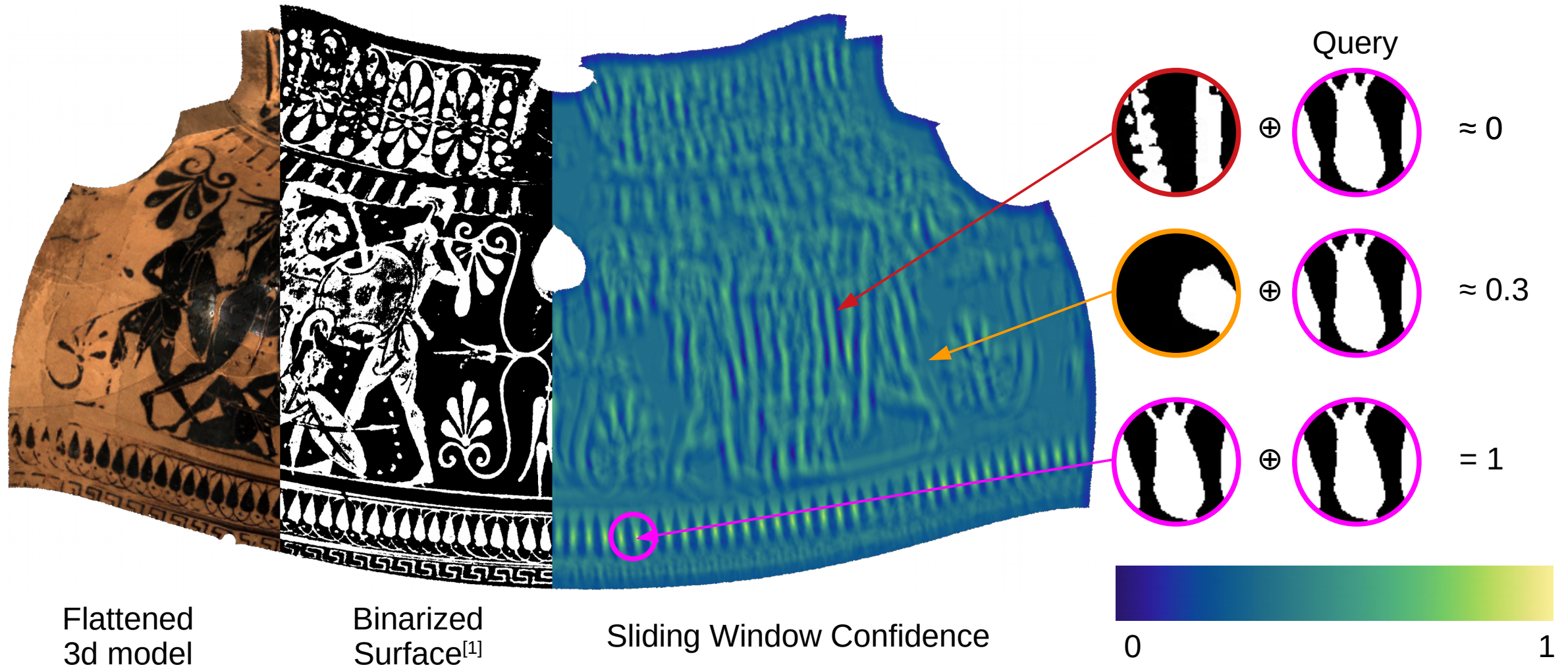
Flattened
3d model

Self-similarity Detection



^[1]Singh, T.R., Roy, S., Singh, O.I., Sinam, T. and Singh, K., 2012. A new local adaptive thresholding technique in binarization. arXiv preprint arXiv:1201.5227.

Self-similarity Detection



^[1]Singh, T.R., Roy, S., Singh, O.I., Sinam, T. and Singh, K., 2012. A new local adaptive thresholding technique in binarization. *arXiv preprint arXiv:1201.5227*.

Self-similarity Detection

- Rotation invariance required



Alternating orientation of ornaments



Flattening-induced distortions

Self-similarity Detection

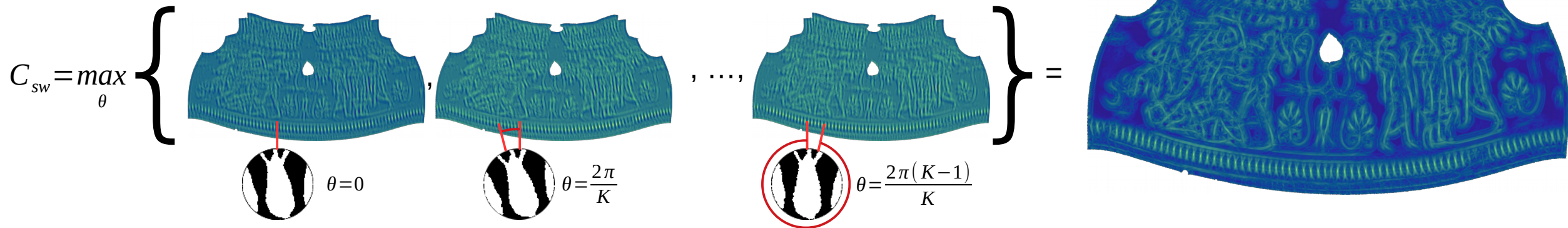
- Rotation invariance required



Alternating orientation of ornaments



Flattening-induced distortions



Self-similarity Detection

- Non Maximum Suppression (NMS)



Query

Self-similarity Detection

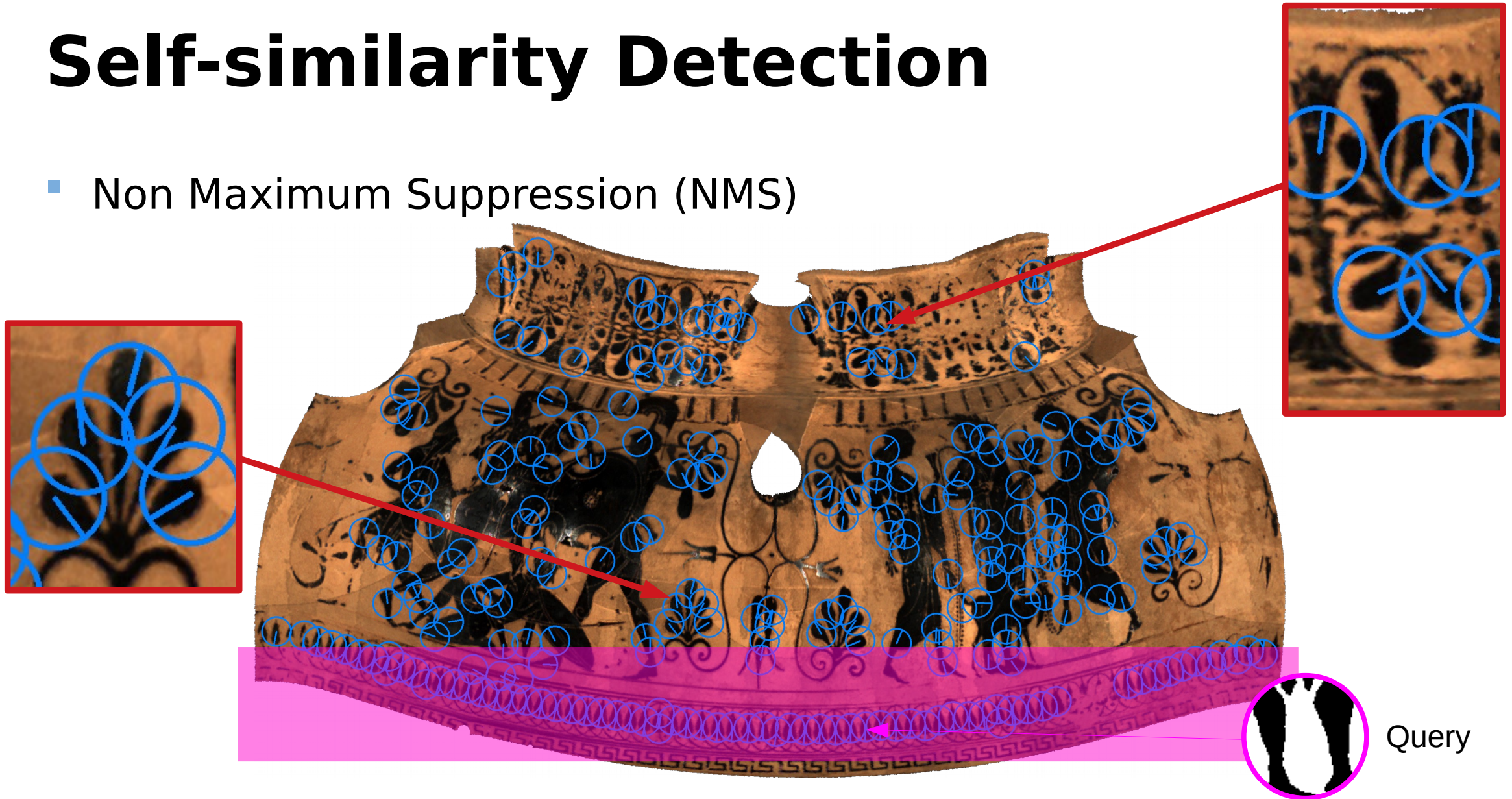
- Non Maximum Suppression (NMS)



Query

Self-similarity Detection

- Non Maximum Suppression (NMS)



Query

Refinement with Isohypsese Map

- **Assumption:** Repeating ornaments are arranged in ornamental bands around the rotational axis of the solid of revolution.

Refinement with Isohypsese Map

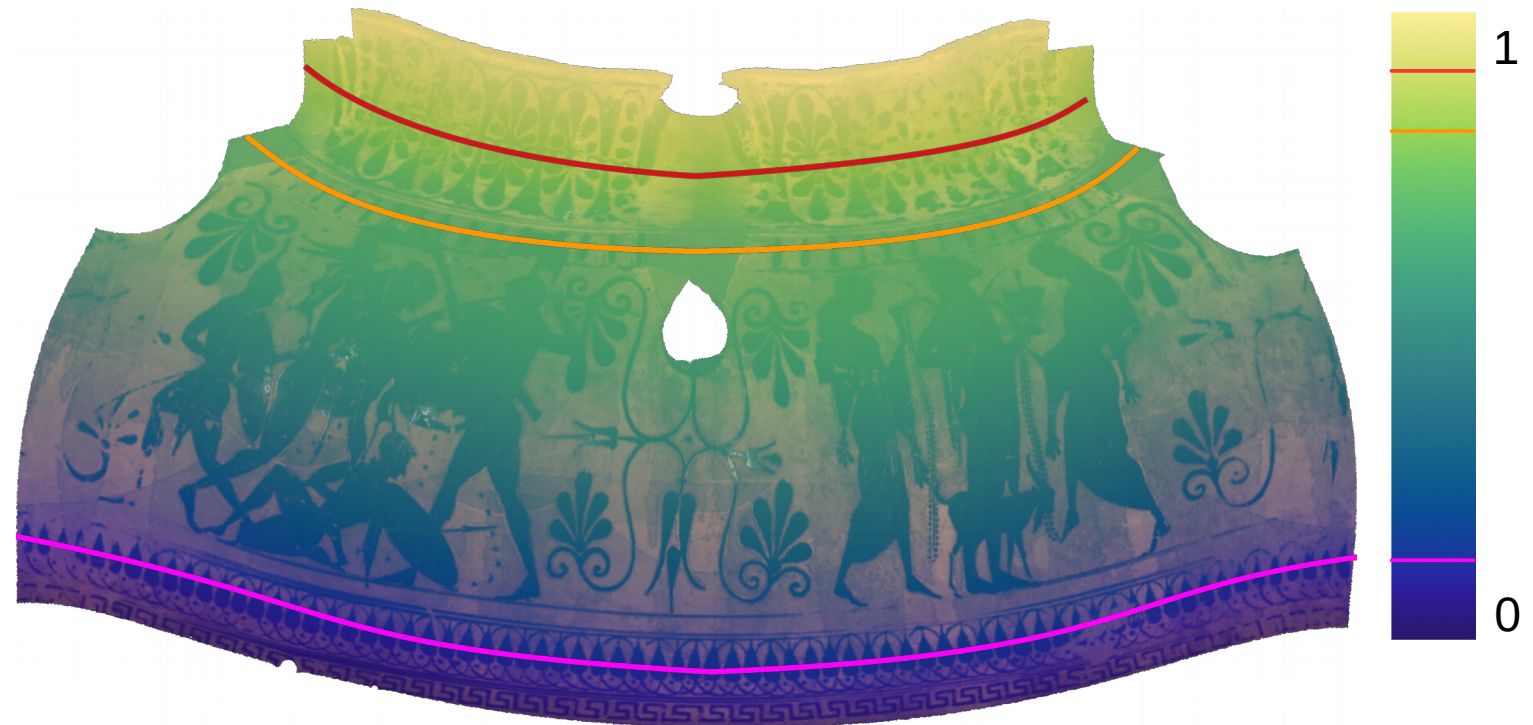
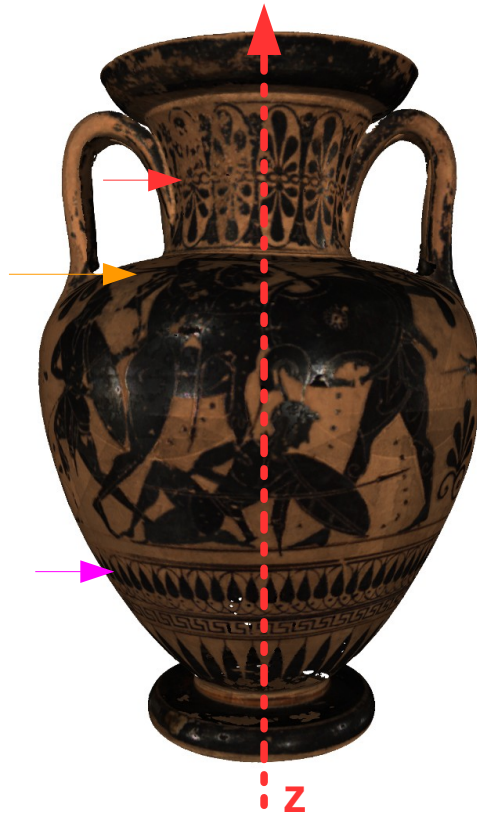
- **Assumption:** Repeating ornaments are arranged in ornamental bands around the rotational axis of the solid of revolution.



Isohypsese Mapping

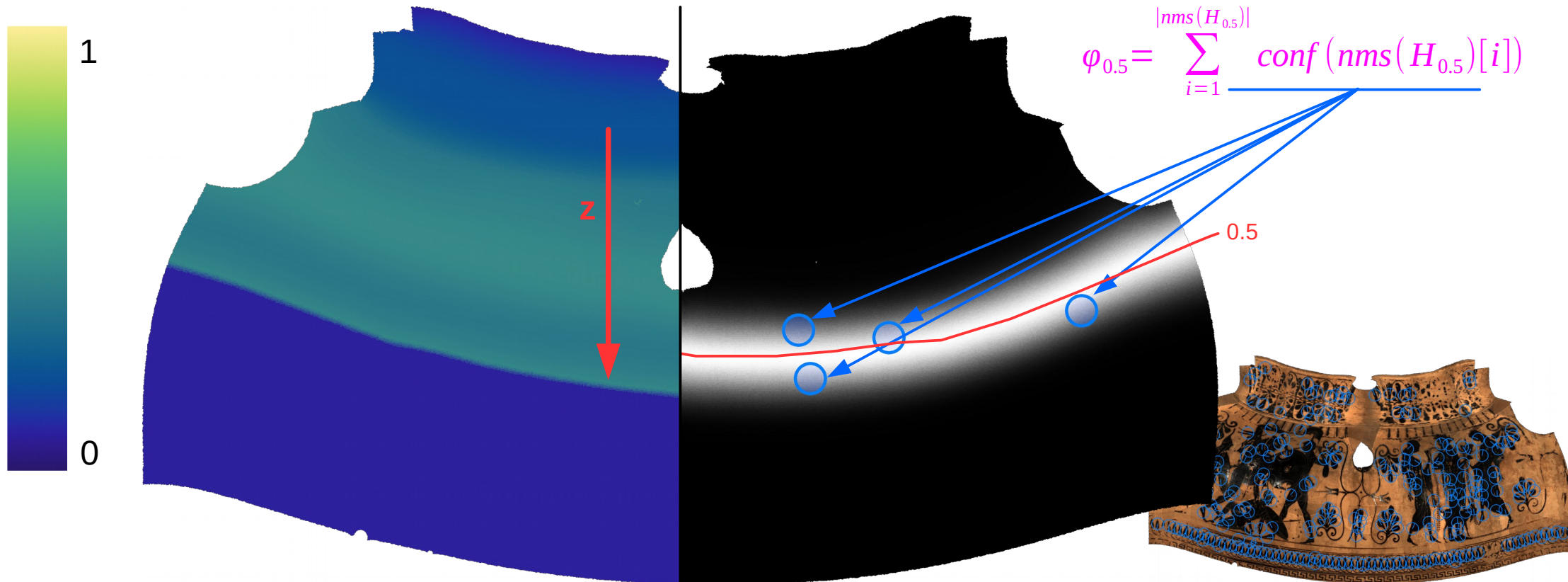
Refinement with Isohypsese Map

- **Assumption:** Repeating ornaments are arranged in ornamental bands around the rotational axis of the solid of revolution.



Isohypsese Mapping

Refinement with Isohypses Map



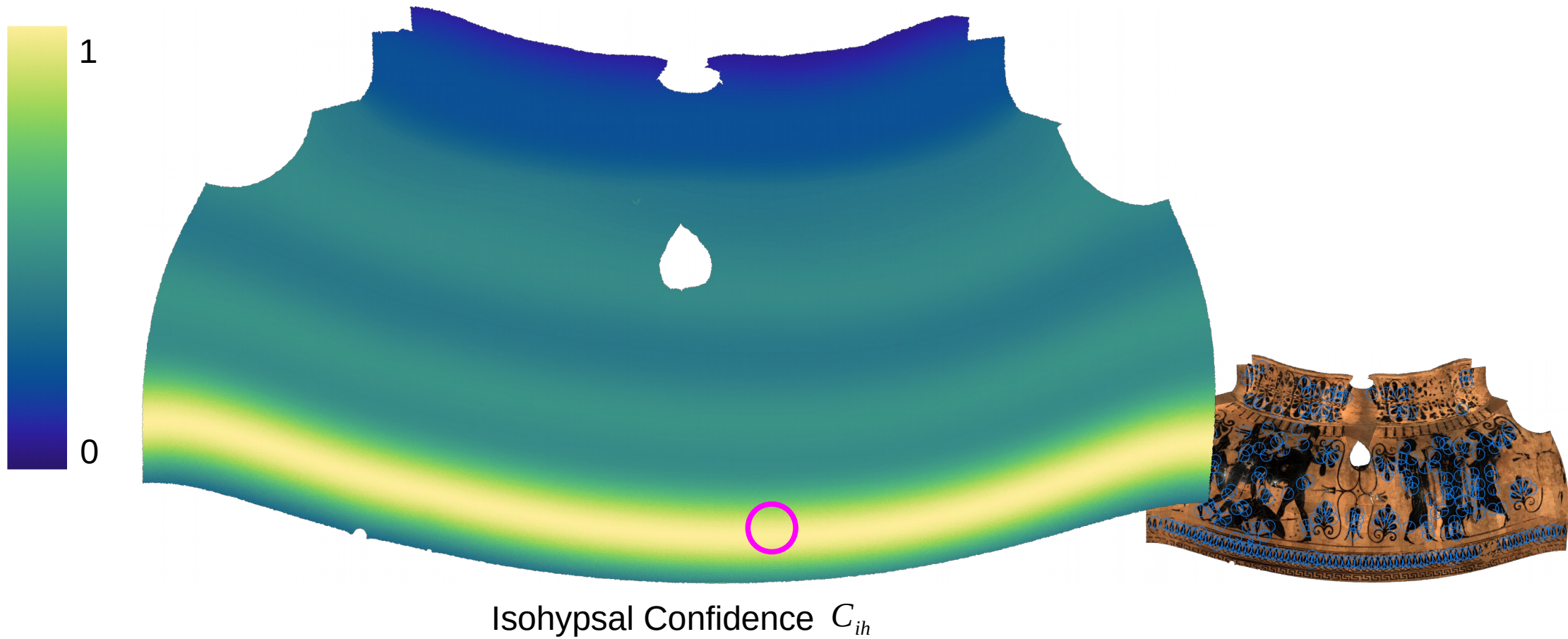
Weighted Candidates

$$\varphi_{0.5} = \frac{\sum_{i=1}^{|nms(H_{0.5})|} conf(nms(H_{0.5})[i])}{|nms(H_{0.5})|}$$

Ishoypsal Confidence $C_{ih} = \sum H_z \varphi_z$

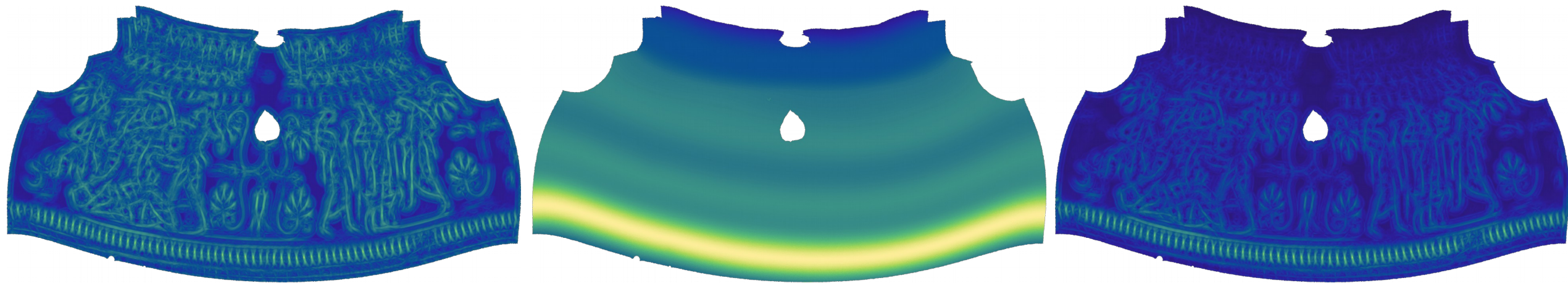
Ishoypsal Mask $H_{0.5} = N(0.5, \sigma^2)$

Refinement with Isohypses Map



Refinement with Isohypses Map

- Refined confidence map results from element-wise multiplication of sliding-window and isohypsal confidence



Sliding Window Confidence C_{sw} \odot

Isohypsal Confidence C_{ih} =

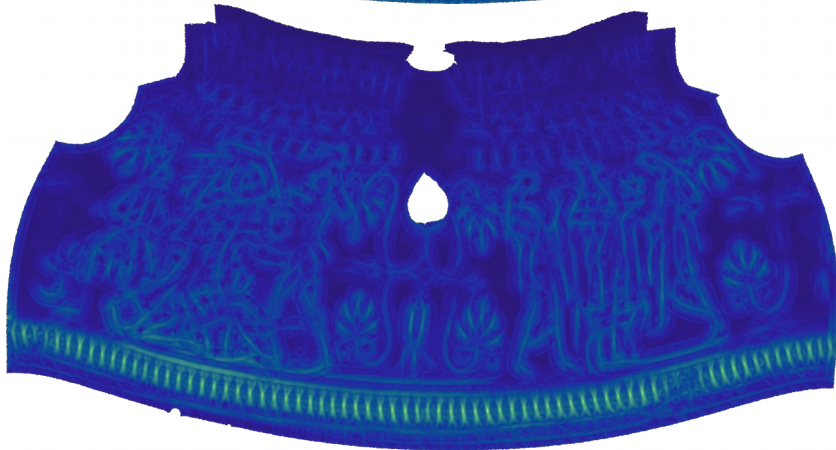
Combined confidence C

Refinement with Isohypsese Map

Sliding Window
Confidence



Combined
Confidence



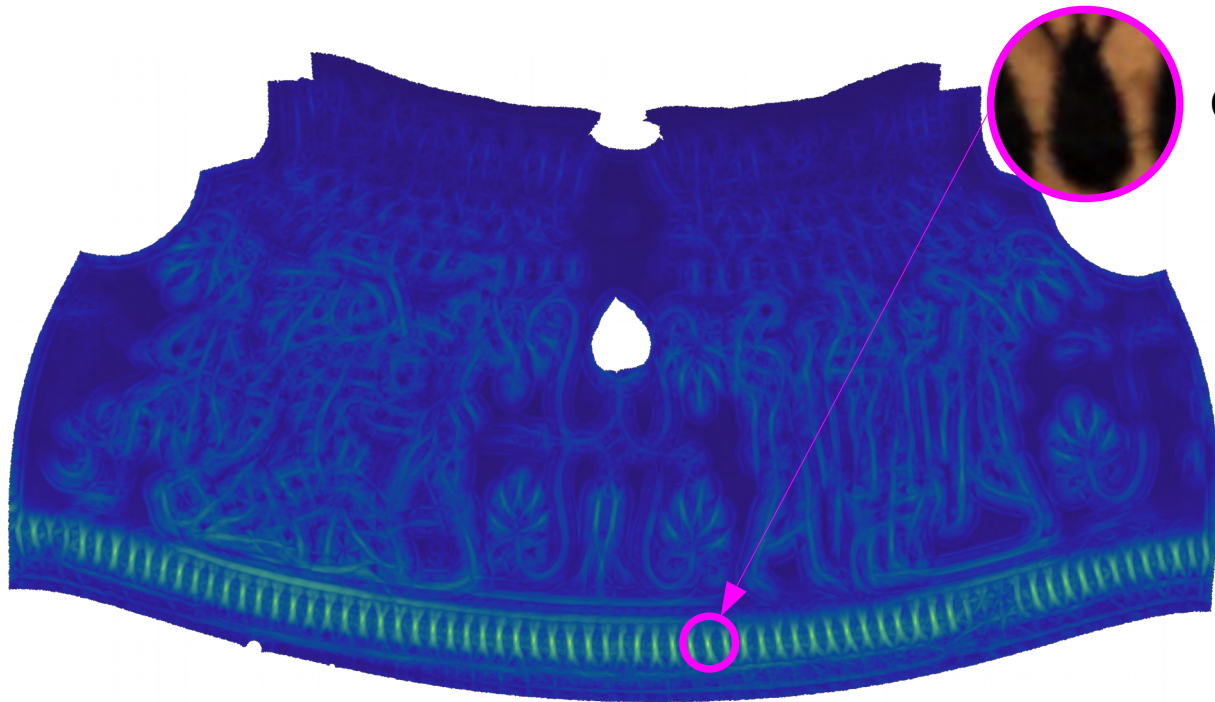
Confidence Maps

Candidates after NMS

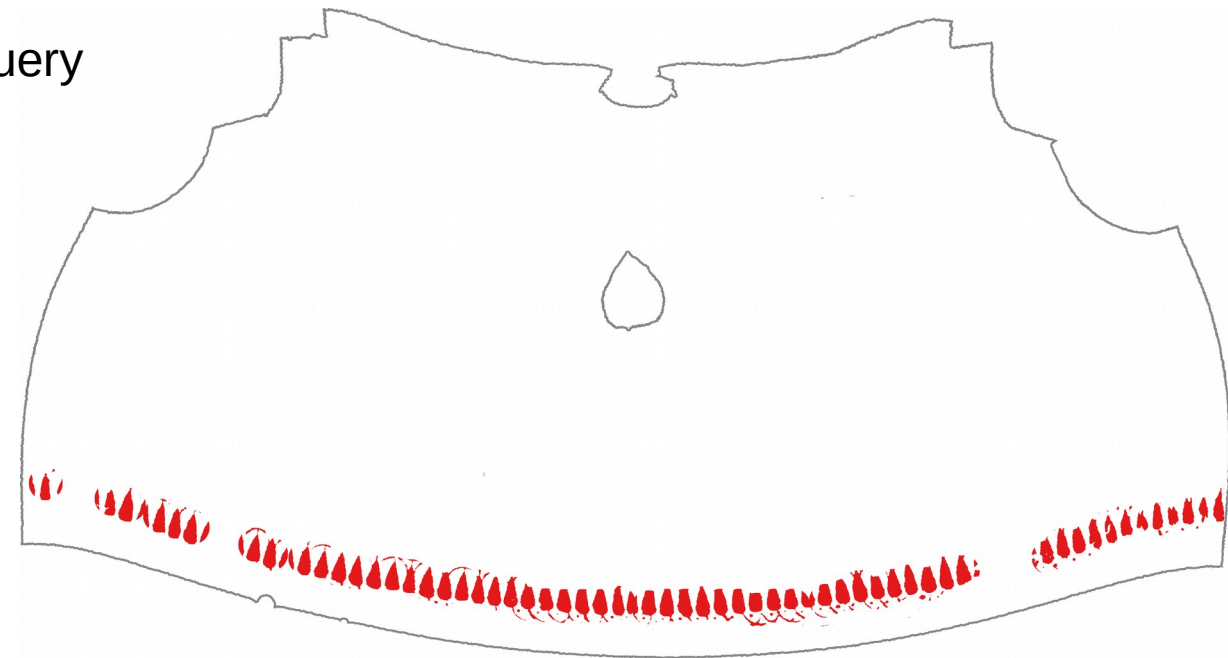
Experimental Results

Experimental Results

- Attic black-figured amphora (Kunsthistorisches Museum, Vienna)



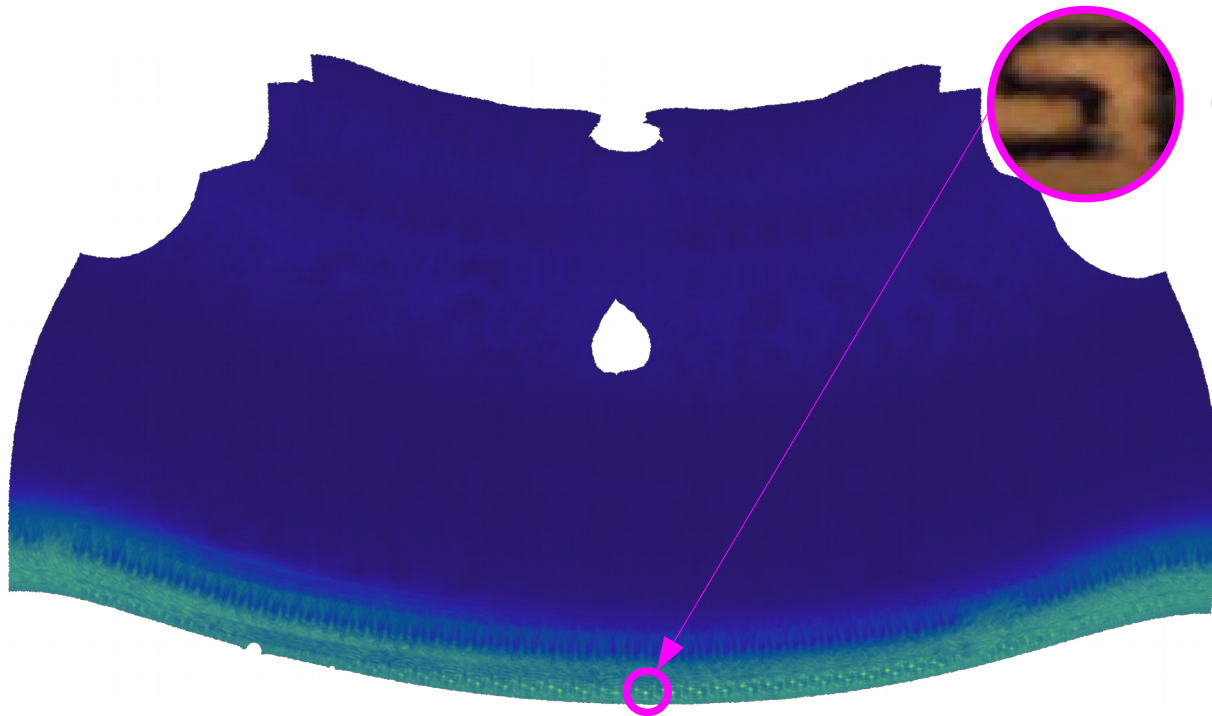
Combined Confidence



Canvas

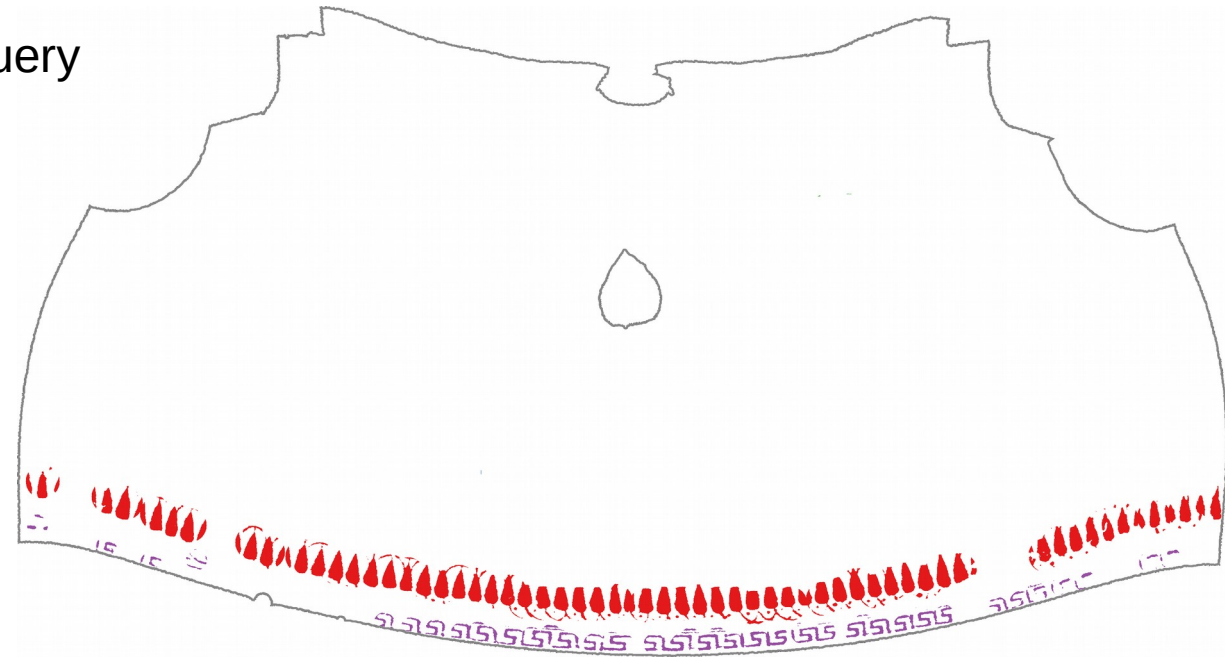
Experimental Results

- Attic black-figured amphora (Kunsthistorisches Museum, Vienna)



Combined Confidence

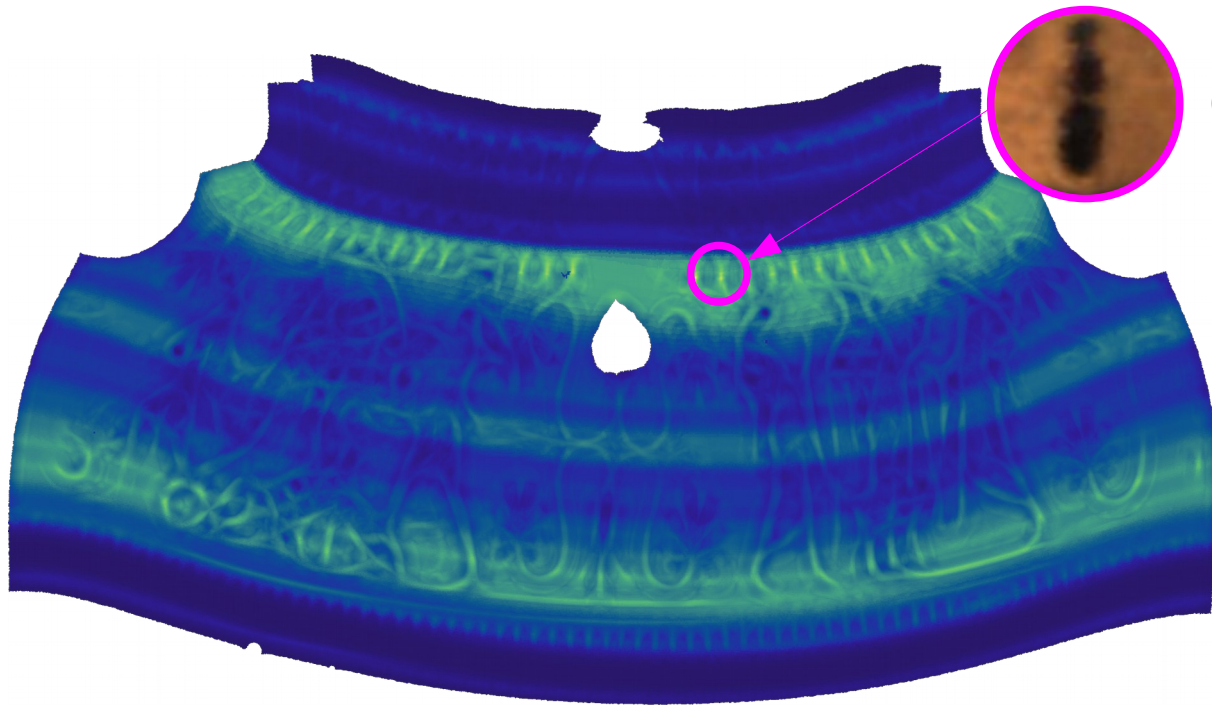
Query



Canvas

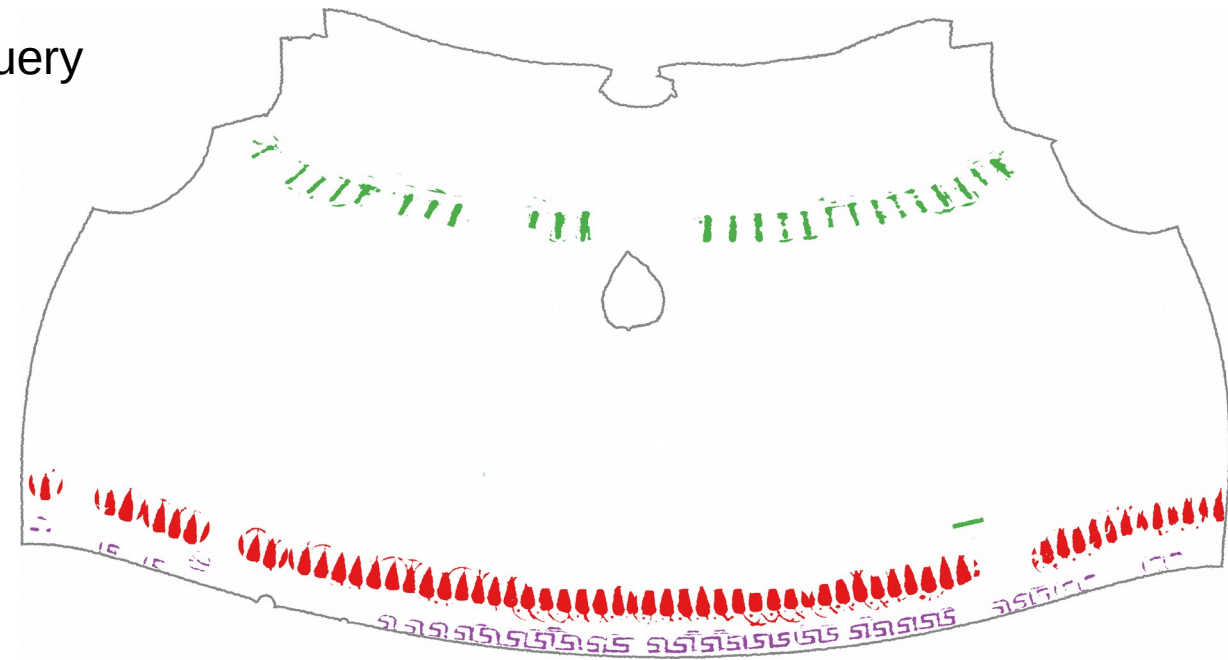
Experimental Results

- Attic black-figured amphora (Kunsthistorisches Museum, Vienna)



Combined Confidence

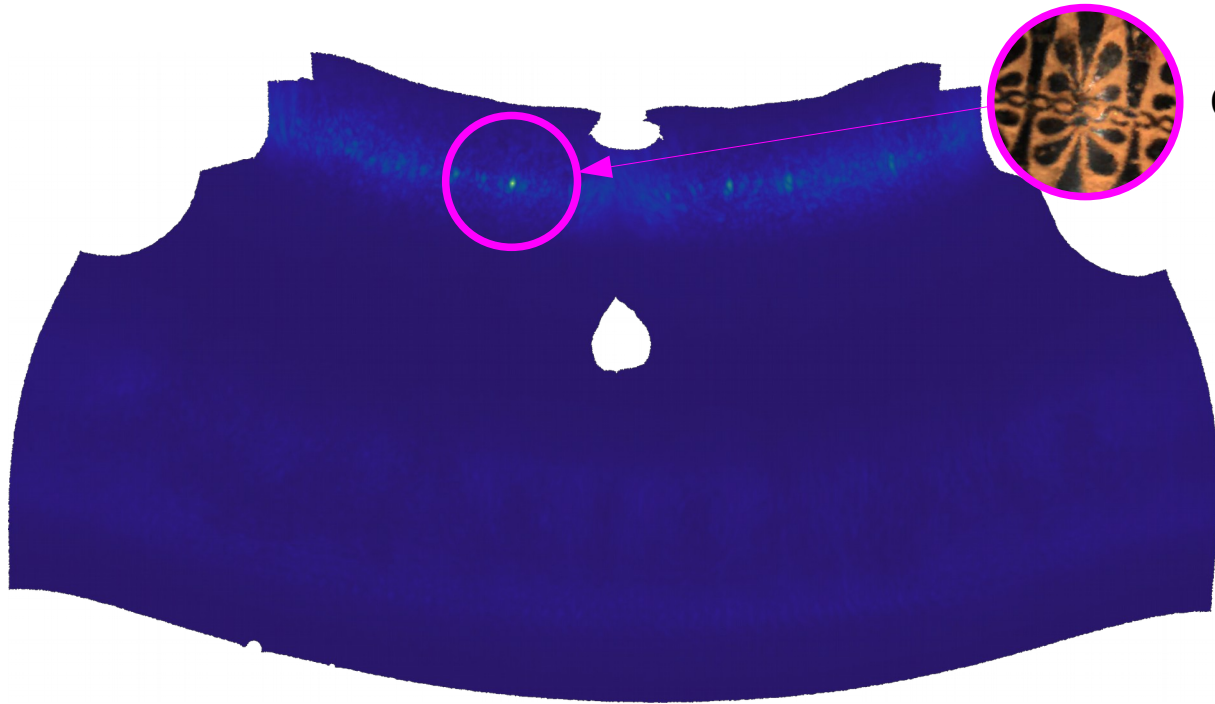
Query



Canvas

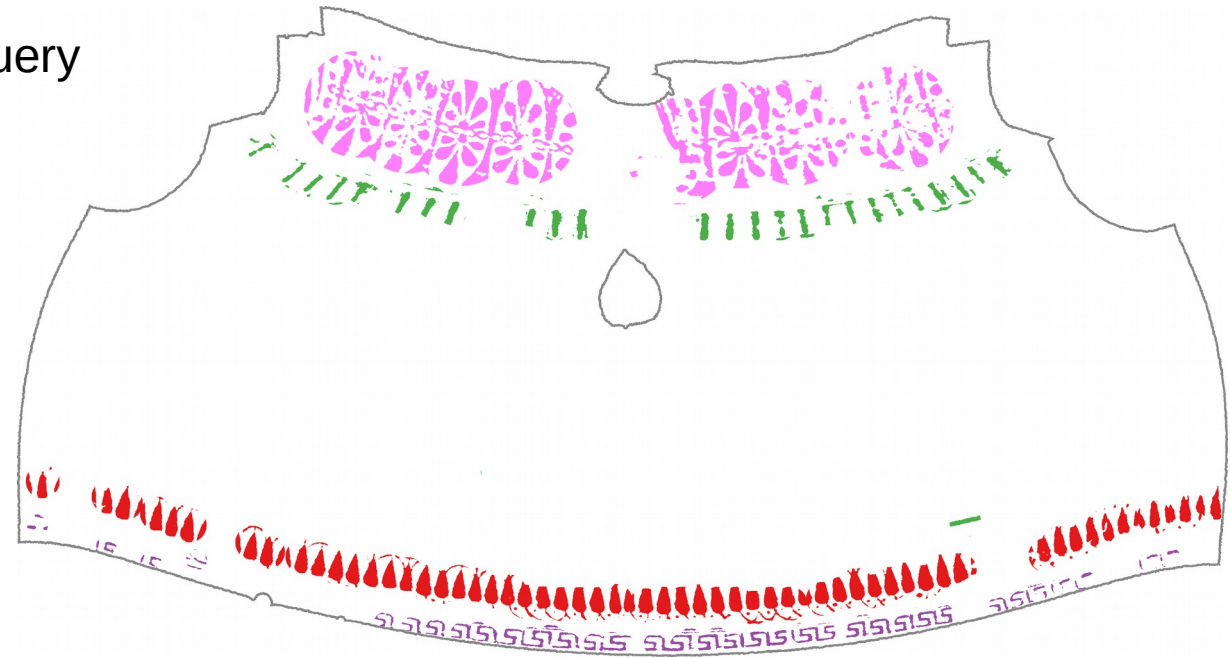
Experimental Results

- Attic black-figured amphora (Kunsthistorisches Museum, Vienna)



Combined Confidence

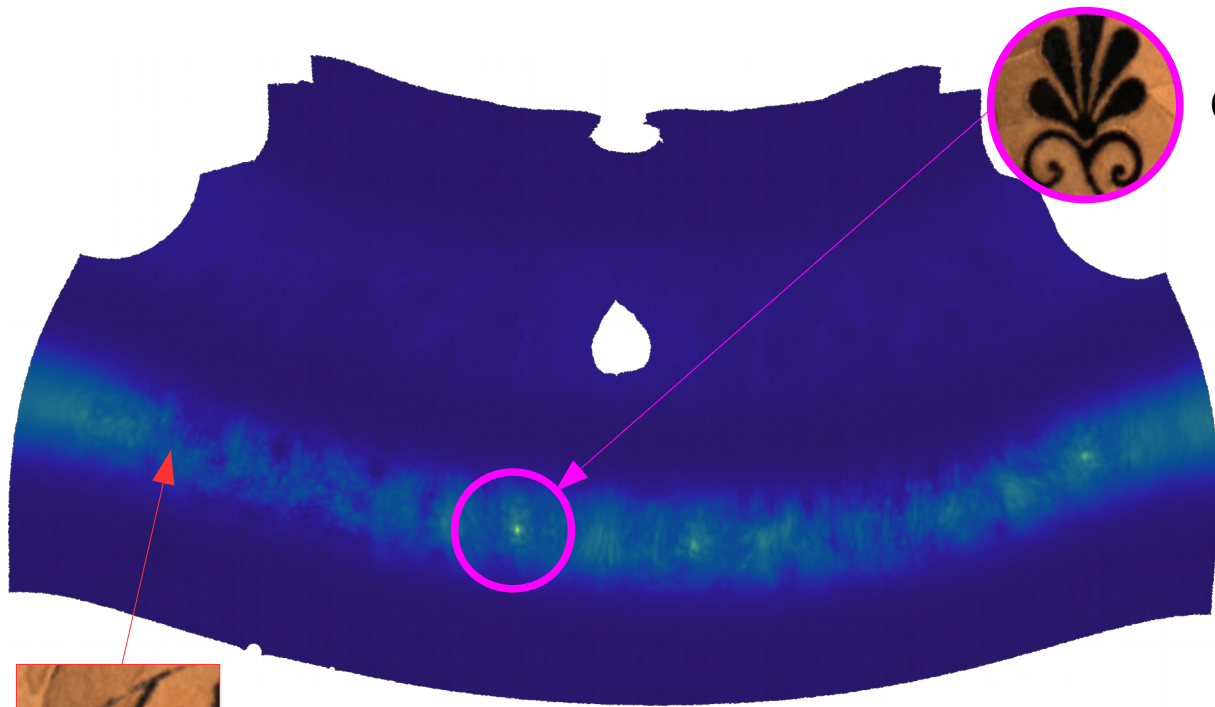
Query



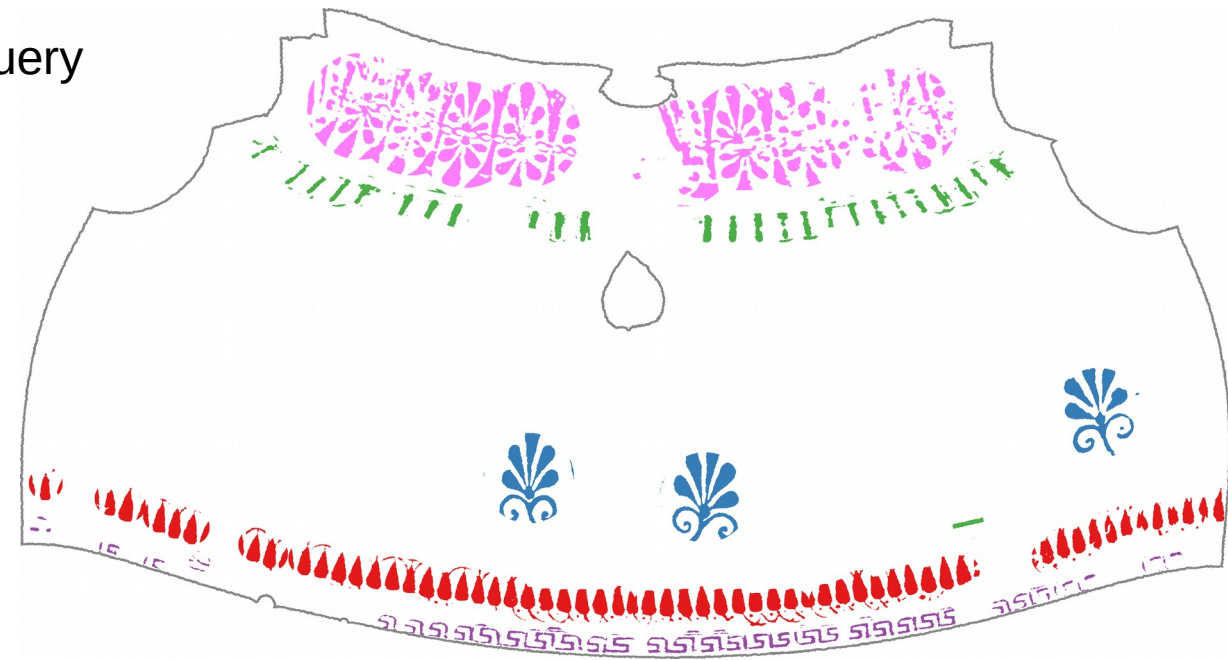
Canvas

Experimental Results

- Attic black-figured amphora (Kunsthistorisches Museum, Vienna)



Combined Confidence



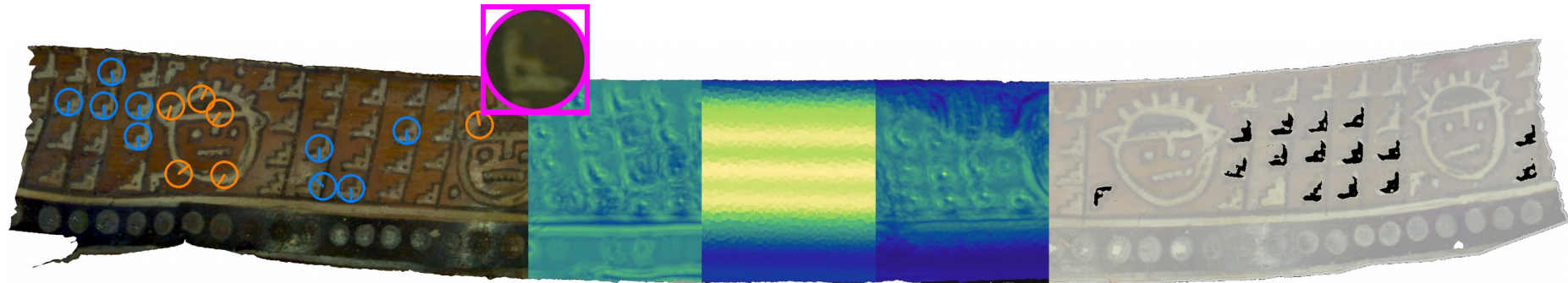
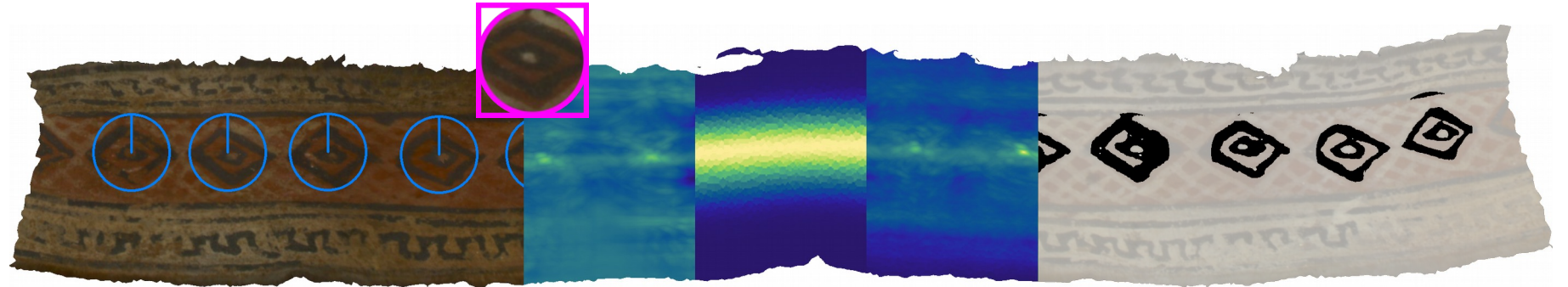
Canvas

Experimental Results

- Pre-Columbian pots (Josefina Ramos de Cox museum, Lima, Peru)

Experimental Results

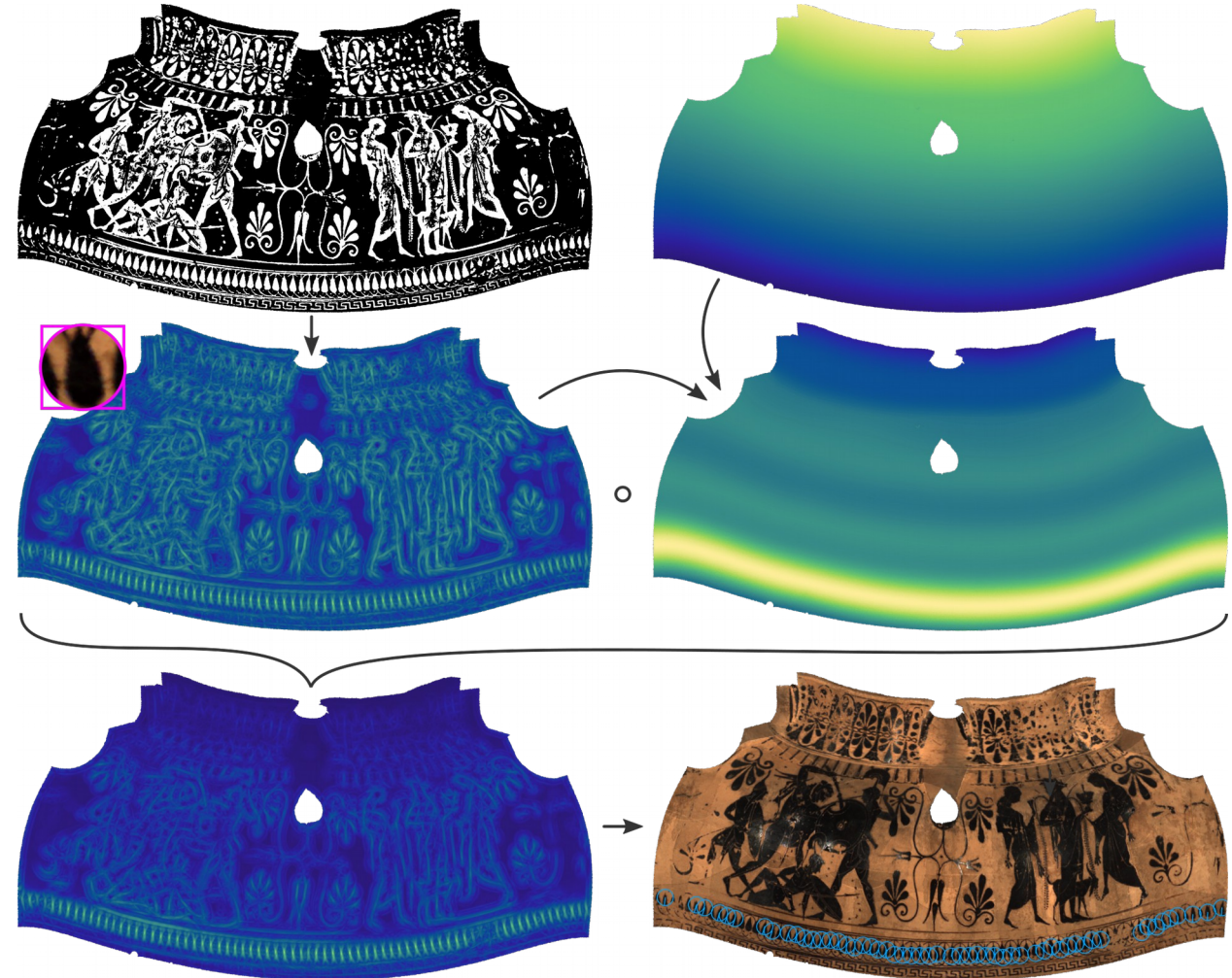
- Pre-Columbian pots (Josefina Ramos de Cox museum, Lima, Peru)



3d model

Flattened Surface $\rightarrow C_{sw} \odot C_{ih} = C \rightarrow$ Resulting Canvas

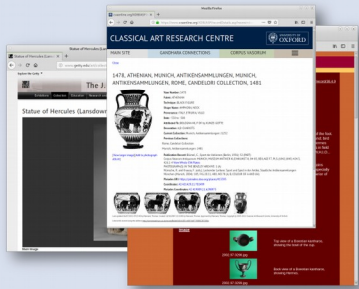
Questions?



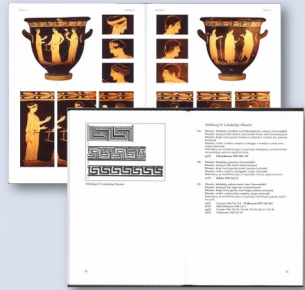
Lengauer, S., Komar, A., Labrada, A., Karl, S., Trinkl, E., Preiner, R., Bustos, B. and Schreck, T., 2019. Motif-driven Retrieval of Greek Painted Pottery. In *Eurographics Workshop on Graphics and Cultural Heritage* (pp. 91-98). Eurographics-European Association for Computer Graphics.

Lengauer, S., Komar, A., Karl, S., Trinkl, E., Sipiran, I., Schreck, T. and Preiner, R., 2020. Semi-automated Annotation of Repetitive Ornaments on 3D Painted Pottery Surfaces. In *Eurographics Workshop on Graphics and Cultural Heritage*. Eurographics Assoc..

Sources



Repositories

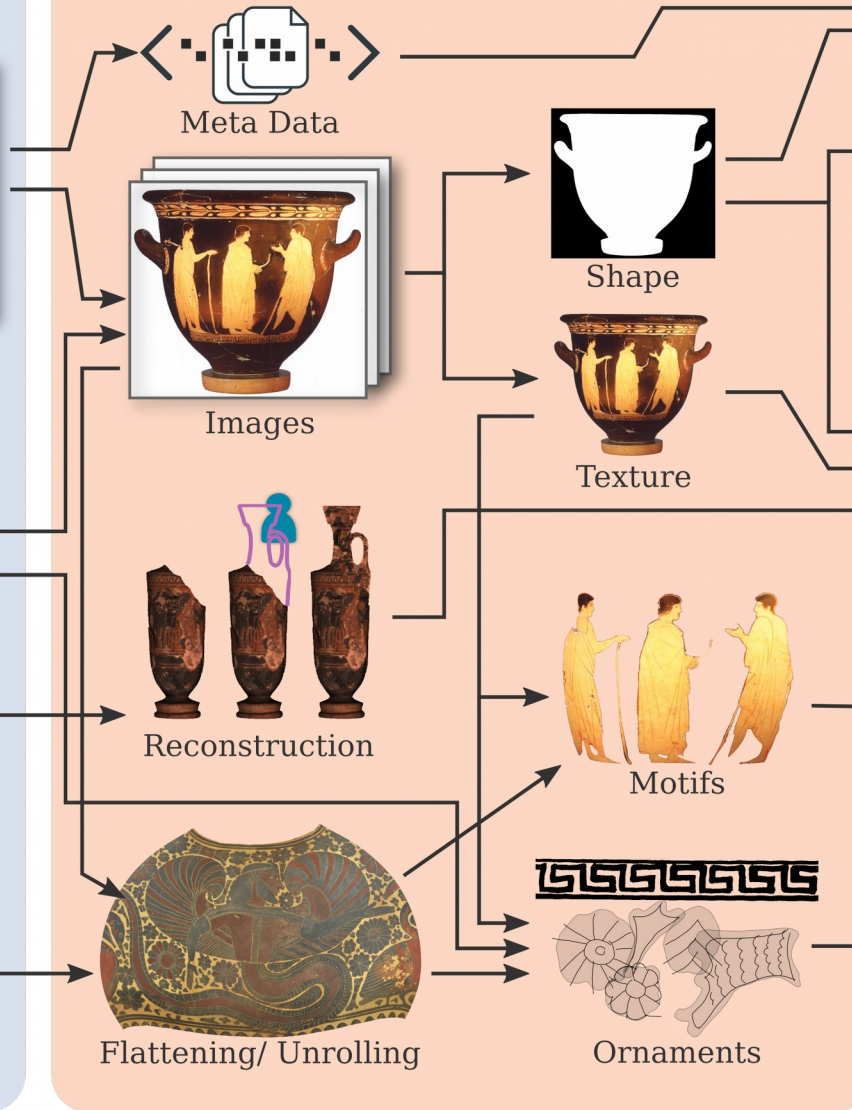


Volumes



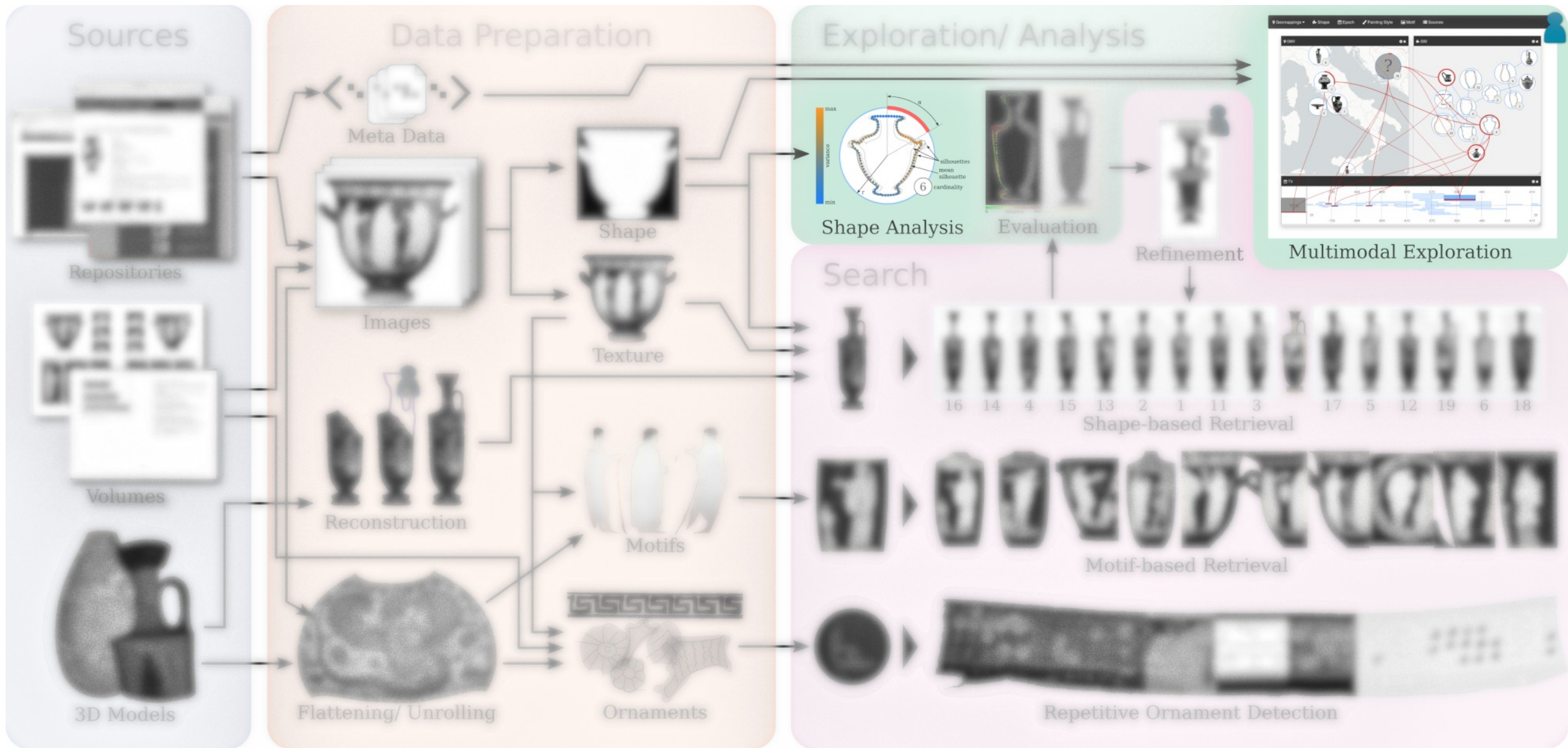
3D Models

Data Preparation



Exploration/ Analysis





Motivation

- Relations of objects along different traits essential for gaining new insights
- Different modalities have to be considered simultaneously
 - Shape
 - Provenance
 - Date
 - Fabric
 - ...
- Established techniques for single modalities




9032359, ATHENIAN, Berlin, Antikensammlung, F2238



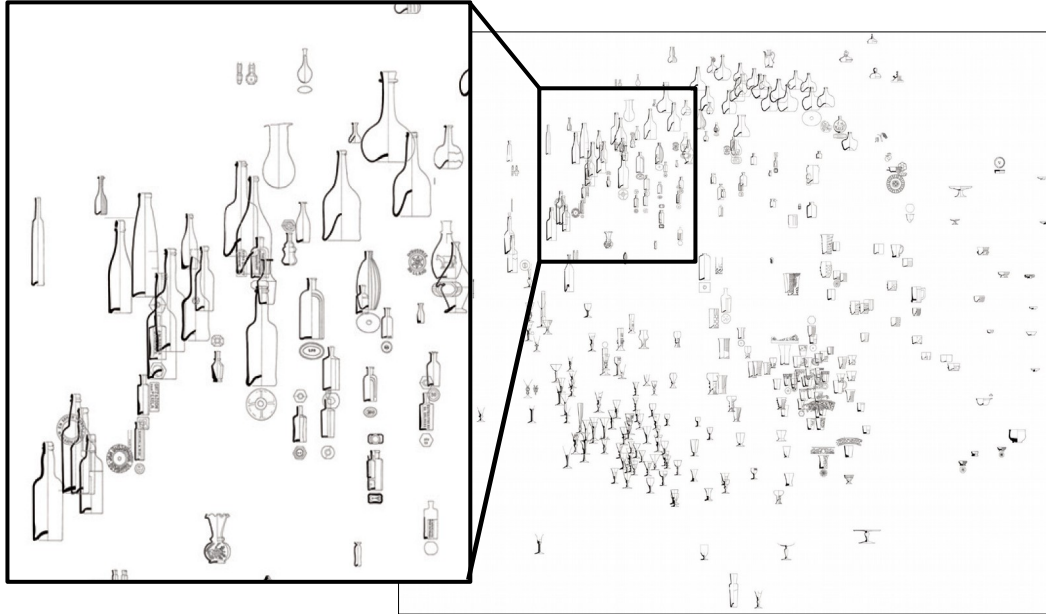
- Vase Number: 9032359
- Fabric: ATHENIAN
- Technique: BLACK GLAZE
- Shape Name: LEKYTHOS
- Provenance: ITALY, NOLA
- Decoration: Body: UNDECORATED
- Current Collection: Berlin, Antikensammlung: F2238
- Publication Record: Corpus Vasorum Antiquorum: BERLIN PL (4548) 55.1-3 [View Whole CVA Plates](#)
- Pleiades URI: <https://pleiades.stoa.org/places/432981>
- Coordinates: 40.930481,14.52847
- Pleiades Coordinates: 40.926823,14.524545

208452, ATHENIAN, Berlin, Antikensammlung, F2225

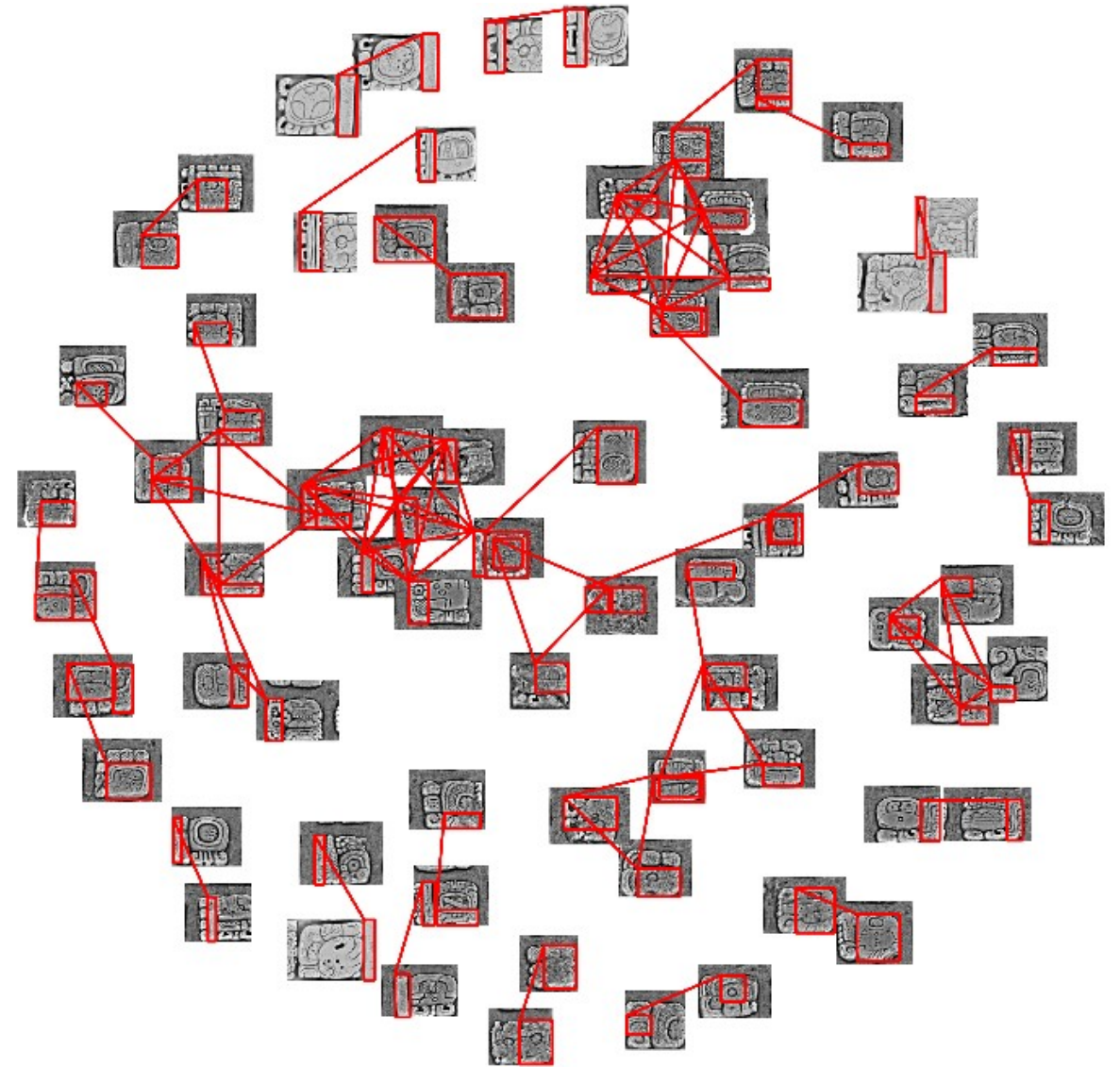


- Vase Number: 208452
- Fabric: ATHENIAN
- Technique: RED-FIGURE
- Shape Name: LEKYTHOS
- Provenance: ITALY, NOLA
- Date: -475 to -425
- Attributed To: SEIRENISKE P by BEAZLEY
- Decoration: Body: NIKE RUNNING TO ALTAR
- Current Collection: Berlin, Antikensammlung: F2225
- Publication Record: Beazley, J.D., Attic Red-Figure Vase-P Corpus Vasorum Antiquorum: BERLIN, ANTIKENSAMMLUNG CVA Plates
- Pleiades URI: <https://pleiades.stoa.org/places/432981>
- Coordinates: 40.930481,14.52847
- Pleiades Coordinates: 40.926823,14.524545

Related Work

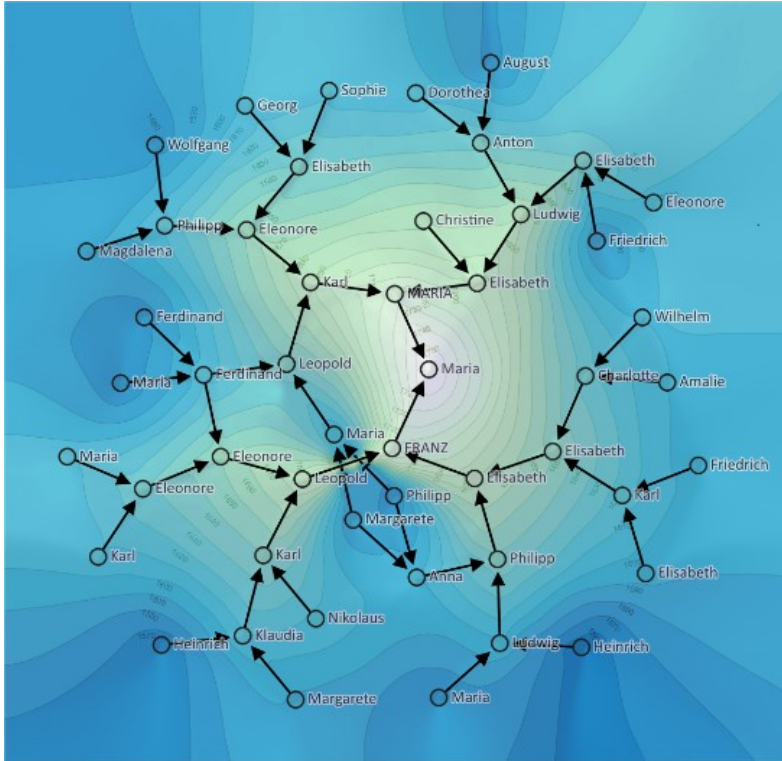


van der Maaten, L., Boon, P., Lange, G., Paijmans, H. and Postma, E., 2006. Computer vision and machine learning for archaeology. *Proceedings of Computer Applications and Quantitative Methods in Archaeology*, pp.112-130.

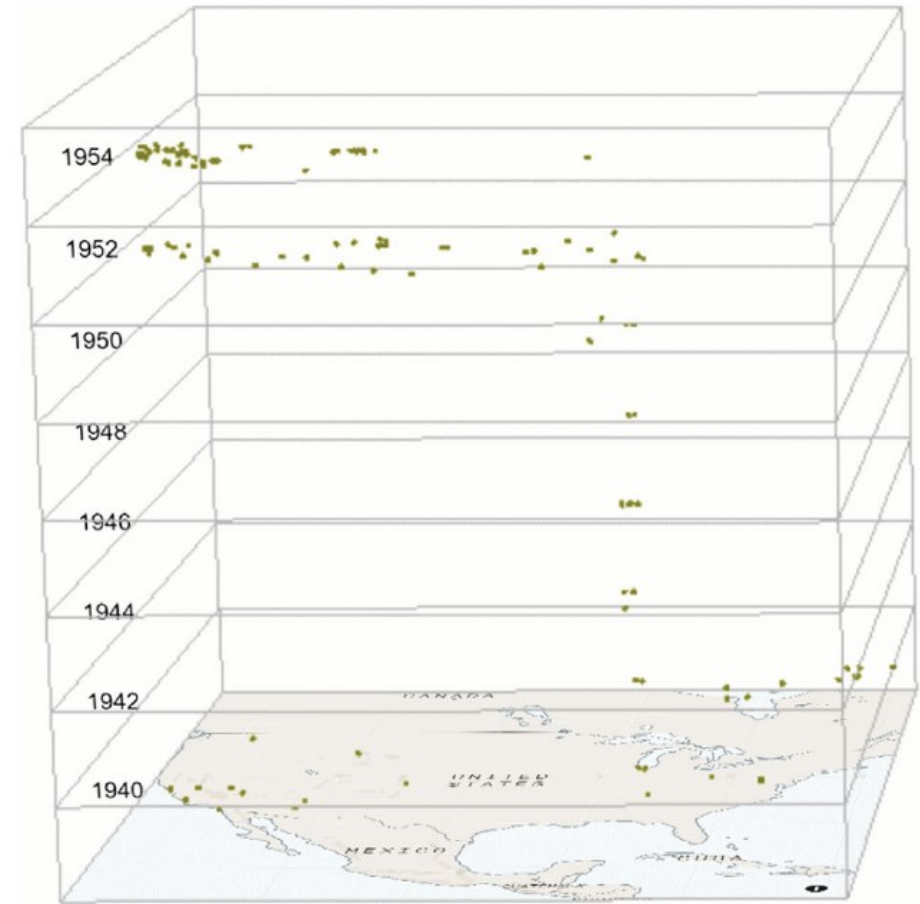


Bogacz, B., Feldmann, F., Prager, C. and Mara, H., 2018. Visualizing Networks of Maya Glyphs by Clustering Subglyphs. In *Proceedings of the Eurographics Workshop on Graphics and Cultural Heritage*.

Related Work



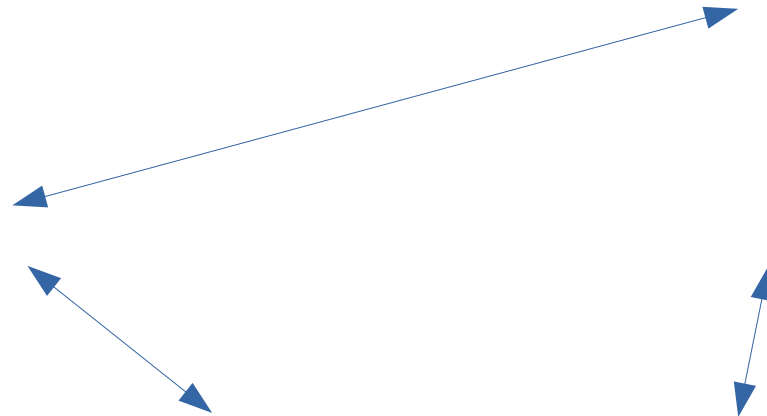
Preiner, R., Schmidt, J., Krösl, K., Schreck, T. and Mistelbauer, G., 2020, June. Augmenting Node-Link Diagrams with Topographic Attribute Maps. In *Computer Graphics Forum* (Vol. 39, No. 3, pp. 369-381).



Windhager, F., Salisu, S., Leite, R.A., Filipov, V., Miksch, S., Schreder, G. and Mayr, E., 2020. Many Views Are Not Enough: Designing for Synoptic Insights in Cultural Collections. *IEEE Computer Graphics and Applications*, 40(3), pp.58-71.

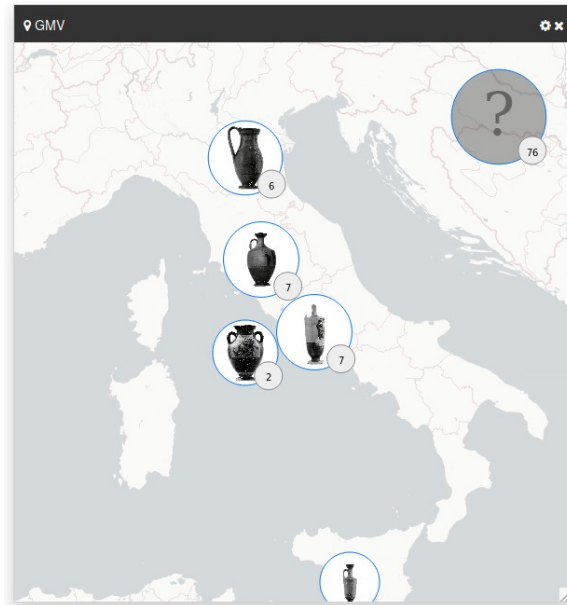
Our Approach

- Established views for individual modalities
- Linking of interactive views
- Currently supported modalities:

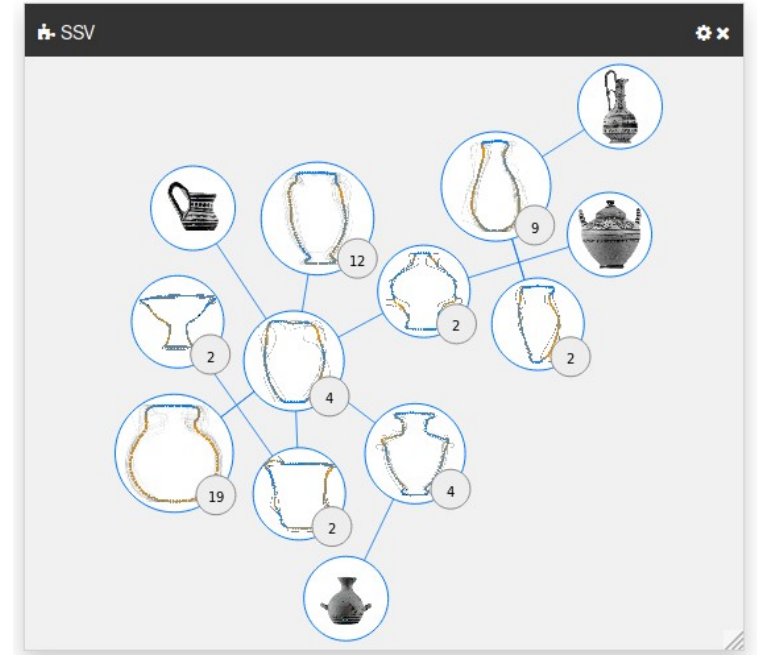


Our Approach

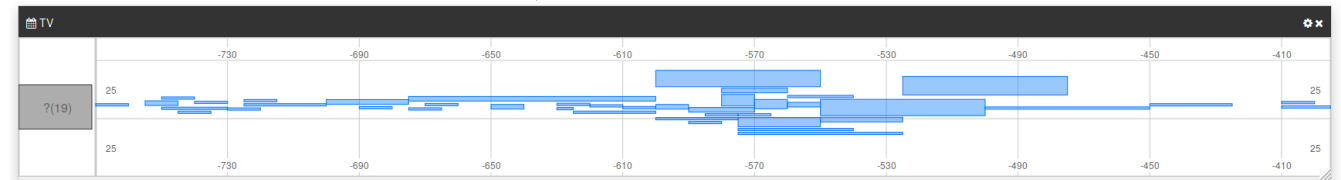
- Established views for individual modalities
- Linking of interactive views
- Currently supported modalities:



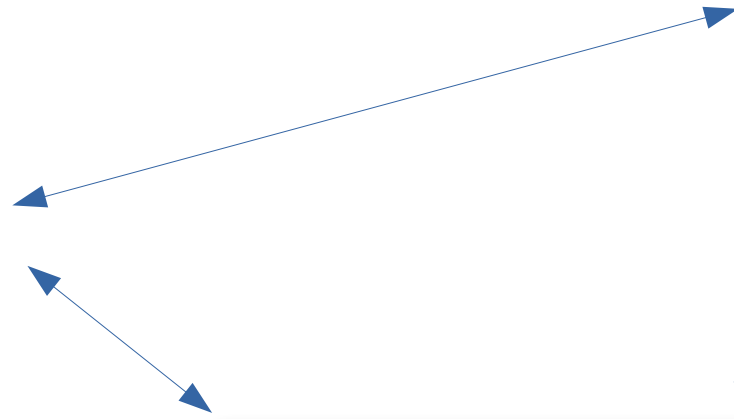
Findplace



Shape

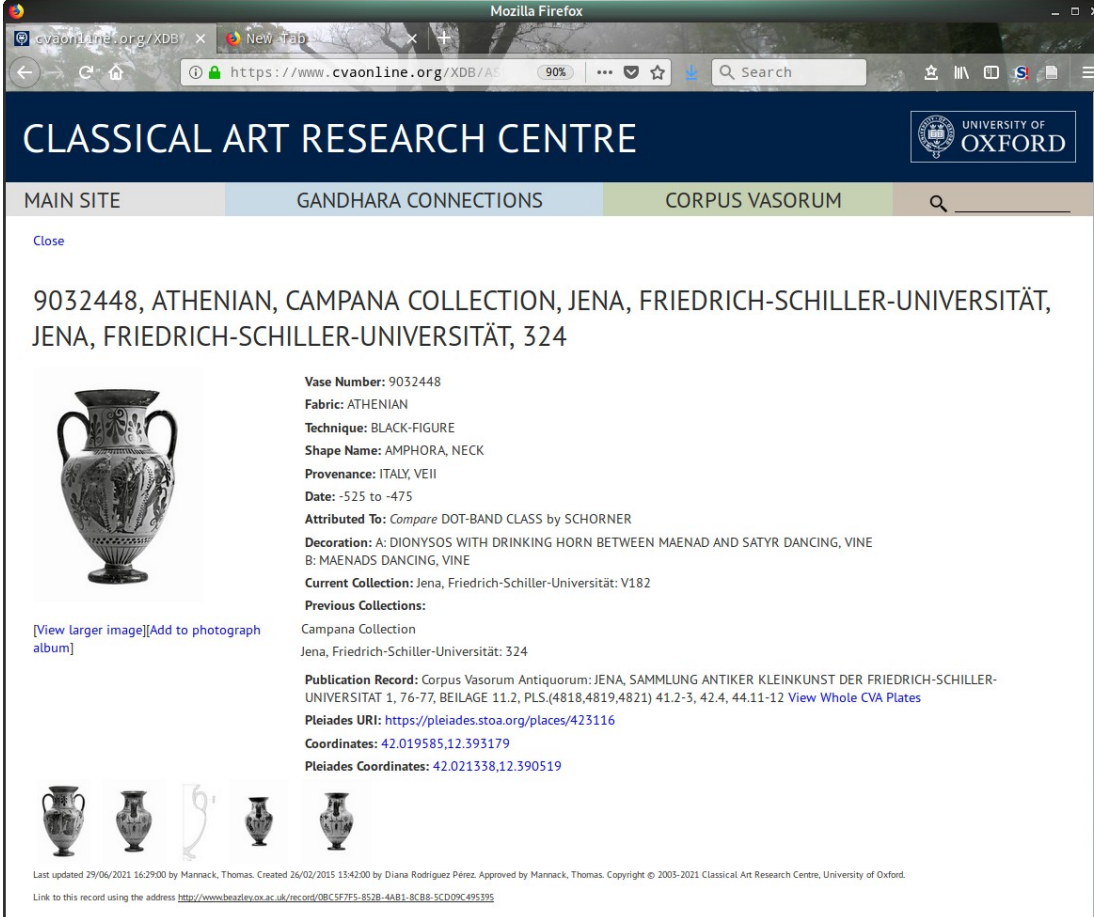


Date



Sources

- Sources: CVA Volumes
 - Dresden 2
 - Erlangen 2
 - Göttingen 3
 - Jena 1
 - Munich 16
- Related Metadata extracted from the *Beazley Archive Pottery Database*^[6]
- 614 Vases with 2,799 images
 - 61% have dating information
 - 32% have provenance information



The screenshot shows a web browser window displaying the Classical Art Research Centre website. The page features a navigation bar with 'MAIN SITE', 'GANDHARA CONNECTIONS', and 'CORPUS VASORUM'. The main content area displays a record for vase 9032448, an Athenian black-figure amphora. The record includes a large image of the vase, a list of metadata (Fabric, Technique, Shape Name, Provenance, Date, Attributed To, Decoration, Current Collection, Previous Collections, Publication Record, Pleiades URI, Coordinates, Pleiades Coordinates), and a list of smaller thumbnail images at the bottom. The website is part of the University of Oxford.

CLASSICAL ART RESEARCH CENTRE

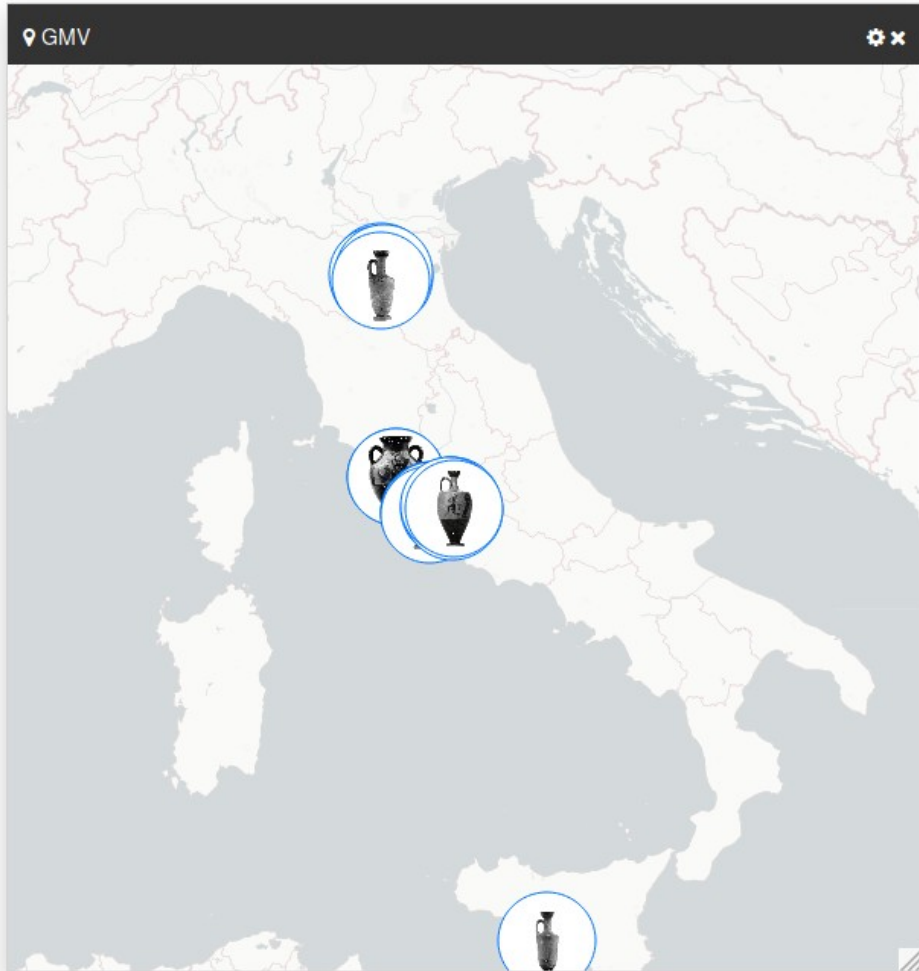
9032448, ATHENIAN, CAMPANA COLLECTION, JENA, FRIEDRICH-SCHILLER-UNIVERSITÄT, JENA, FRIEDRICH-SCHILLER-UNIVERSITÄT, 324

Vase Number: 9032448
Fabric: ATHENIAN
Technique: BLACK-FIGURE
Shape Name: AMPHORA, NECK
Provenance: ITALY, VEII
Date: -525 to -475
Attributed To: Compare DOT-BAND CLASS by SCHORNER
Decoration: A: DIONYSOS WITH DRINKING HORN BETWEEN MAENAD AND SATYR DANCING, VINE B: MAENADS DANCING, VINE
Current Collection: Jena, Friedrich-Schiller-Universität: V182
Previous Collections: Campana Collection
Jena, Friedrich-Schiller-Universität: 324
Publication Record: Corpus Vasorum Antiquorum: JENA, SAMMLUNG ANTIKER KLEINKUNST DER FRIEDRICH-SCHILLER-UNIVERSITÄT 1, 76-77, BEILAGE 11.2, PLS.(4818,4819,4821) 41.2-3, 42.4, 44.11-12 [View Whole CVA Plates](#)
Pleiades URI: <https://pleiades.stoa.org/places/423116>
Coordinates: 42.019585,12.393179
Pleiades Coordinates: 42.021338,12.390519

Last updated 29/06/2021 16:29:00 by Mannack, Thomas. Created 26/02/2015 13:42:00 by Diana Rodriguez Pérez. Approved by Mannack, Thomas. Copyright © 2003-2021 Classical Art Research Centre, University of Oxford.
Link to this record using the address <http://www.beazley.ox.ac.uk/record/GRCSF7FS-853B-4AB1-8CBB-SCD09C495395>

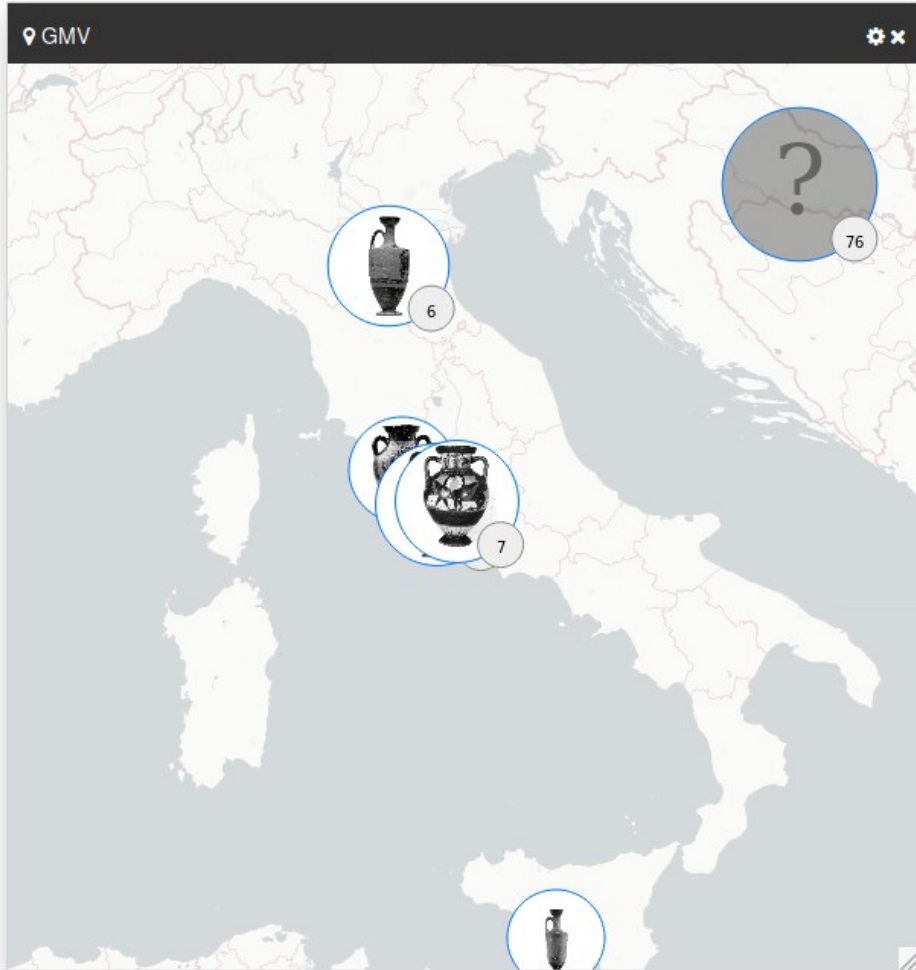
[6] <https://www.beazley.ox.ac.uk/index.htm>

Findspot View



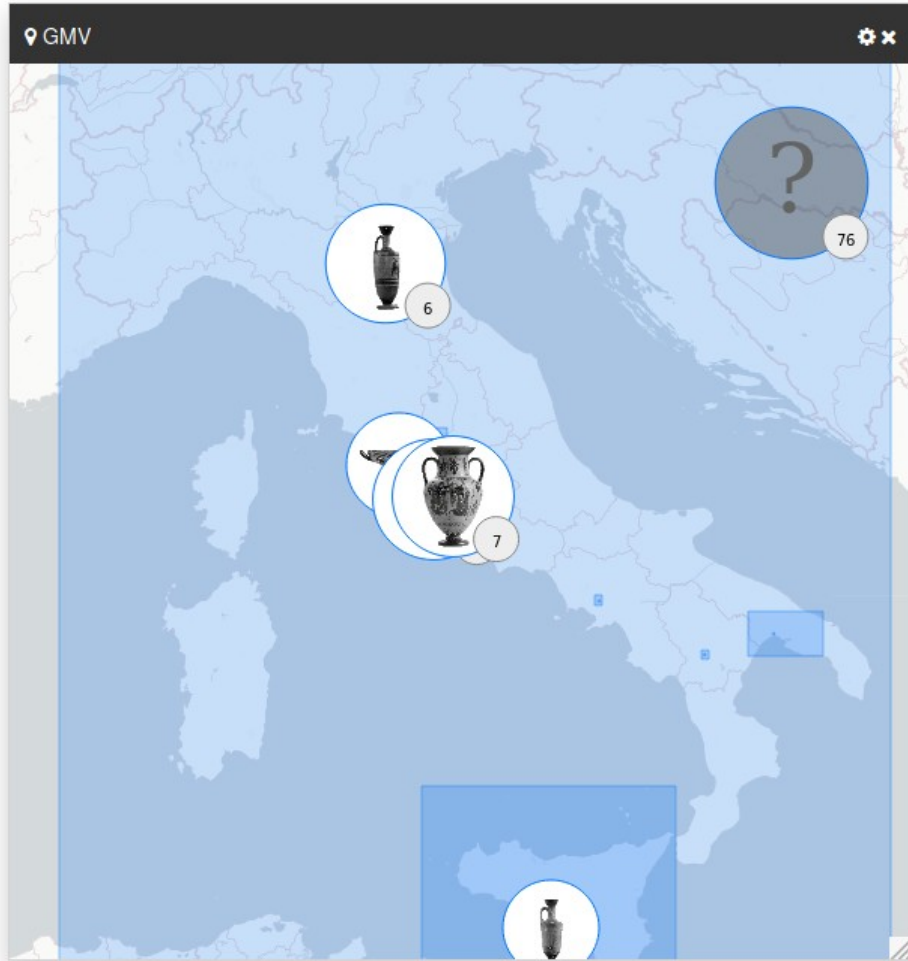
- Geographic map with object previews

Findspot View



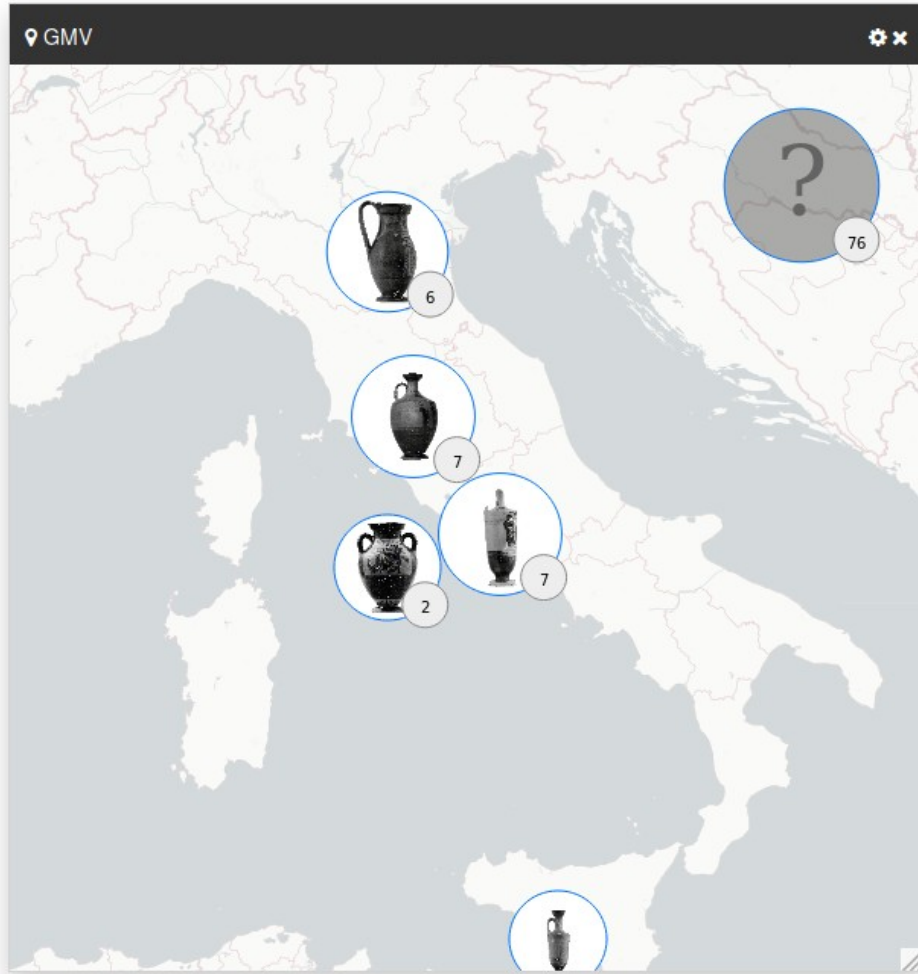
- Geographic map with object previews
- Visual enhancement
 - Aggregation by findplace

Findspot View



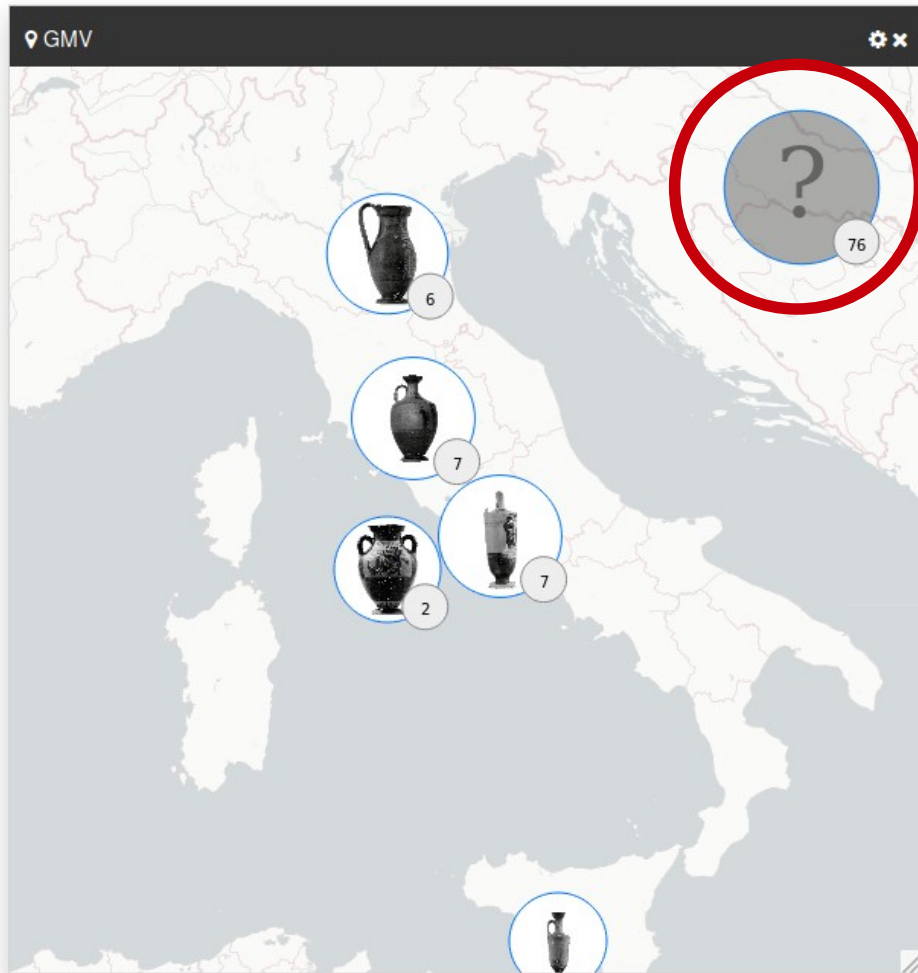
- Geographic map with object previews
- Visual enhancement
 - Aggregation by findplace

Findspot View



- Geographic map with object previews
- Visual enhancement
 - Aggregation by findplace
 - Collision Avoidance

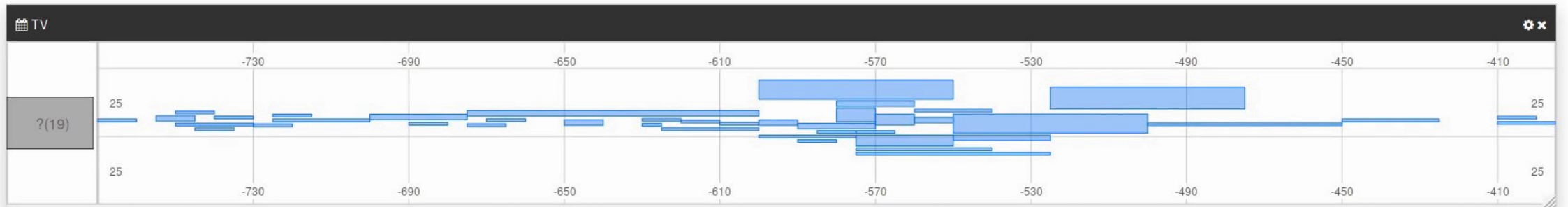
Findspot View



- Geographic map with object previews
- Visual enhancement
 - Aggregation by findplace
 - Collision Avoidance
 - **Separate node for unattributed objects**

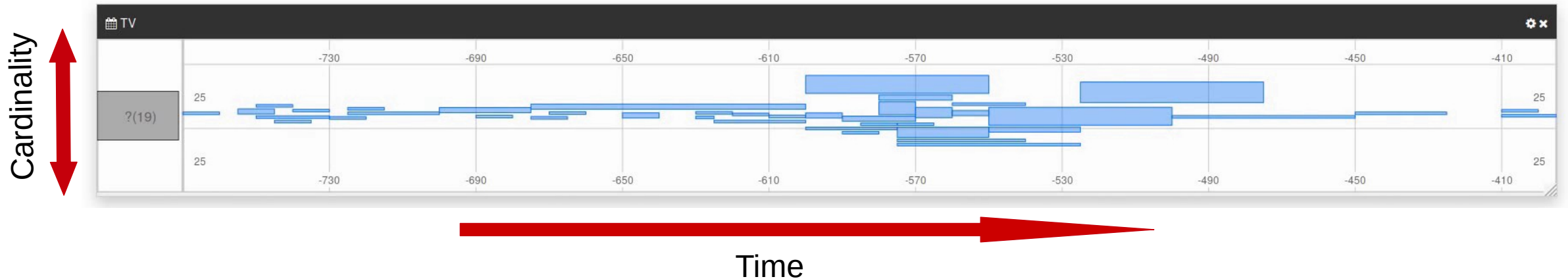
Timeline View

- Dating information given as (half open) interval
 - E.g. “-525 to -475”
- Objects aggregated into interval blocks
 - Thickness of block signifies the number of objects
- Layout governed by force simulation



Timeline View

- Dating information given as (half open) interval
 - E.g. “-525 to -475”
- Objects aggregated into interval blocks
 - Thickness of block signifies the number of objects
- Layout governed by force simulation

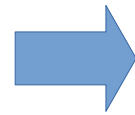


Shape Similarity Viewer

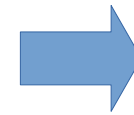
- Extract silhouettes from object depictions



Source



Fg/Bg Segmentation



Silhouette

- Silhouette similarities determined by *Shape Contour Descriptor*^[6]

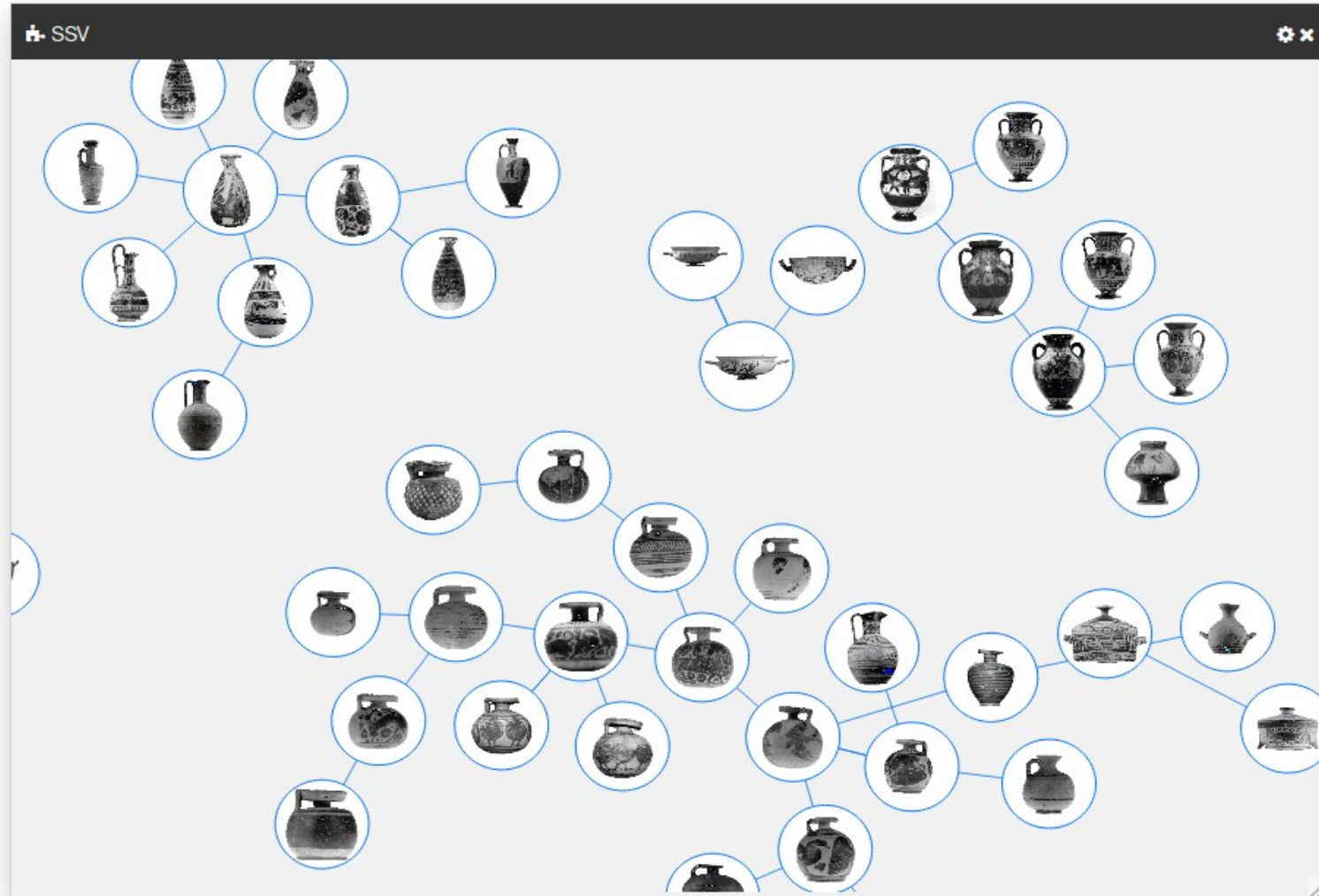
^[6]Attalla, E. and Siy, P., 2005. Robust shape similarity retrieval based on contour segmentation polygonal multiresolution and elastic matching. *Pattern Recognition*, 38(12), pp.2229-2241.

Shape Similarity Viewer



- Network visualization for shape similarity
 - Similarity indicated by connecting links
- **Issue:** Links between all nodes overconstrain the layout

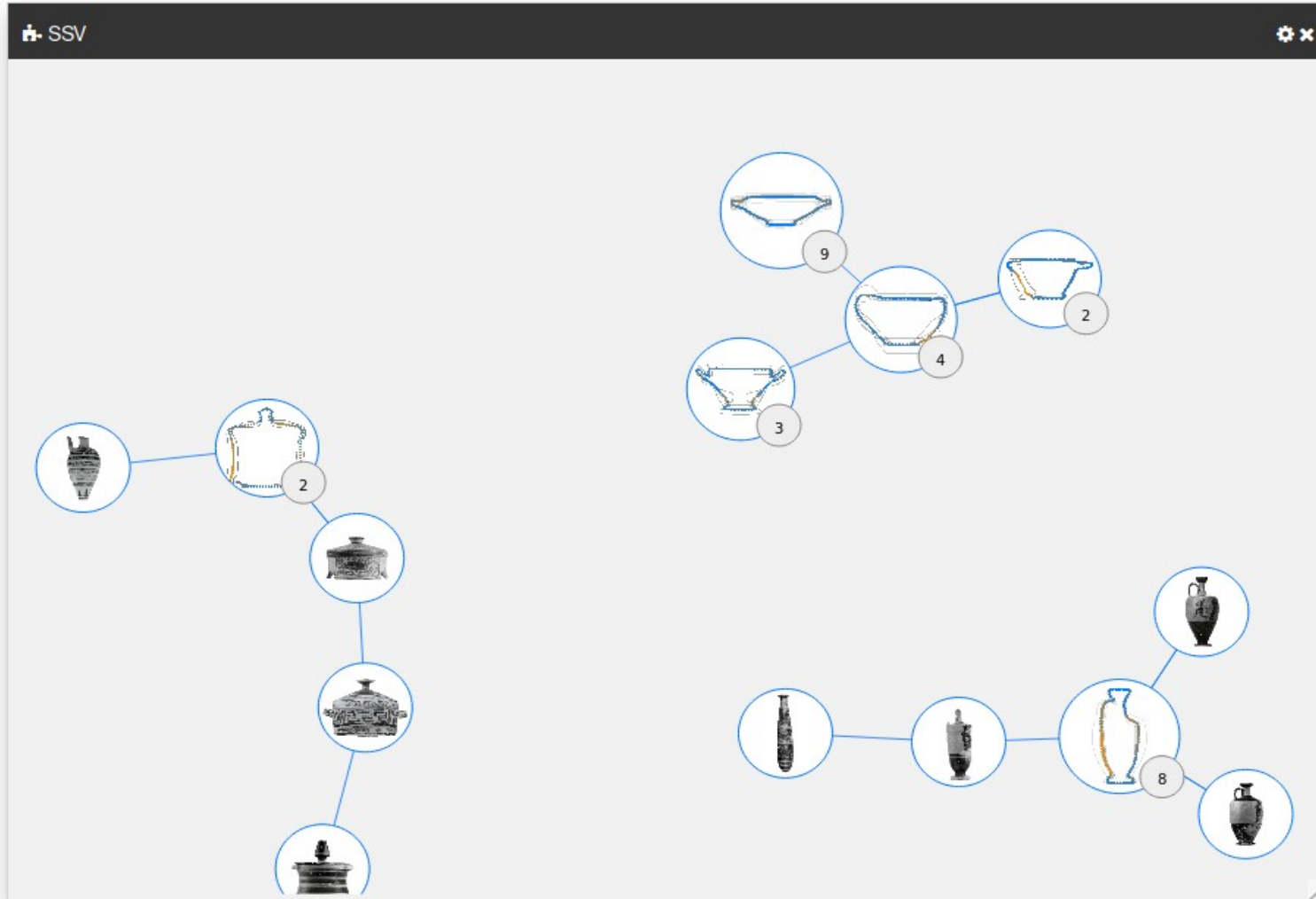
Shape Similarity Viewer



- Link sparsification^[8] preserves only the *'most significant'* links

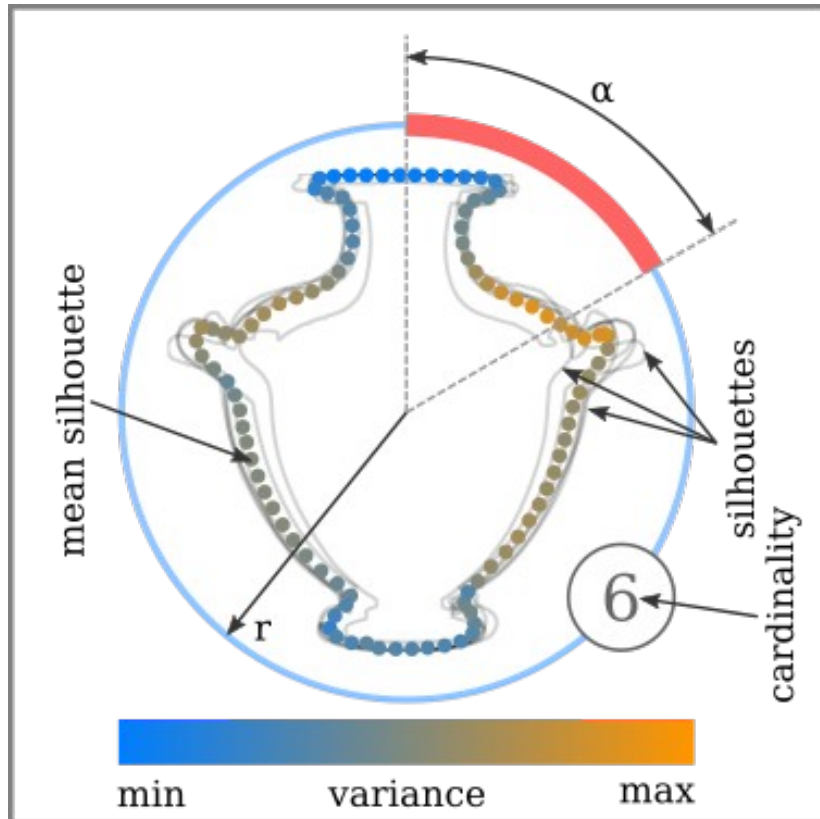
^[8]Satuluri, V., Parthasarathy, S. and Ruan, Y., 2011, June. Local graph sparsification for scalable clustering. In *Proceedings of the 2011 ACM SIGMOD International Conference on Management of data* (pp. 721-732).

Shape Similarity Viewer



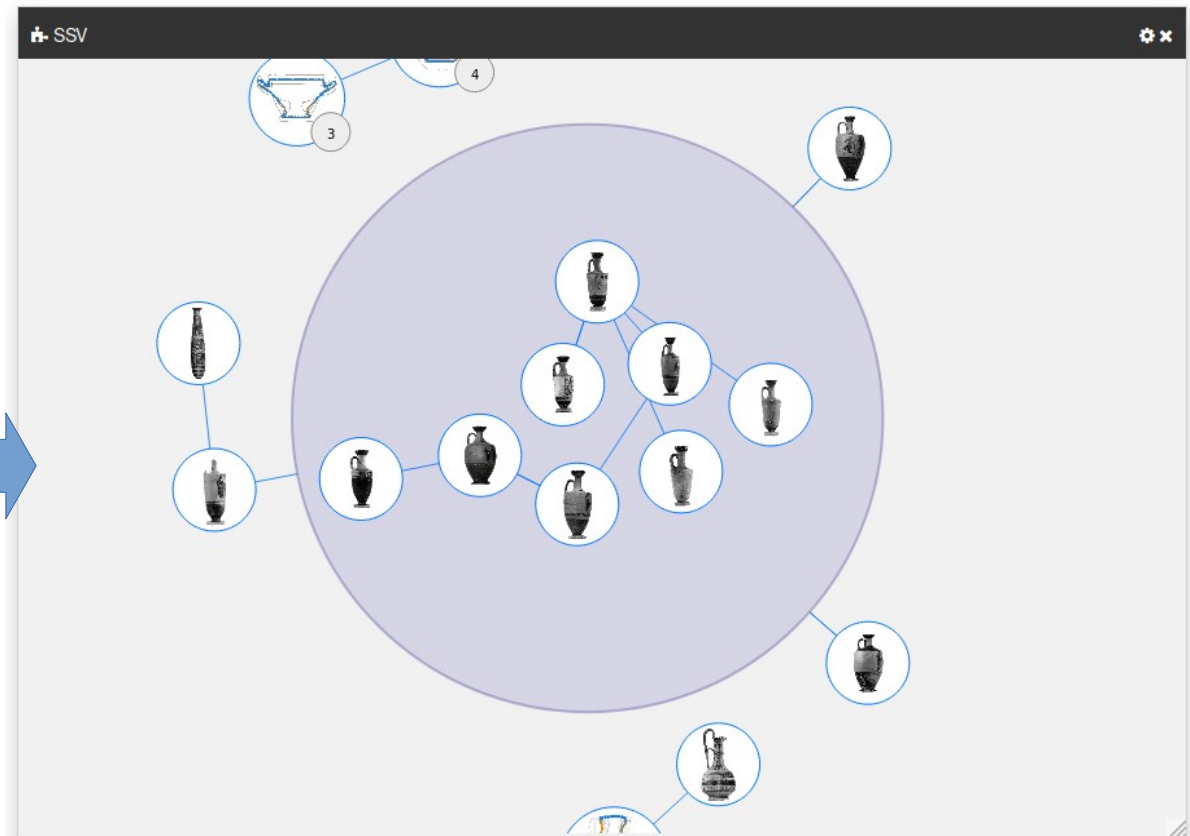
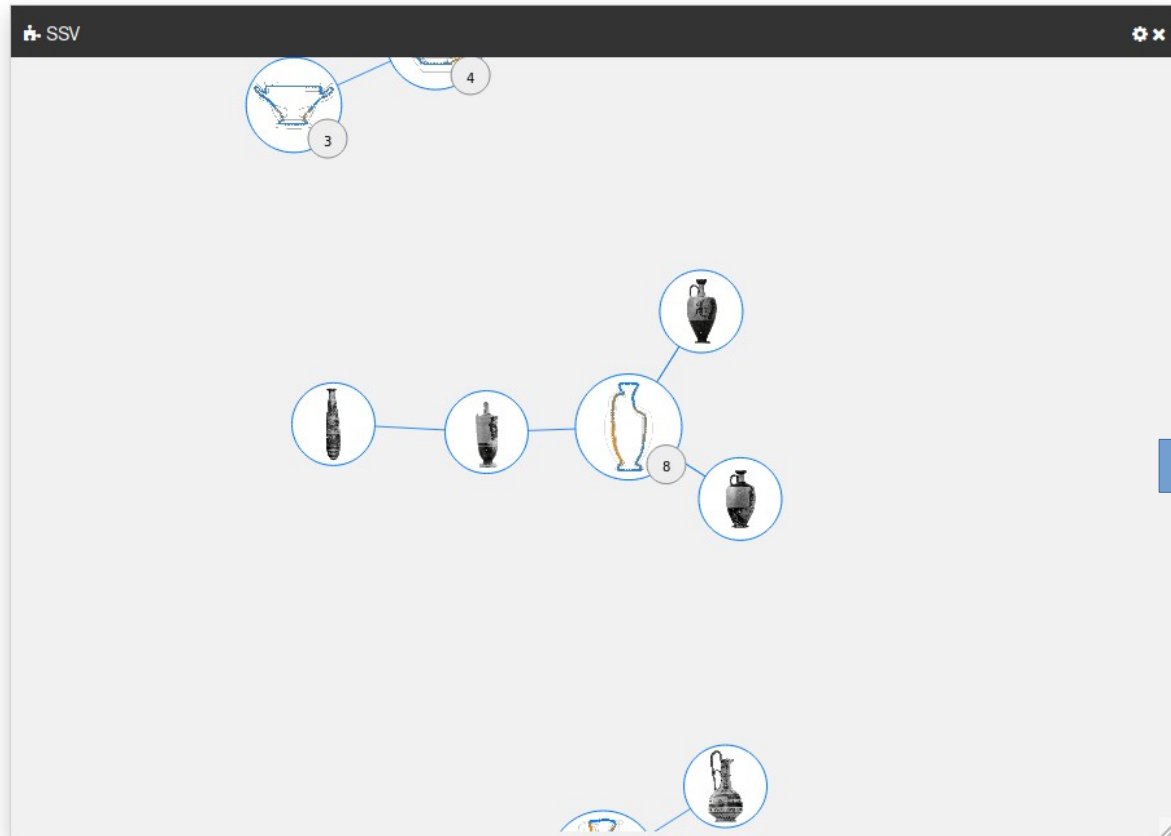
- Pairwise aggregation of objects with strongest link force

Shape Preview Surrogate

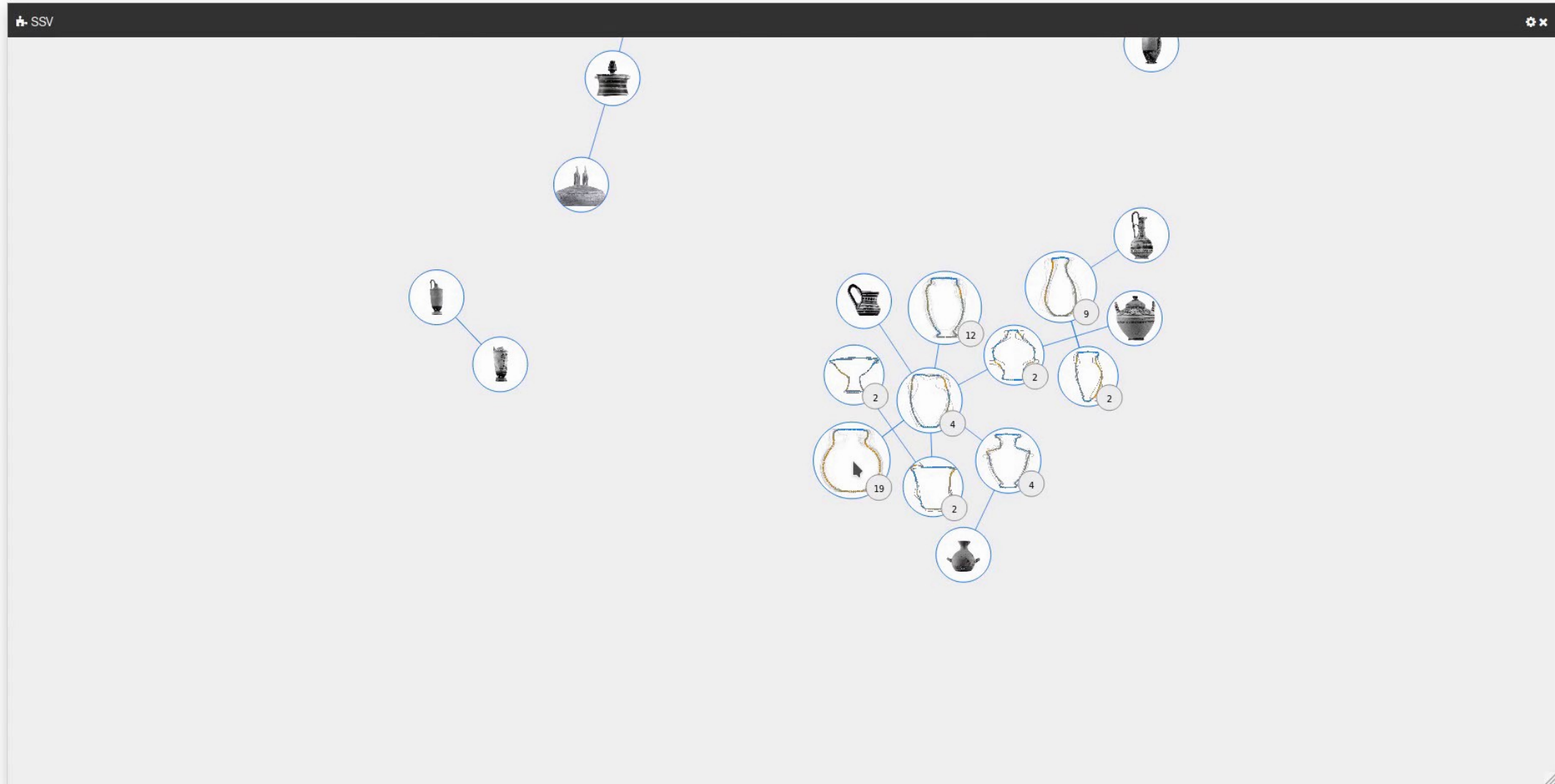


- Multi-object preview for aggregated nodes
- Silhouettes
 - All silhouettes as semi-transparent gray line
 - Mean silhouette as dotted line (the color encodes the local variance)
- Cardinality := # of incorporated objects
- Radius $r = r(\text{'cardinality'})$

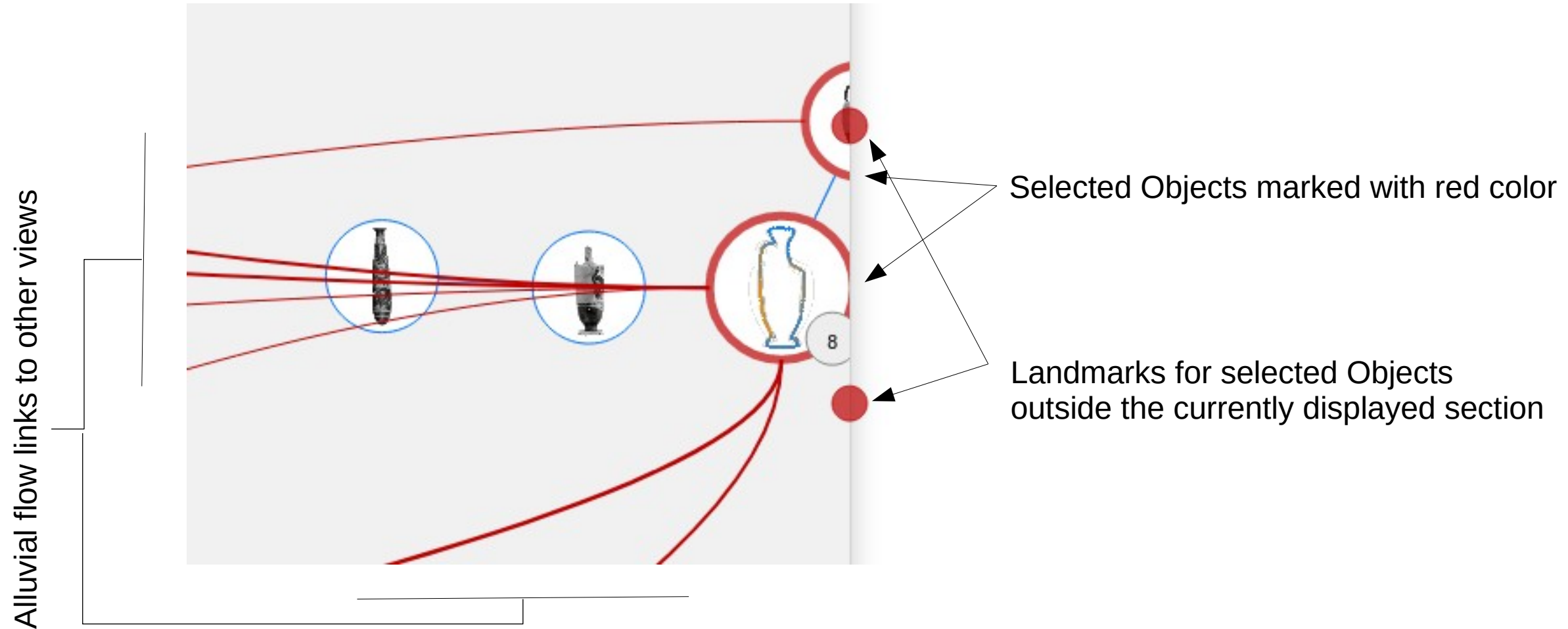
Hierarchic Balloons



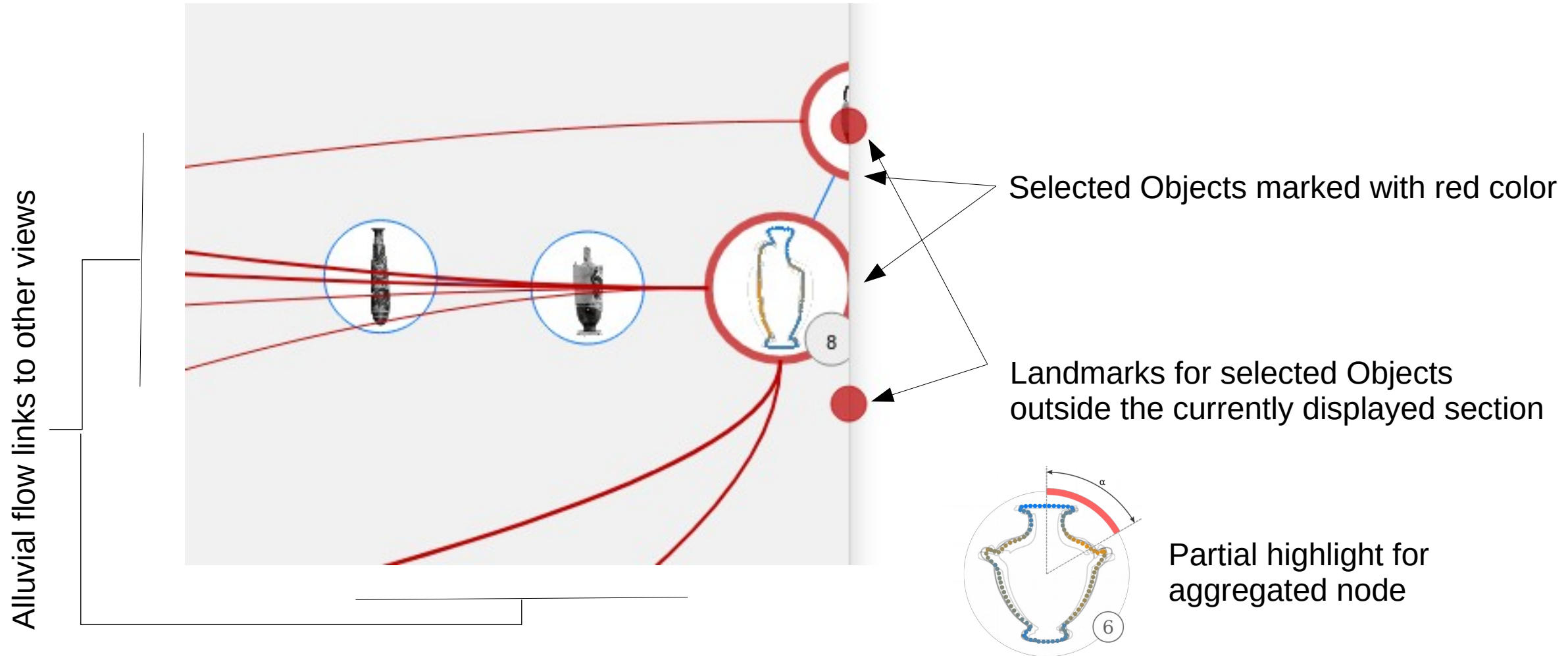
Hierarchic Balloons



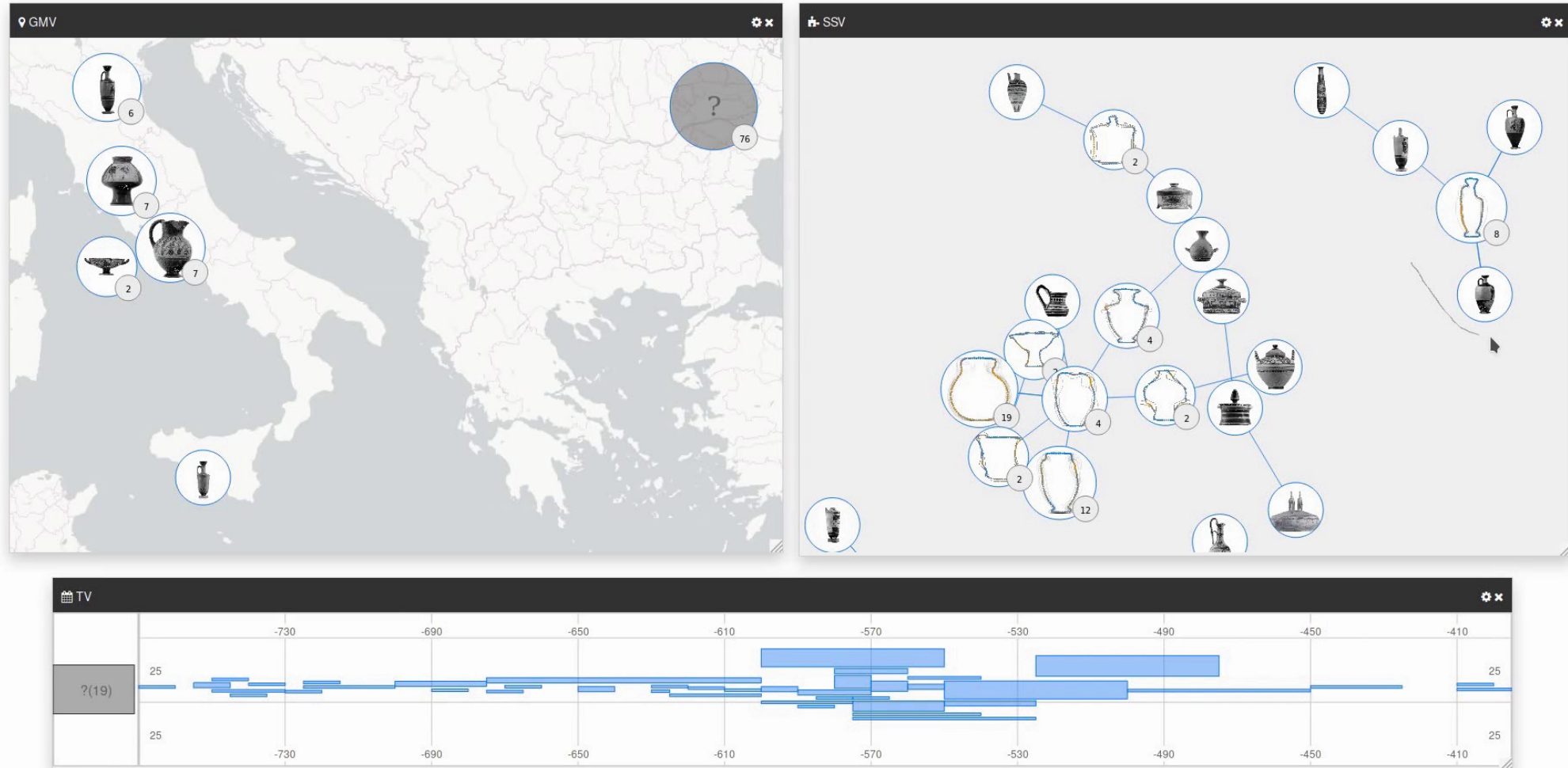
Intra-View Highlighting



Intra-View Highlighting

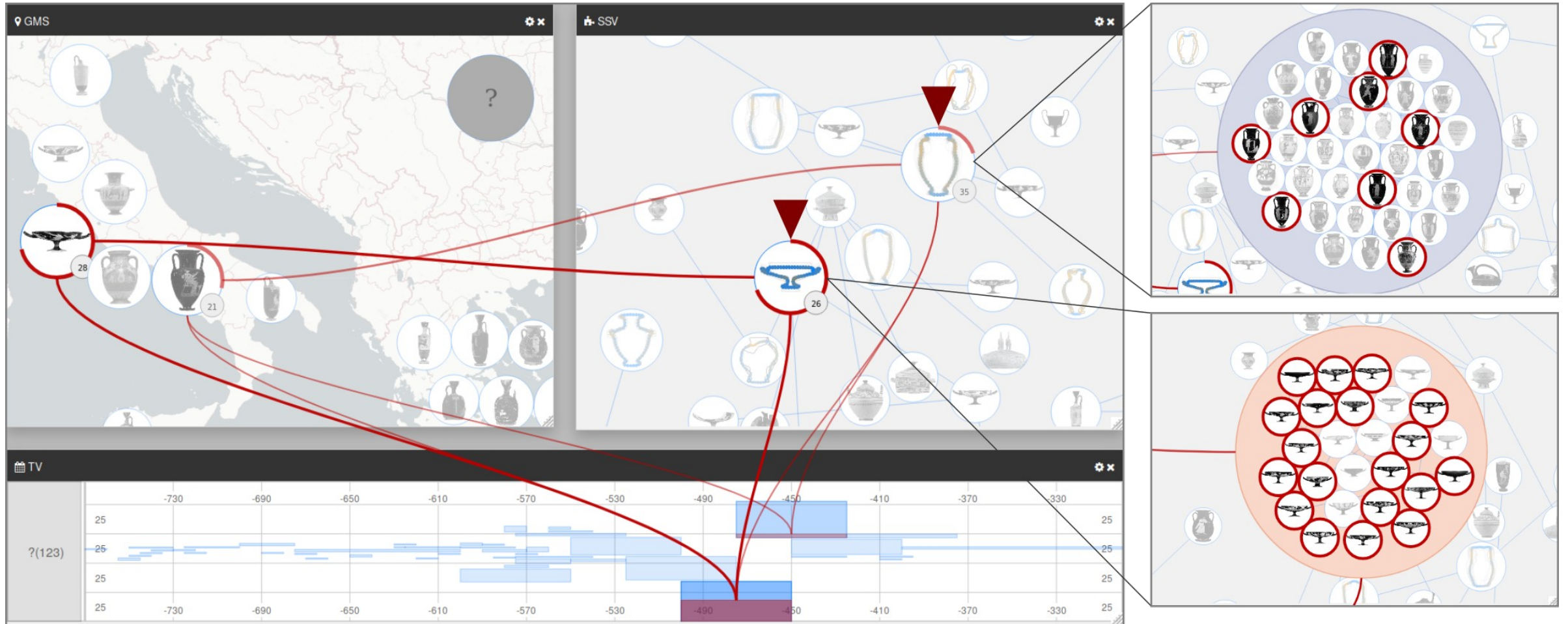


Intra-View Highlighting



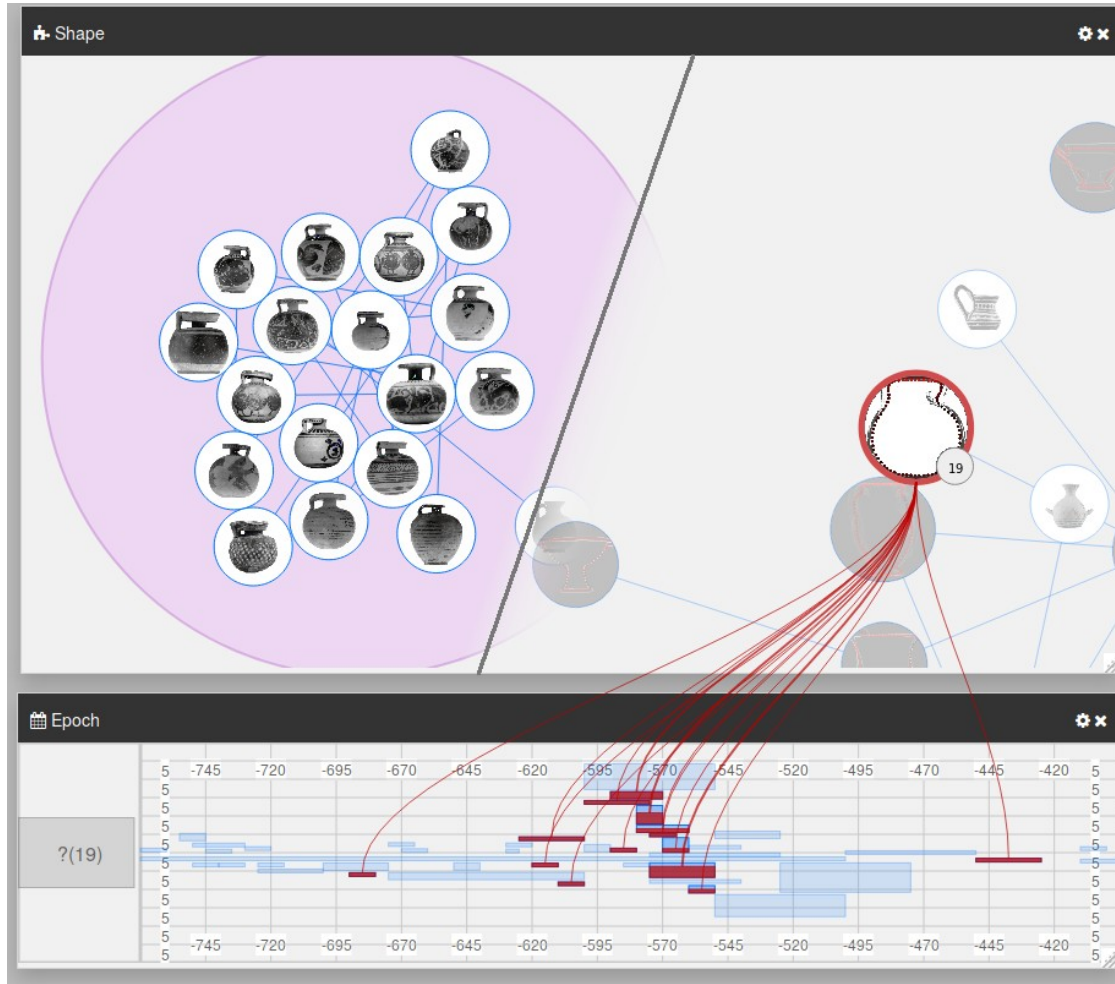
Highlighting based on user selection

Intra-View Highlighting



'Most significant' links determined by Intra-view cross-correlation

Expert Feedback



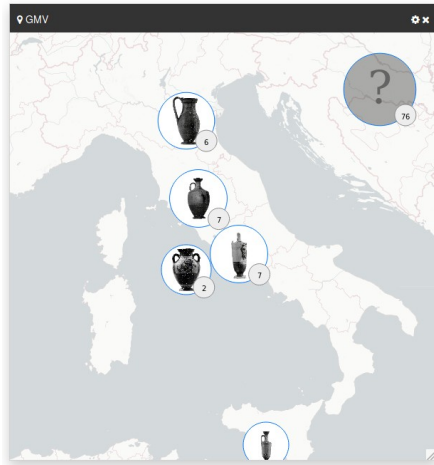
Which dating is related to *aryballoi* shape?



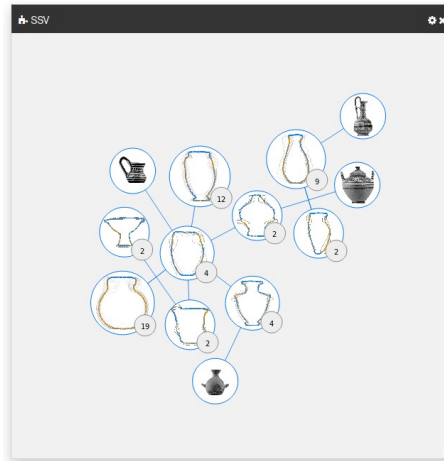
Which other objects belong to the same period?

Limitations / Future Work

- Extend and adapt views for additional modalities



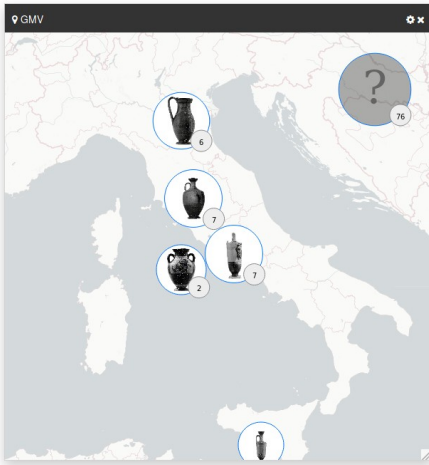
- Collection
- Fabric



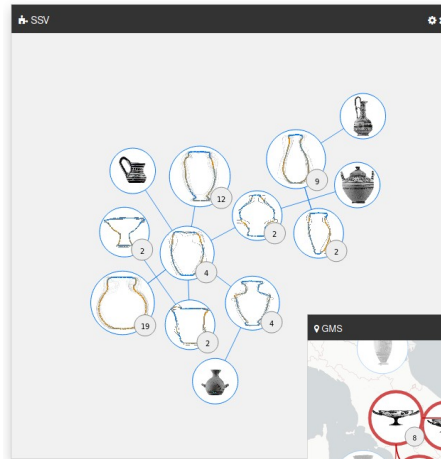
- Texture
- Decoration
- Motif depictions

Limitations / Future Work

- Extend and adapt views for additional modalities



- Collection
- Fabric



- Texture
- Decoration
- Motif depictions

- Optimize link bundling/routing

