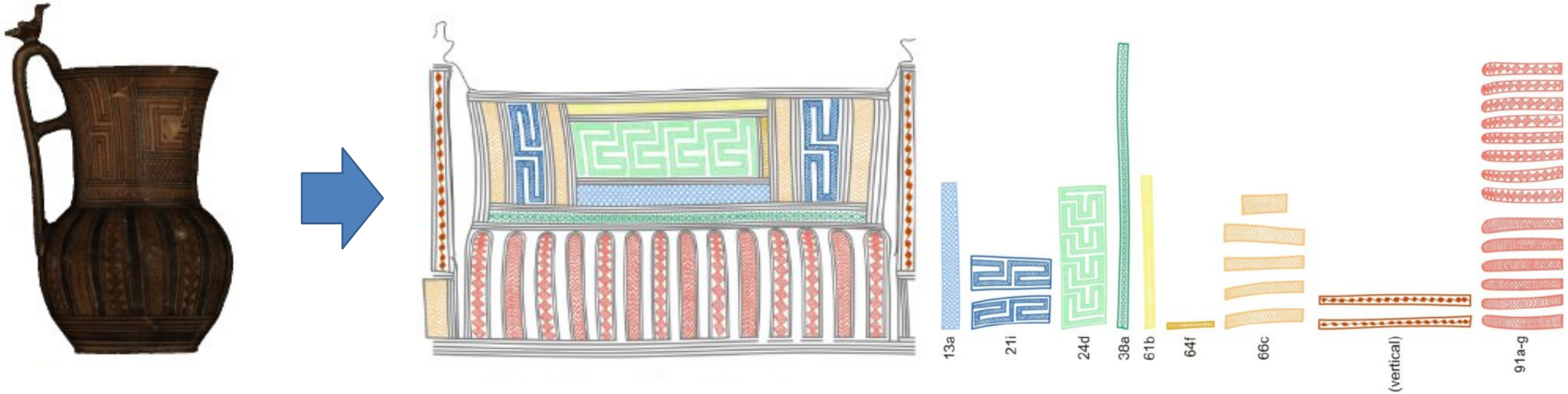

Computerized Ornament Classification in Geometric Vase Paintings

Stefan Lengauer
Graz University of Technology, Institute of Computer Graphics and Knowledge Visualization, Austria

4th Workshop on “Analyse von digitalen Daten musealer Objekte”
November 10, 2023

Recap

- **2019-2022:** Crossmodal Search and Visual Exploration of 3D Cultural Heritage Objects (CrossSAVE-CH)
  - 10/2019: “Crossmodale Suche und visuele Exploration von digitalen Kulturgutobjekten” at 2nd Annual Workshop on *Neue Analysen von digitalen Daten musealer Objekte*
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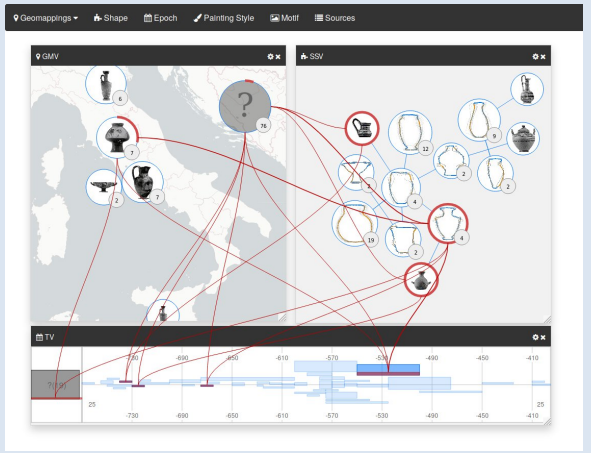

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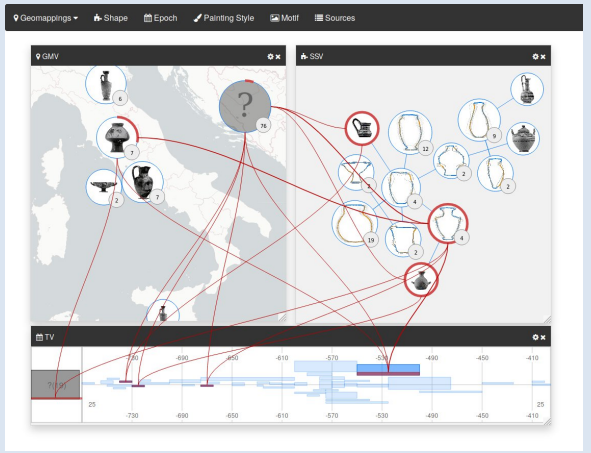

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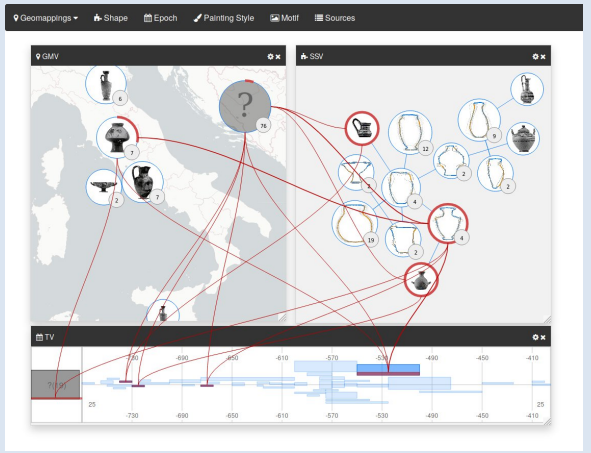

- **2024?:** New Approaches for REcognition, ClassificatiON, and iNtEraCTive vIsualizatiON (RECONNECTION) of Ancient Geometric Vase Paintings
  - Proposal Phase

Why Geometric Pottery?

- Geometric period - 900-700 BCE
  - First artistic period in ancient Greece
  - Vase paintings characterized by simplistic geometric shapes
    - Finite number of different ornament classes
  - Pottery used for various trade goods and also exporting

Kunsthistorisches Museum, IV 2

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- Relevance for **archaeology** (Coldstream 2004)
  - Measure time in a time before written records
  - Infer commercial contacts and trade routes
- Relevance for **computer science**
  - Faceted, largely unresolved, pattern recognition/classification problem
  - Simplicity of ornaments
    - Necessary training data for ML approaches could be generated procedually
    - Generalization of developed methods for other domains

Kunsthistorisches Museum, IV 2

Ornaments from the Geometric Period

- **Data Basis:** Norbert Kunisch. *Ornamente geometrischer Vasen. Ein Kompendium.* Cologne, Weimar, Vienna: Böhlau, 1998.
  - 776 distinct pattern classes, from 50 different domain publications
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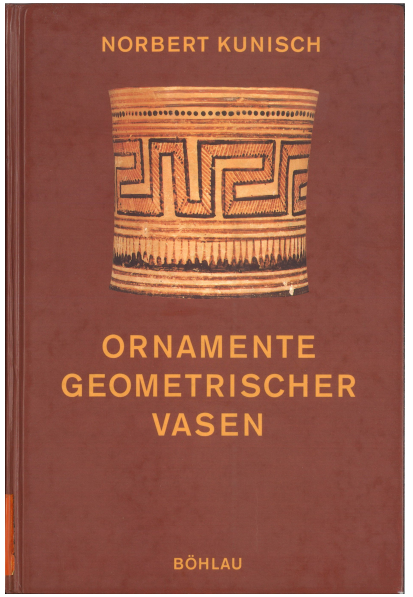

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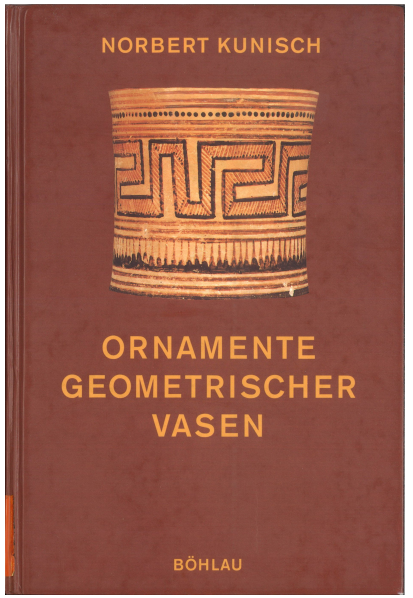

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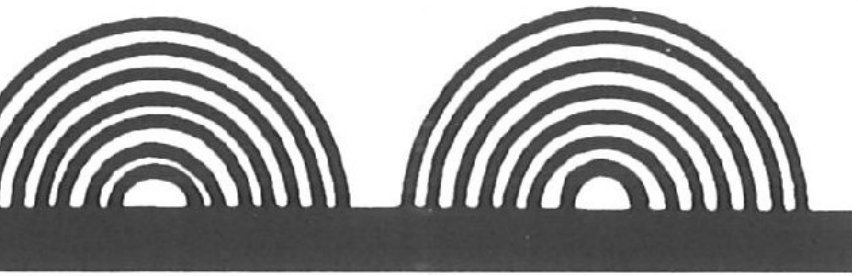

73c Konzentrische Halbkreise, hängend, innen schwarze Balken, Horizontalfeld
Concentric semicircles, pendent, in the centre solid bars, horizontal panel
Demi-cercles concentriques, pendants, aux centre poteau noir, panneau horizontal
Semicerchi concentrici, penduli, al centro bastoncelli neri, campo orizzontale
Ομόκεντρα ημικύκλια, κρεμάμενα, στον κεντρικό δίσκο μελανές ταινίες, οριζόντια ζώνη
thesPG **Desborough 1952 Taf. 20**

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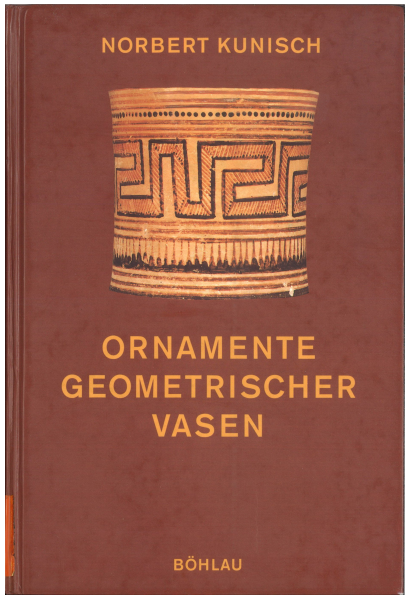

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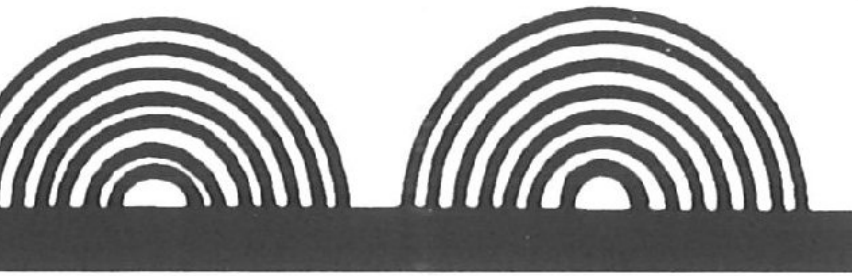

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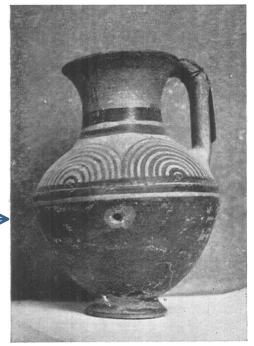

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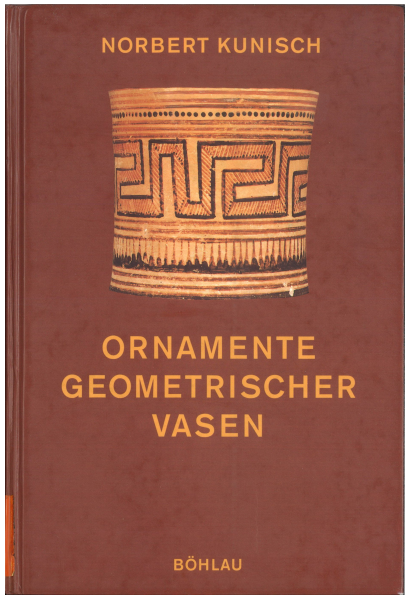

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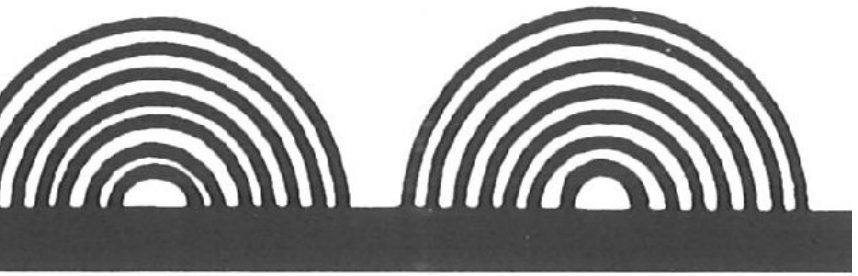

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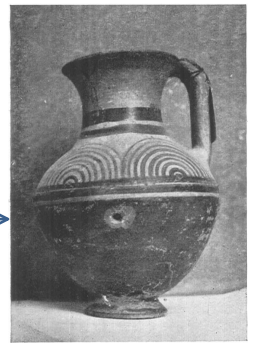
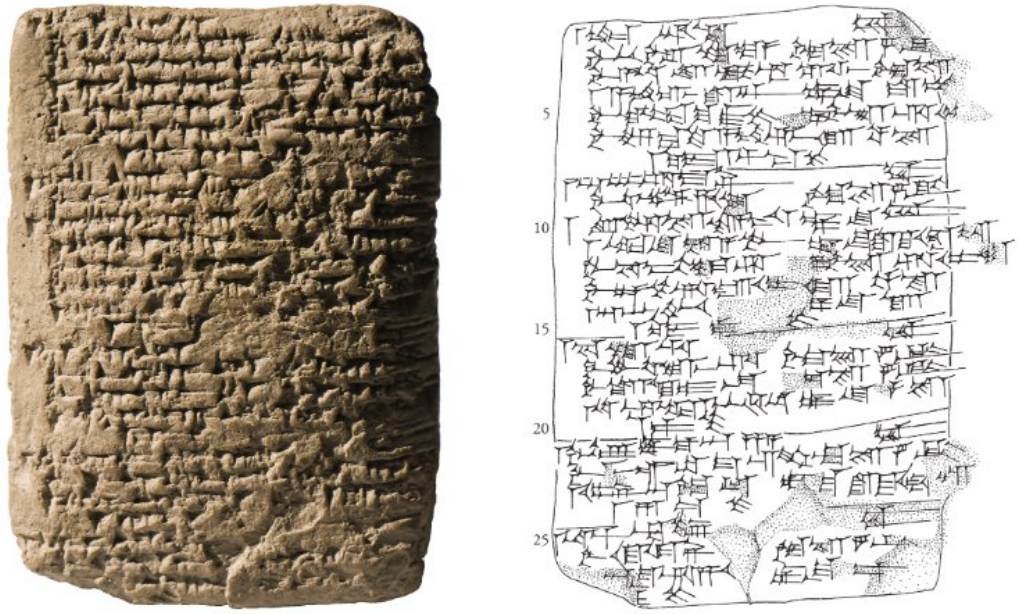


(Desborough 1952, Pl. 20)

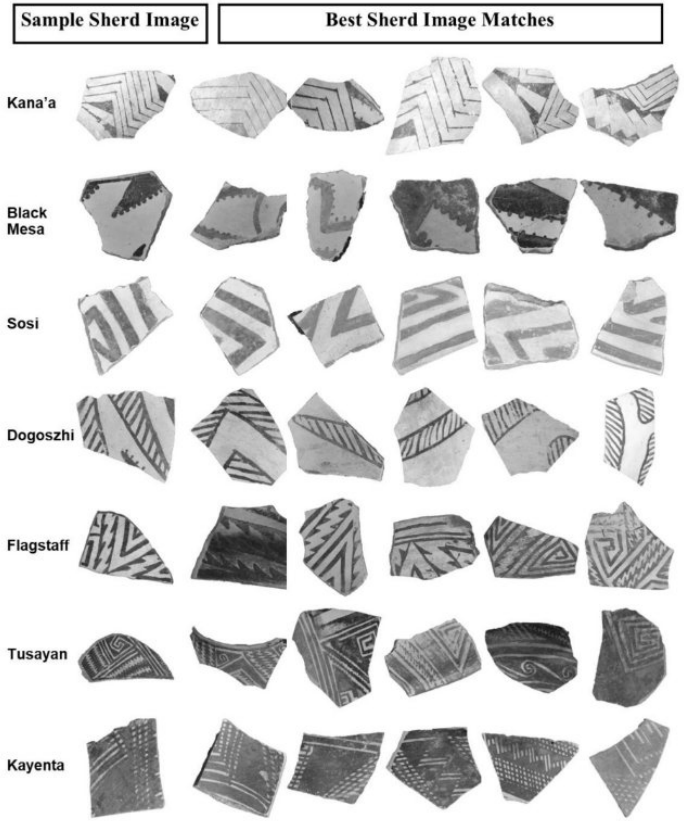
- According to author neither extensive nor encompassing

Previous and Ongoing Work on Colorimetric/Relief Patterns

- Several works for colorimetric/relief patterns in general (not only vases)
  - Query-by-example approaches
  - Self similarity
  - ...



GigaMesh (Bogacz and Mara 2017)



(Pawlowicz and Downum 2021)

Previous and Ongoing Work on Colorimetric/Relief Patterns

- Geometric Reconstruction and Novel Semantic Reunification of Cultural Heritage Objects (GRAVITATE, http://www.archaide.eu/)

Local Binary Patterns (Thompson et al. 2019)

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- Möglichkeiten und Perspektiven der digitalen Malerzuweisung bei attischen Vasen (EGRAPHSEN, https://www.uni-goettingen.de/de/598165.html)

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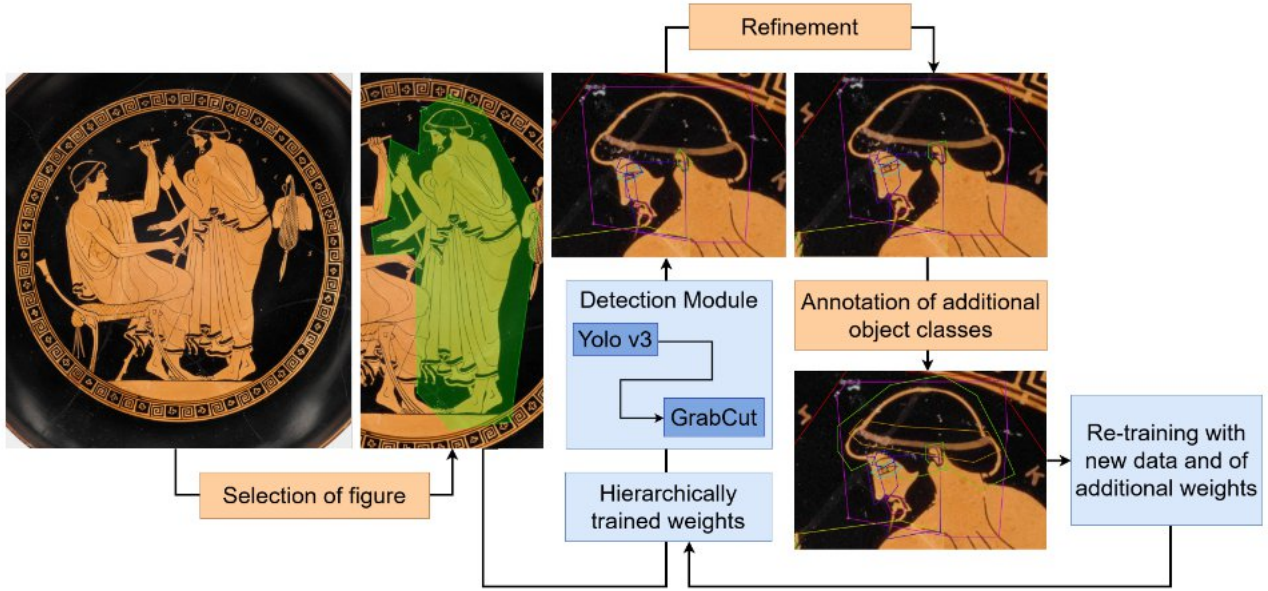

Deep Level Annotation (Kipke et al. 2022)

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- CrossSAVE-CH Project
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Motif Search (Lengauer et al. 2019)

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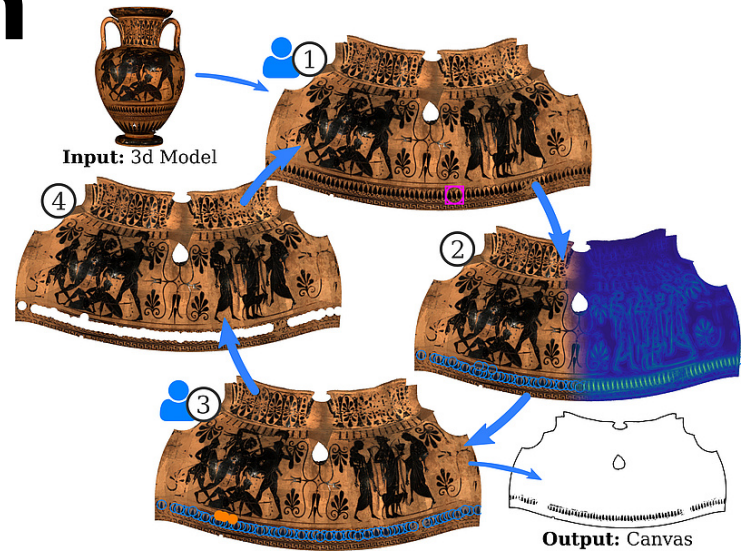

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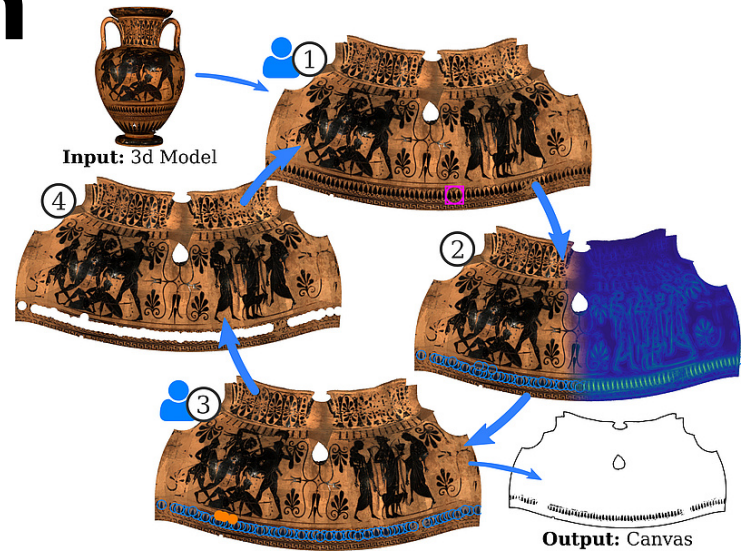

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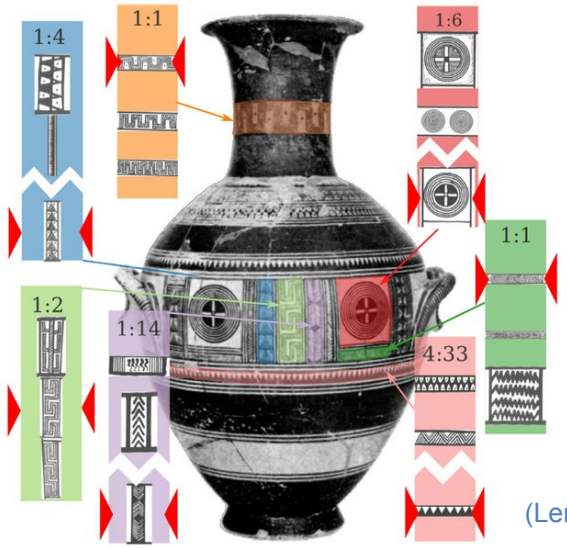
  - *Semi-automated Annotation of Repetitive Ornaments on 3D Painted Pottery Surfaces*
  - *Interactive annotation of Geometric ornamentation on painted pottery assisted by deep learning*
    - → Revealed research gap in terms of classification of Geometric pottery



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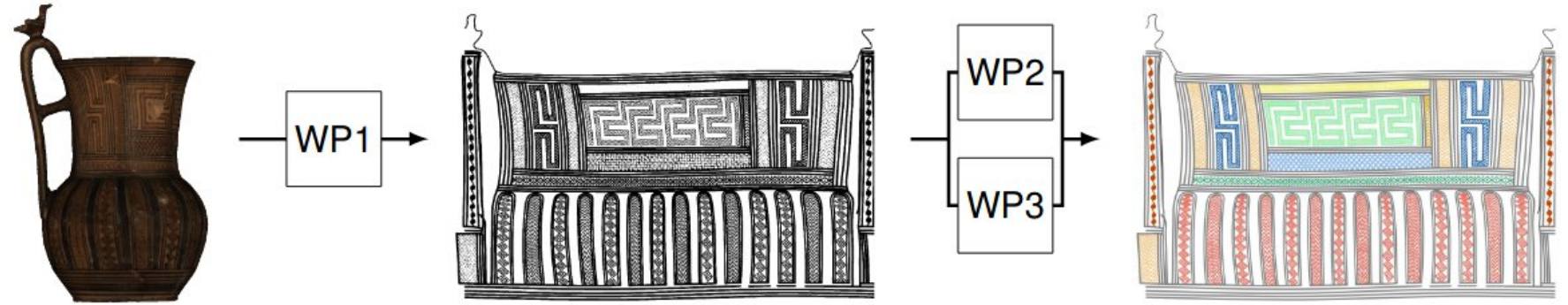
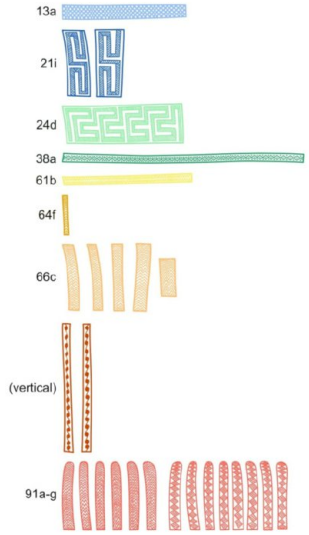
Scope of the proposed Project





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  - Normalized representation from different input modalities (photographs, 3D, drawings)
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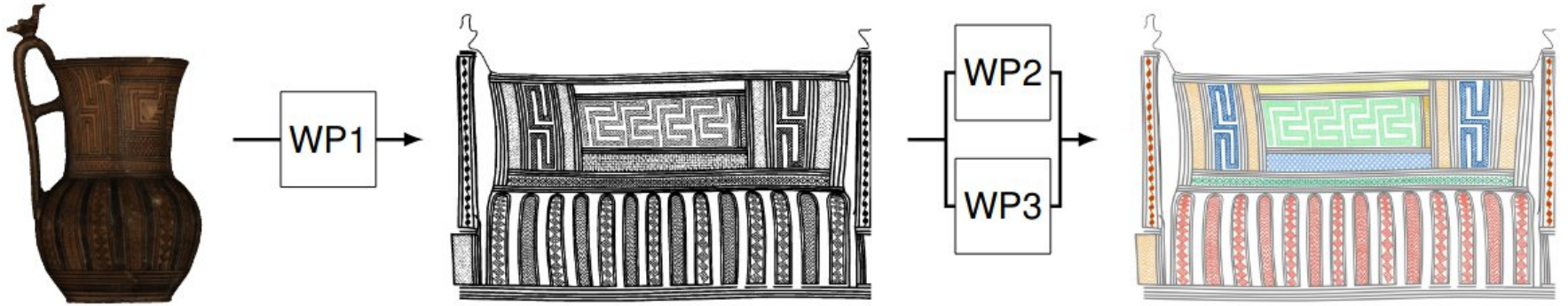

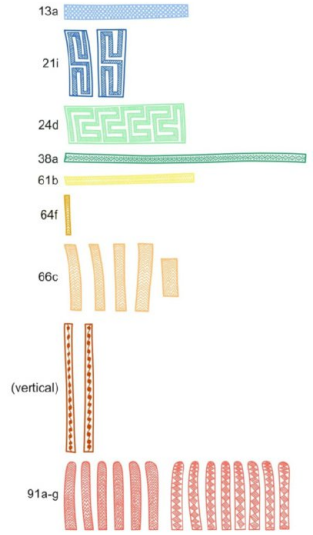

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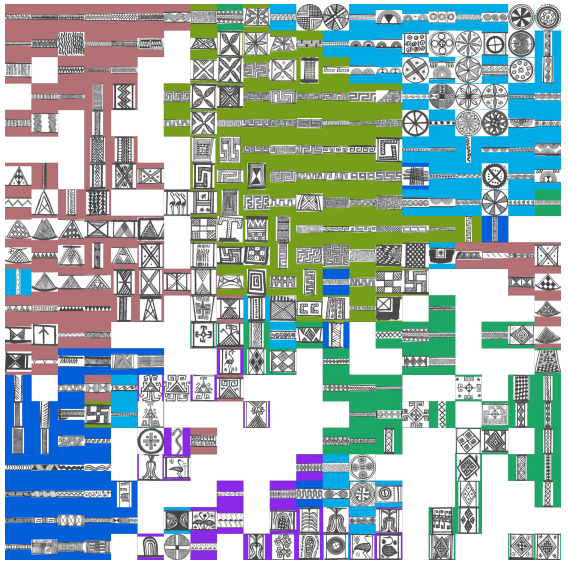
- **WP4** Interactive Visualization and Human-in-the-loop
  - Result presentation
  - Error correction/explicit feedback



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- **H1:** Curved 3D surface can be reduced to a 2D approximation (cf. “archaeological drawings”)
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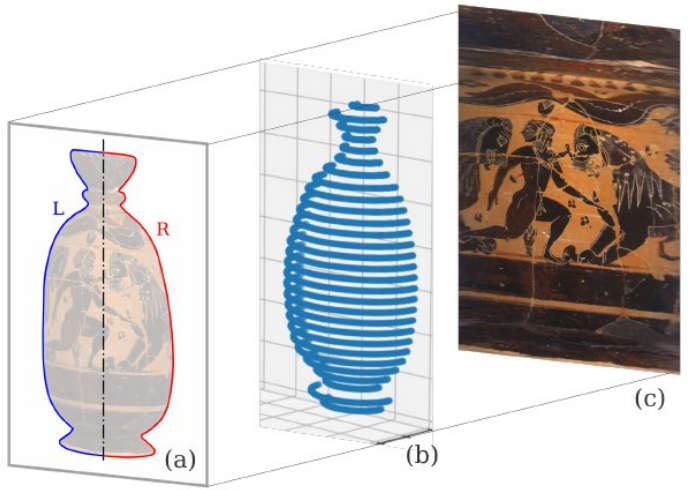
  - \+ Automatically generated drawing as a by-product
  - \- Some degree of distortion may be introduced

Elastic Flattening (Preiner et al. 2018)



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- **A1:** Flattening of vase body
  - Solids of revolution can be cut open and unrolled
  - Also for images is vessel shape is visible

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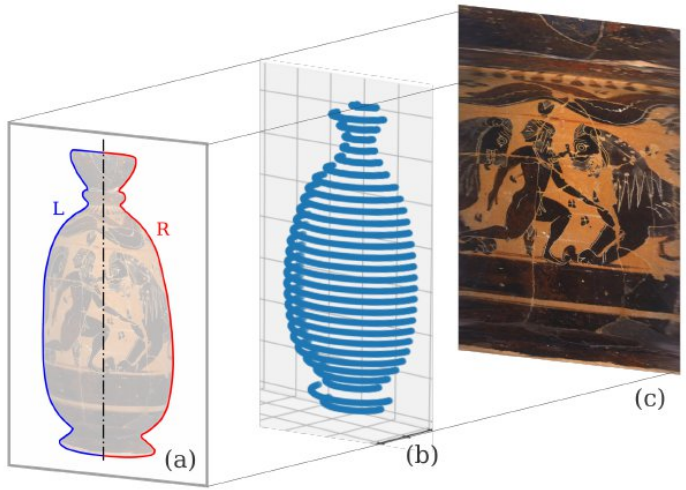

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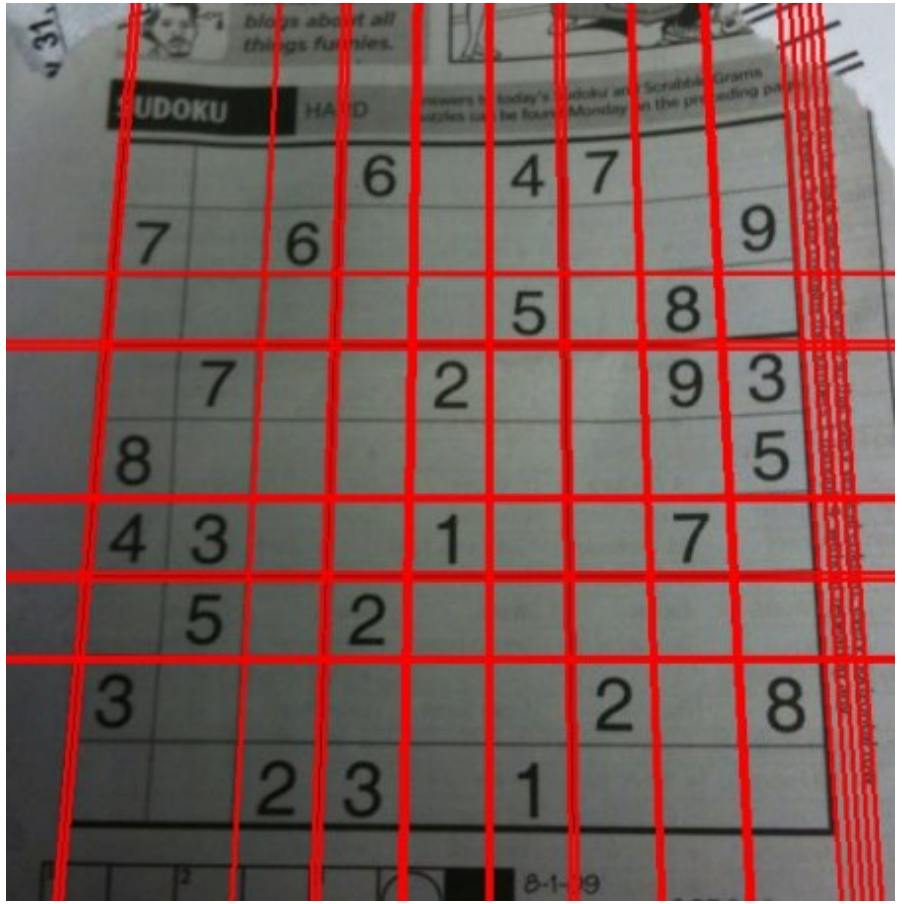
    - User-in-the-loop for interactive error correction



Hough Line Transform
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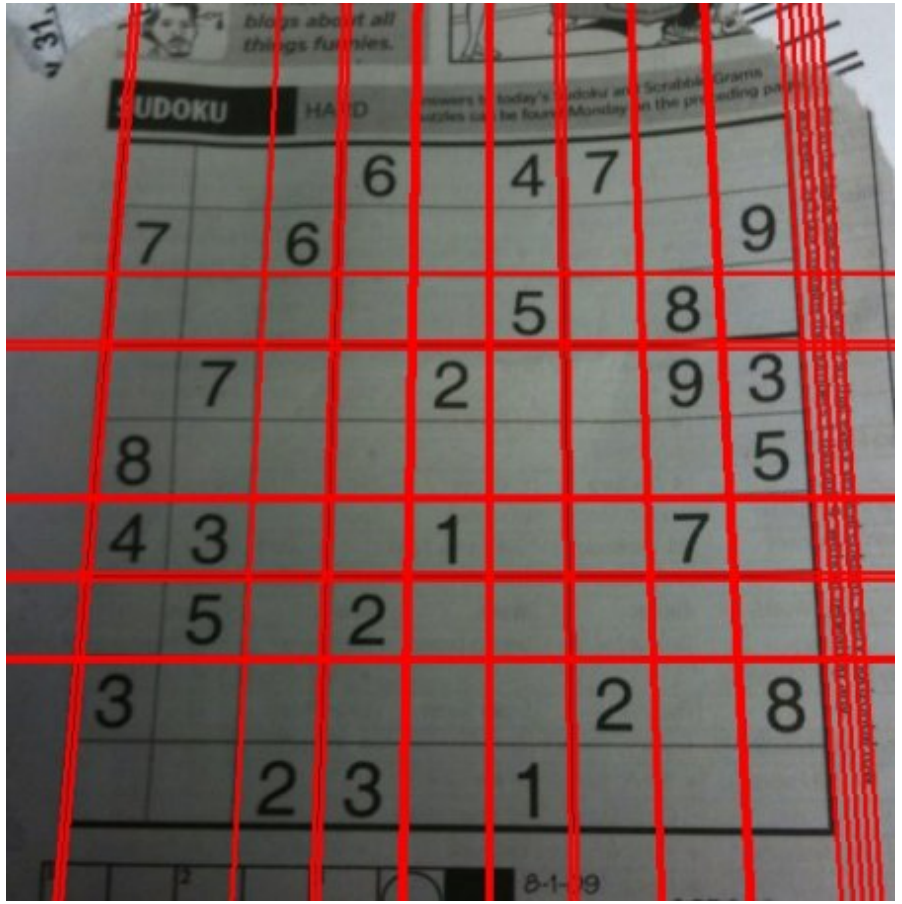
- **A2:** Curve detection
  - Contrast enhancement/thresholding/filtering
  - Curve/circle/… Detection
    - Sobel/Laplacian/Canny Edge Detection
    - Hough Transform



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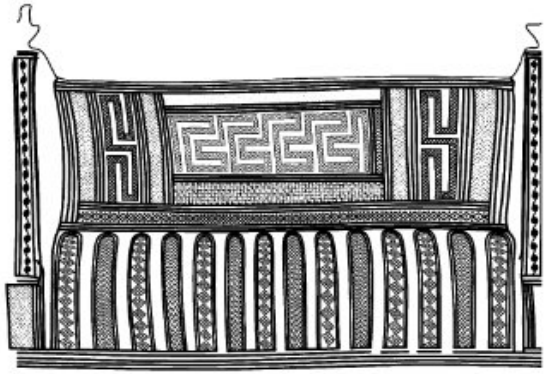
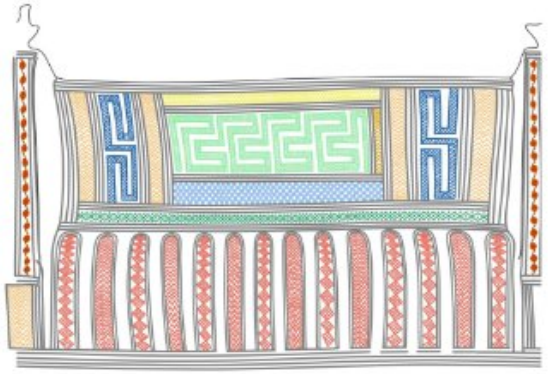


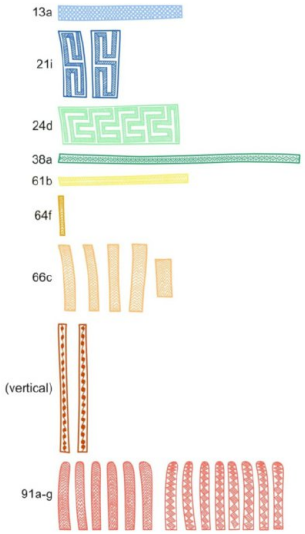
(a) Digital Copy

(b) Stroke Lines

WP2

WP3





(d) Classified Surface

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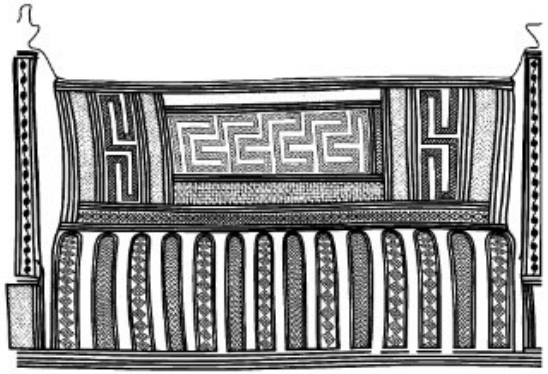

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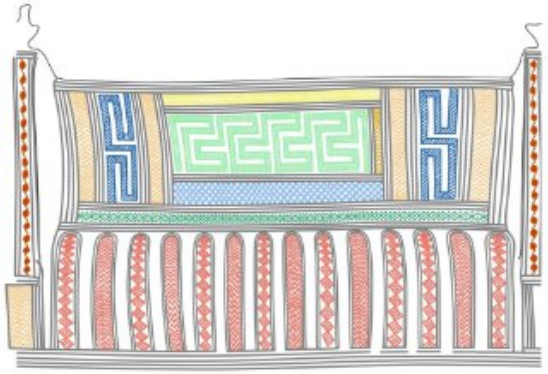
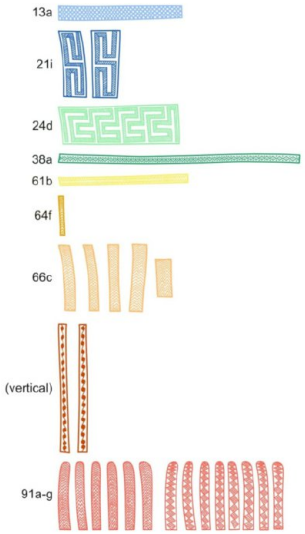




(d) Classified Surface

WP2: Cascaded Hierarchic Segmentation and Classification

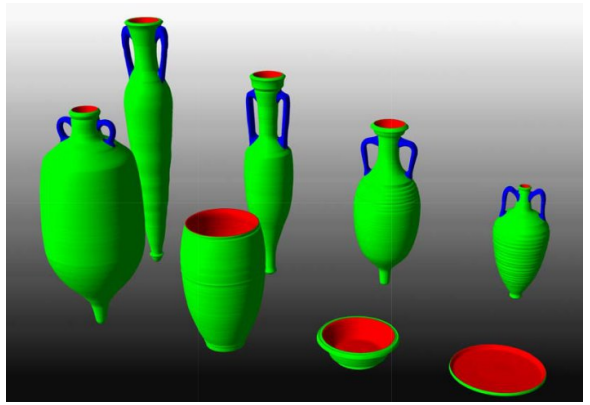
- Cascaded segmentation
  - Part-out the vase painting into ever smaller coherent parts (down to ornaments)
  - Different hierarchy levels
    1. Registers
    2. Ornament groups
    3. Individual ornaments
  - (Error correction by human-in-the-loop)

Semantic Segmentations (Lengauer et al. 2019)

WP2: Cascaded Hierarchic Segmentation and Classification

- Cascaded segmentation
  - Part-out the vase painting into ever smaller coherent parts (down to ornaments)
  - Different hierarchy levels
    1. Registers
    2. Ornament groups
    3. Individual ornaments
  - (Error correction by human-in-the-loop)
- Ornament classification
  - Base taxonomy from (Kunisch 1998)
  - Purposely trained CNN
    - Parametric descriptions of pattern classes
    - Automatically generated synthetic training data

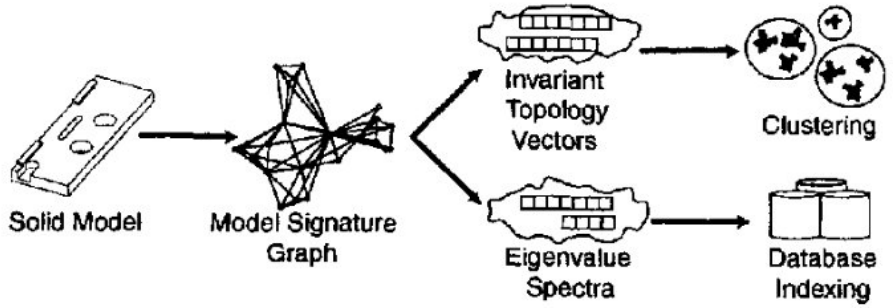
Semantic Segmentations (Lengauer et al. 2019)



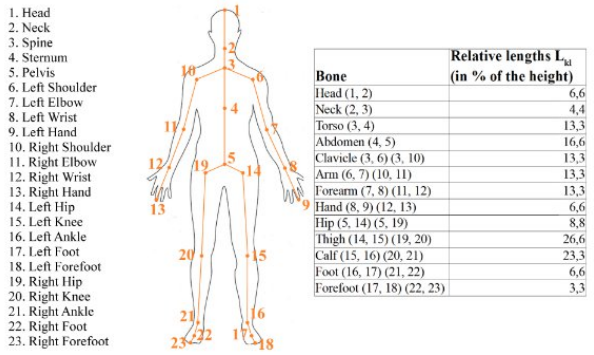
VaseSketch (Banterle et al. 2017)

WP3: Model-based Recognition and Classification

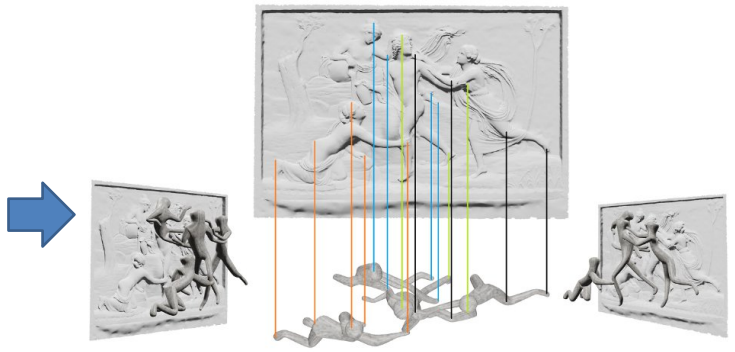
- **H:** Both vase painting and reference ornaments composed of a set of atomic shapes (lines, curves, circles) with relations
- **A:** Model-based approaches
  - Decomposition of vase paintings into atomic building blocks
    - cf. “part-out” methods from 3D processing
    - Indirectly available through line detection (WP1)
  - Description as relation graph
    - Also for reference ornaments
  - Subgraph Matching
    - NP-hard but approximate solutions for practical applications



Database Retrieval (McWherter et al. 2001)



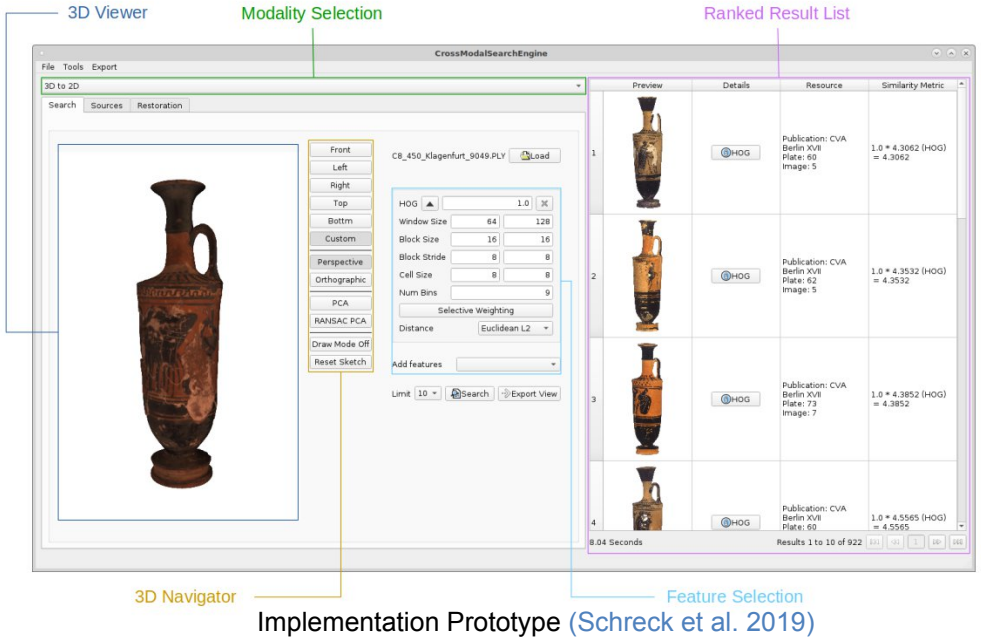
Bone	Relative lengths L_{xi} (in % of the height)
Head (1, 2)	6,6
Neck (2, 3)	4,4
Torso (3, 4)	13,3
Abdomen (4, 5)	16,6
Clavicle (3, 6) (3, 10)	13,3
Arm (6, 7) (10, 11)	13,3
Forearm (7, 8) (11, 12)	13,3
Hand (8, 9) (12, 13)	6,6
Hip (5, 14) (5, 19)	8,8
Thigh (14, 15) (19, 20)	26,6
Calf (15, 16) (20, 21)	23,3
Foot (16, 17) (21, 22)	6,6
Forefoot (17, 18) (22, 23)	3,3



3D Scenes from Bas-Reliefs (Casati et al. 2019)

WP4: Interactive Visualization and Human-in-the-loop

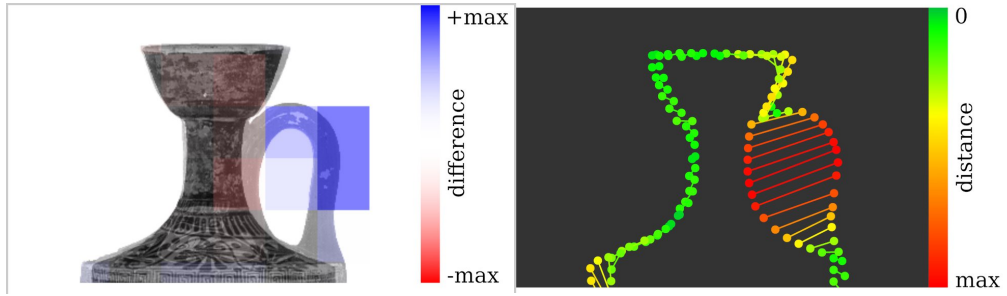
- Interactive Visualization
  - Visualization Framework
    - Data Management (loading, editing, viewing)
      → (3D) viewer, editor
    - Method Execution → setting hyperparameters
  - Visualization of intermediate steps
    - Explainability and debugging



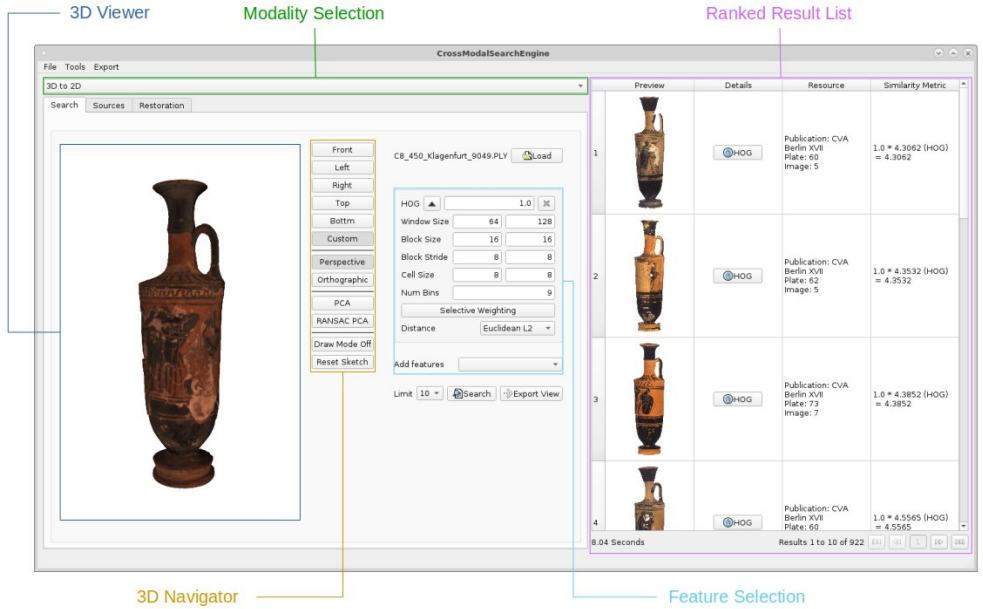
Implementation Prototype (Schreck et al. 2019)

WP4: Interactive Visualization and Human-in-the-loop

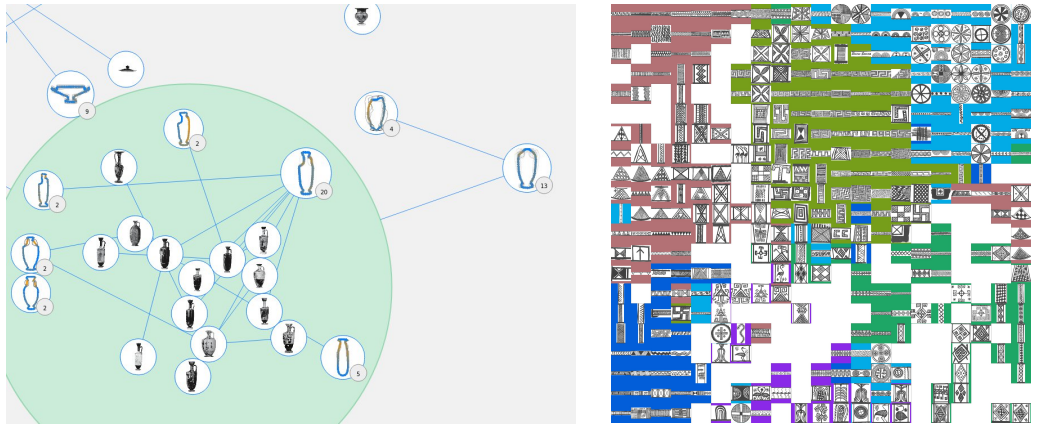
- Interactive Visualization
  - Visualization Framework
    - Data Management (loading, editing, viewing)
      → (3D) viewer, editor
    - Method Execution → setting hyperparameters
  - Visualization of intermediate steps
    - Explainability and debugging
  - Result(s) visualization
    - Micro Level: explanation for a certain result → Errormap
    - Macro Level: similarity clusters, overall structures



Descriptor Visualization (Lengauer et al. 2020)



Implementation Prototype (Schreck et al. 2019)



Objects Similarities (Lengauer et al. 2020, Lengauer et al. 2022)

WP4: Interactive Visualization and Human-in-the-loop

- Human-in-the-loop concepts/Feedback Interfaces
  - Correction erroneous segmentations → Sketching

Providing Shape Hypothesis through Sketching
(Lengauer et al. 2019)

WP4: Interactive Visualization and Human-in-the-loop

- Human-in-the-loop concepts/Feedback Interfaces
  - Correction erroneous segmentations → Sketching
    - Guidance through segmentation hypotheses (cf. Shadowdraw)

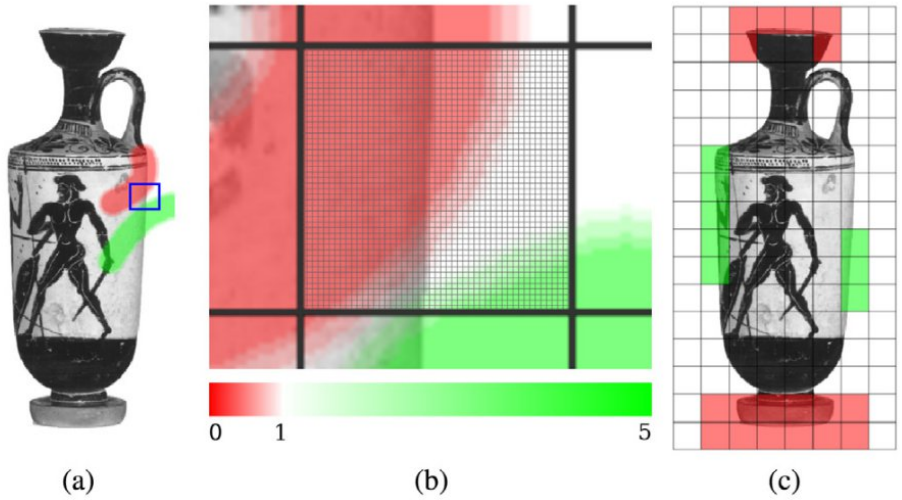
Completion Hypotheses as Guidance (Lee et al. 2011)

Providing Shape Hypothesis through Sketching (Lengauer et al. 2019)

WP4: Interactive Visualization and Human-in-the-loop

- Human-in-the-loop concepts/Feedback Interfaces
  - Correction erroneous segmentations → Sketching
    - Guidance through segmentation hypotheses (cf. Shadowdraw)
    - Setting focal points/weights

Completion Hypotheses as Guidance (Lee et al. 2011)

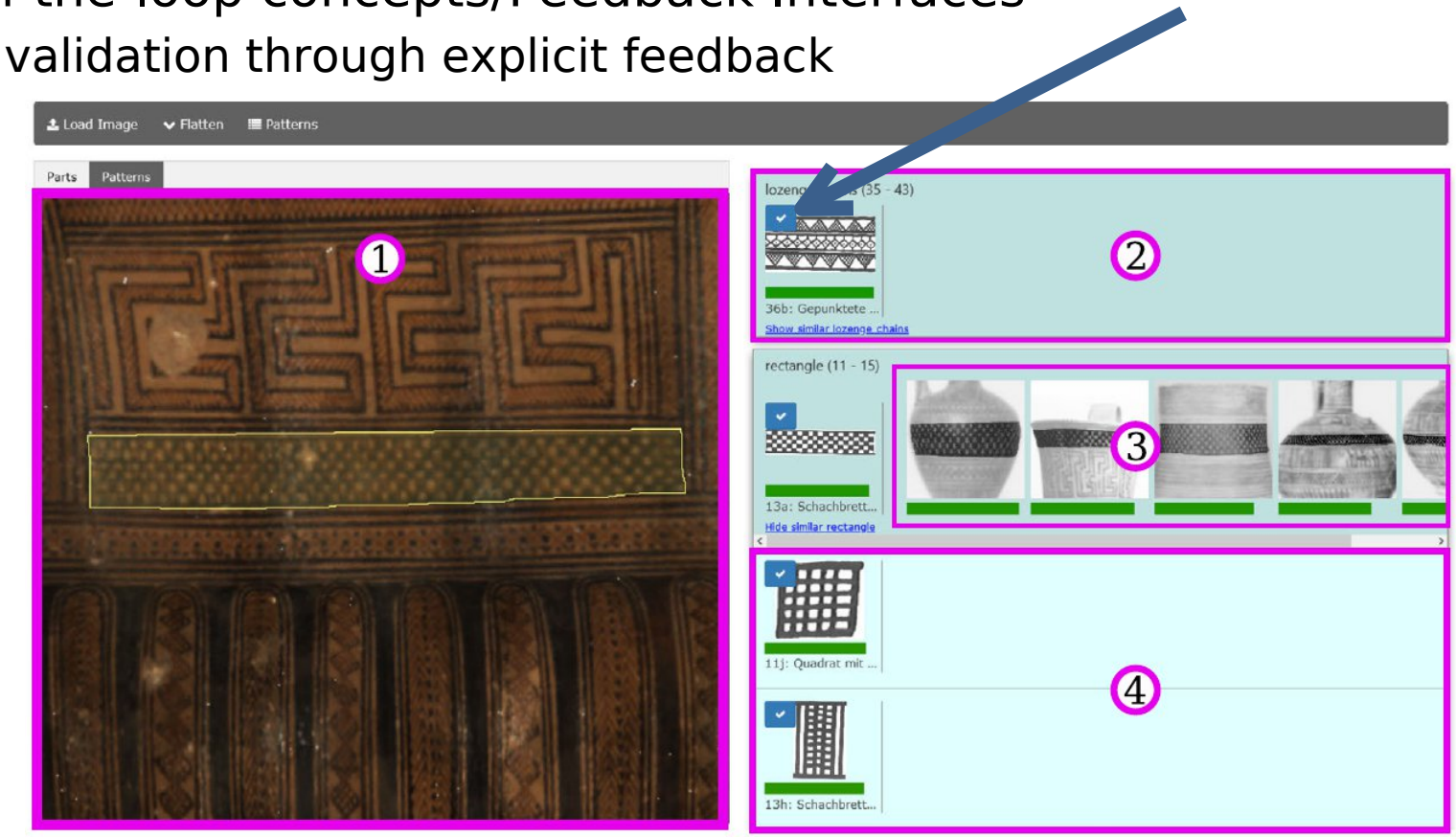


Setting Relevance Weight through Custom Interfaces (Lengauer et al. 2020)

Providing Shape Hypothesis through Sketching (Lengauer et al. 2019)

WP4: Interactive Visualization and Human-in-the-loop

- Human-in-the-loop concepts/Feedback Interfaces
  - Result validation through explicit feedback



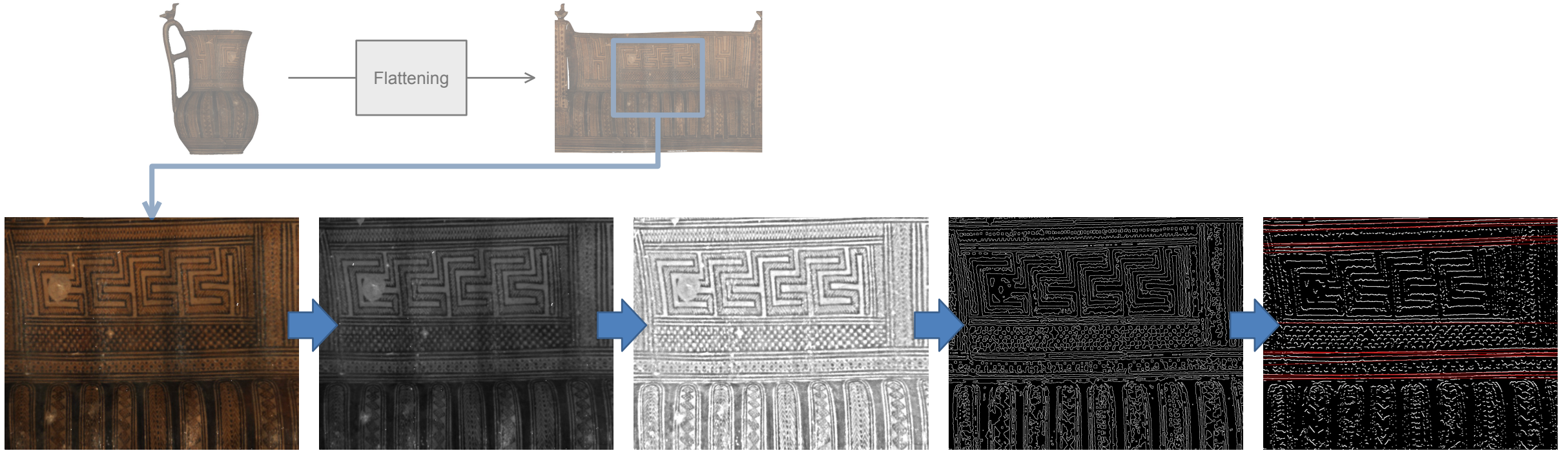
Feedback Interface (Lengauer et al. 2022)

Ongoing Work & Outlook

Ongoing Work & Outlook

Two ongoing Bachelor theses

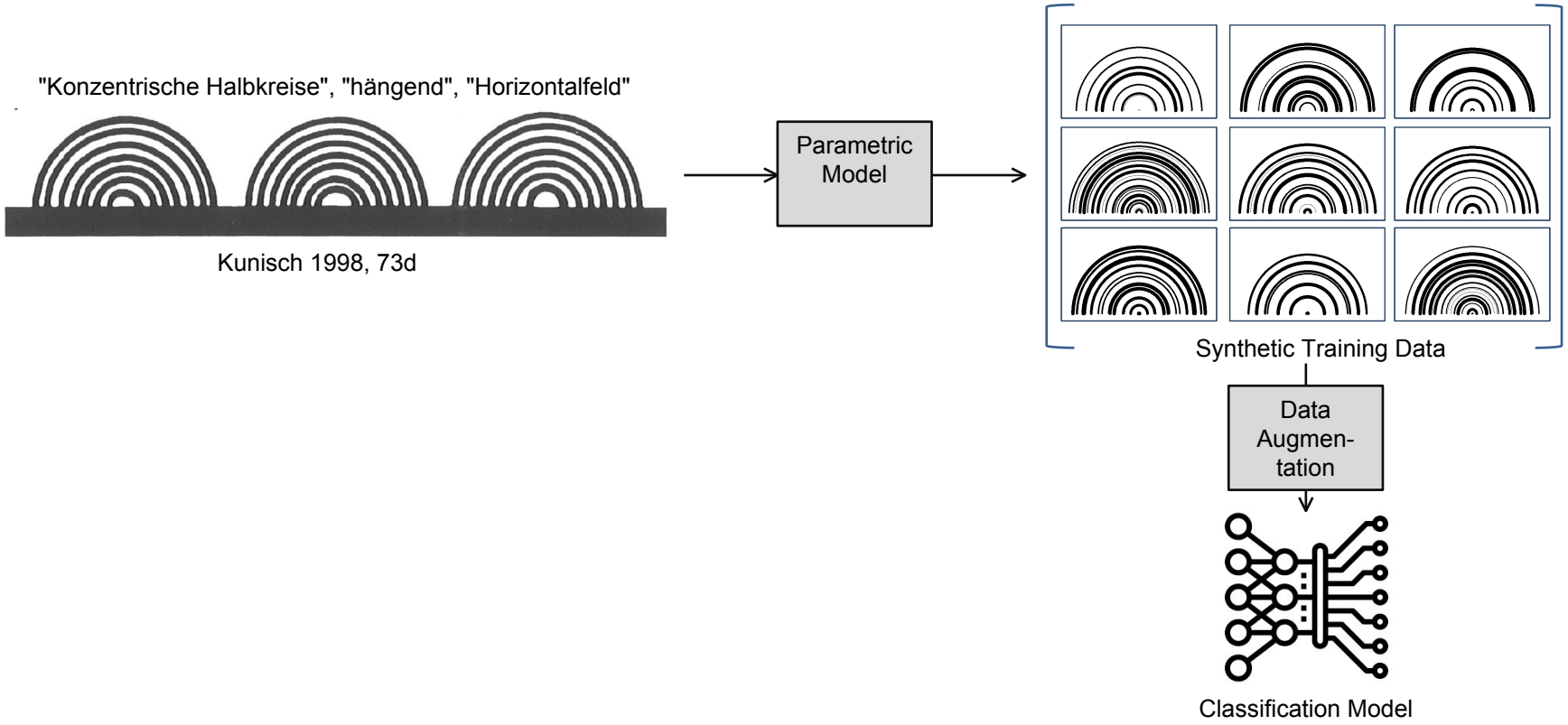
- Daniel Pascal Unger - *Automatic stroke detection in ancient vase paintings* (cf. **WP1**)



Ongoing Work & Outlook

Two ongoing Bachelor theses

- Patrick Balent - *Deep learning for classification of Geometric patterns* (cf. **WP2**)



Ongoing Work & Outlook

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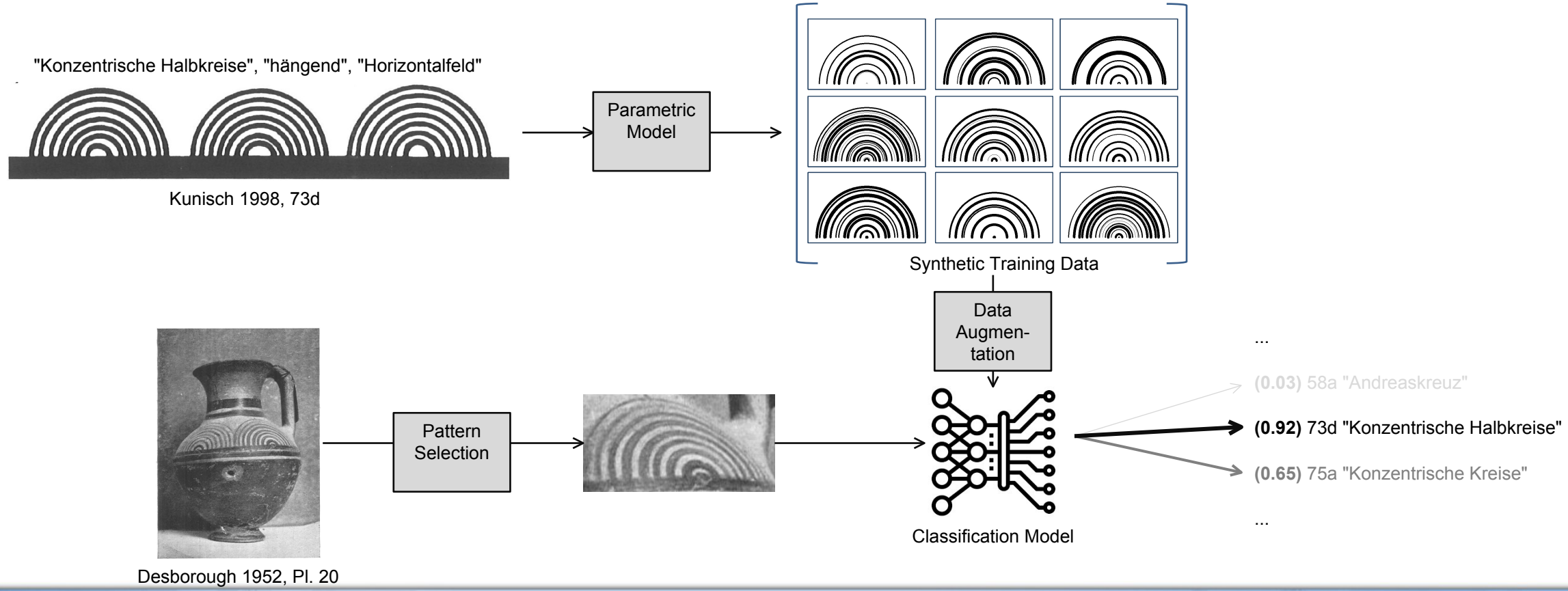
- Patrick Balent - *Deep learning for classification of Geometric patterns* (cf. **WP2**)



Thank You

73c Konzentrische Halbkreise, hängend, innen schwarze Balken, Horizontalfeld
Concentric semicircles, pendent, in the centre solid bars, horizontal panel
Demi-cercles concentriques, pendants, aux centre poteau noir, panneau horizontal
Semicerchi concentrici, penduli, al centro bastoncelli neri, campo orizzontale
Ομόκεντρα ημικύκλια, κρεμάμενα, στον κεντρικό δίσκο μελανές ταινίες, οριζόντια ζώνη
thesPG **Desborough 1952 Taf. 20**