Crossmodal Search and Visual Exploration of Digital Cultural Heritage Objects

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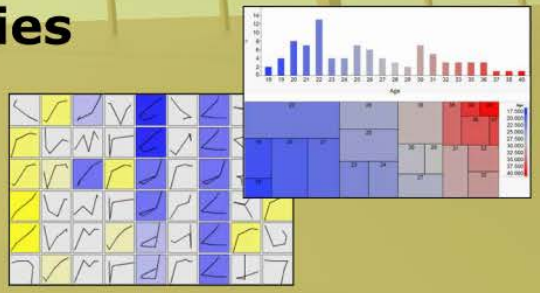
3D Modelling and Processing
Computer Aided Geometric Design
Procedural Modelling
Physics-based Modelling
3D Object Retrieval
3D Restoration

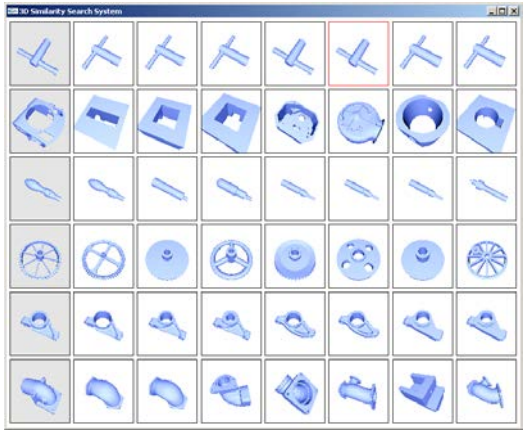
Simulation and Analysis
Analysis and Visualization of
Geometric Information
Isogeometric Analysis
Virtual Reality

Visual Analytics and Digital Libraries
Visual-Interactive Data Exploration
Search Interfaces and
Semantic Annotation
Submission and Review System



Motivation – Many 3D Applications

- Engineering
- Architectural Design
- Simulation and Visualization
- Molecular Biology
- Cultural Heritage & Archaeology



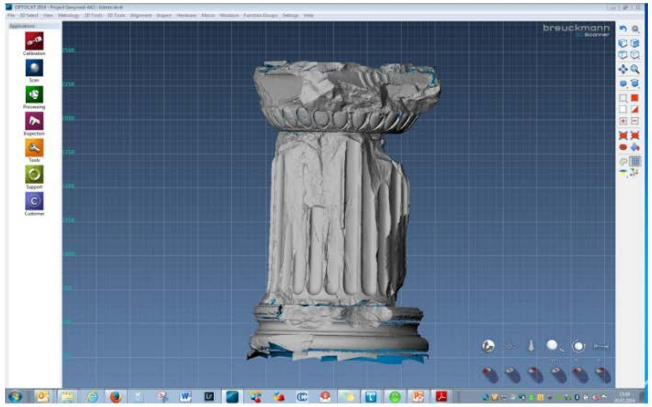
Purdue Engineering Benchmark [JKIR 2006]

Nidaros cathedral artifacts
[http://www.presious.eu/]

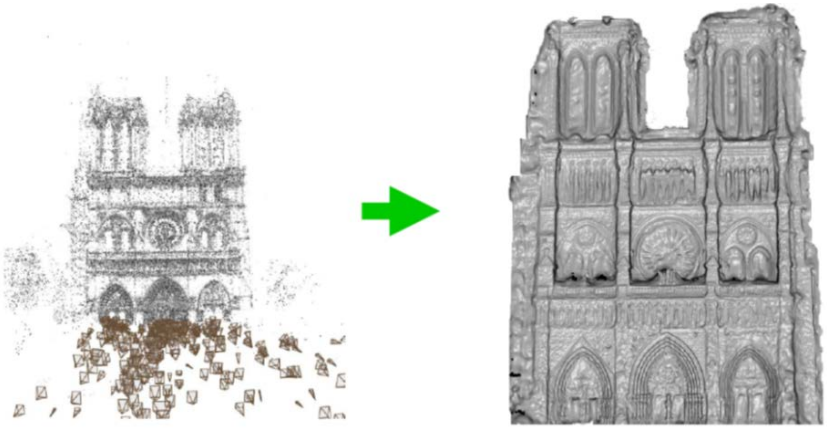
Probado3D Repository
[http://www.probado.de/]

Motivation – 3D Data and “Big” 3D Data

CultLab3D, Fraunhofer IGD
(http://www.cultlab3d.eu/)



High-precision scanning
(Dirk Rieke-Zapp, PRESOUS, AICON 3D)



Kinect Sensor
(Microsoft)

3D reconstruction from crowd photos (courtesy of Michael Goesele) http://www.gris.informatik.tu-darmstadt.de/~mgoesele/

3D Technology in Cultural Heritage

- Documentation and presentation
- Long term preservation
- Restoration
- Search and Comparison
- Classification, typologies
- Domain-specific measurements and analyses
- ...

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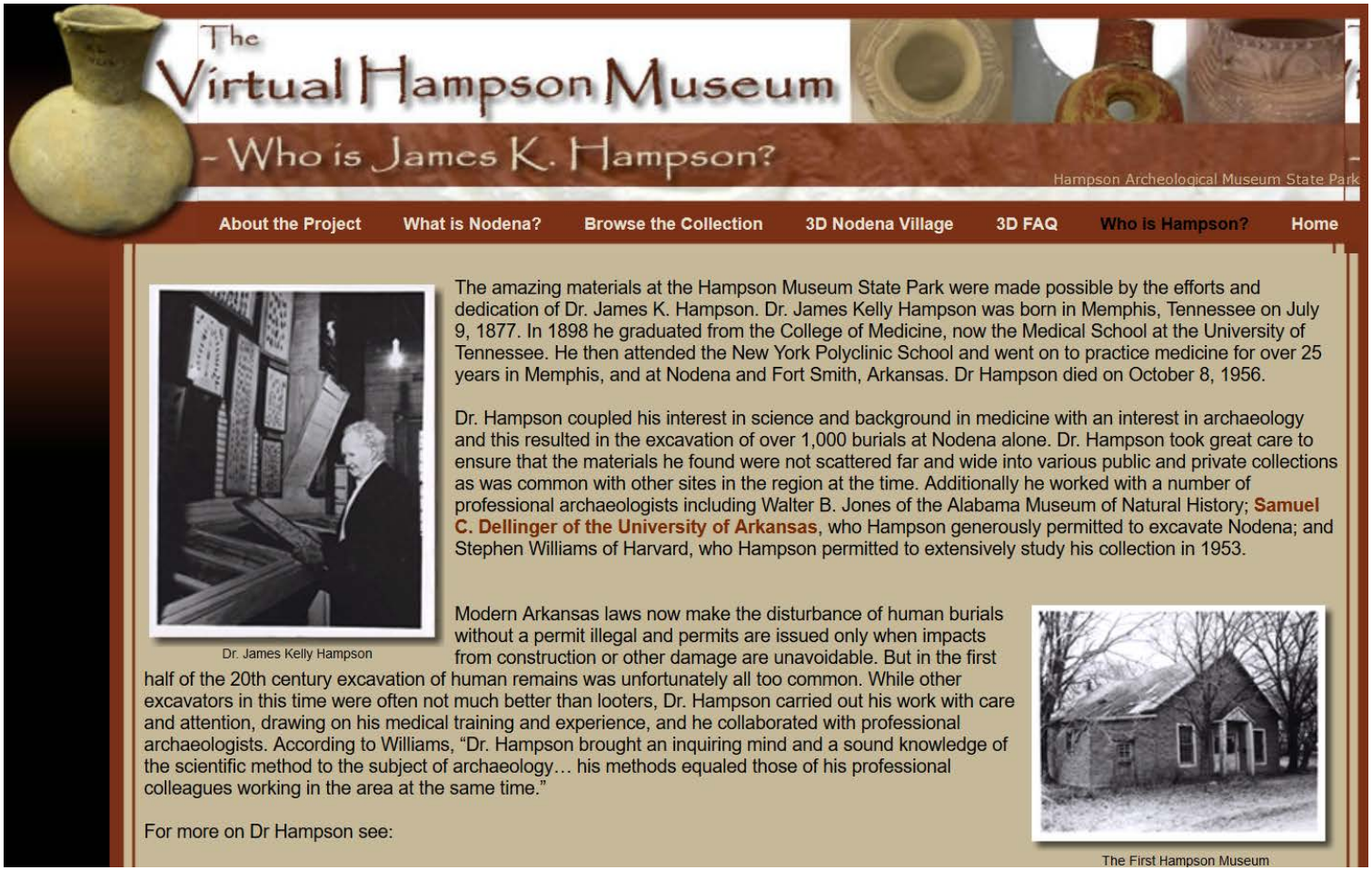
Virtual Hampson Museum



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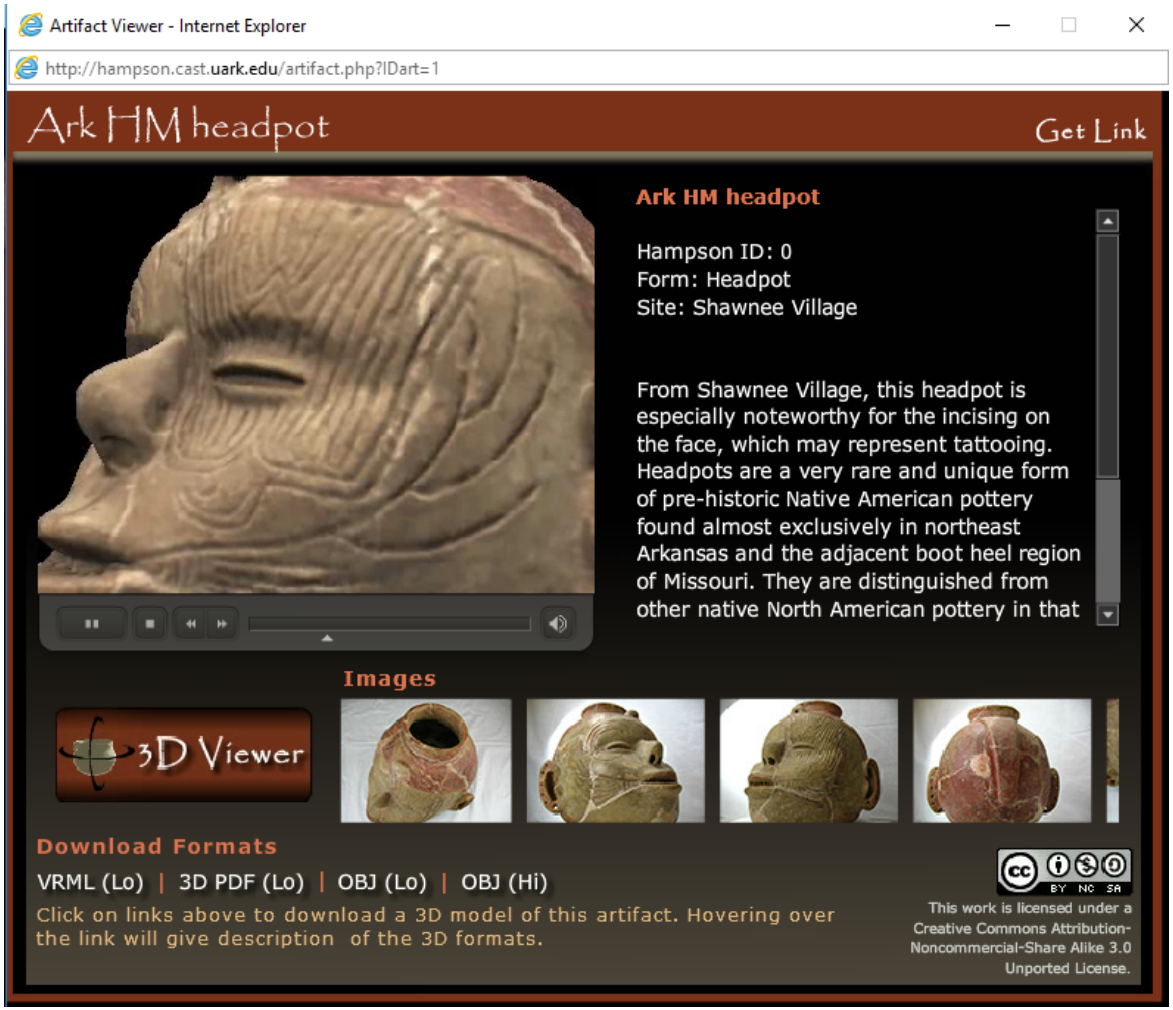

Case Study: Pergamon Web

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- **Restoration**
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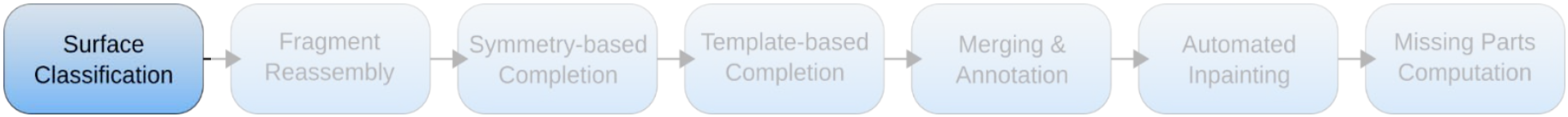
- ...

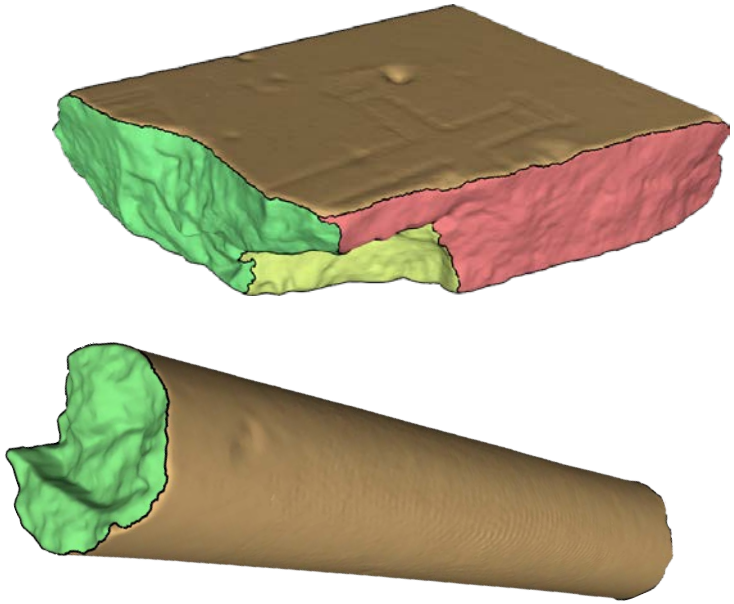
EU Project PRESIOUS (2013-16) Restoration of 3D Archaeologic Data

- Tools for Virtual Archaeology
- Work packages:
  - Predictive scanning
  - Degradation assessment
  - Fragment reassembly
  - Similarity-based object completion and repair

http://www.presious.eu/

Workflow for Virtual Restoration





Fracture surface segmentation is done by clustering or region growing using roughness measure

$$R_r(\mathbf{p}) = \frac{1}{N} \sum_{i=1}^{N} \|\mathbf{n} - \mathbf{n}_i\|^2$$

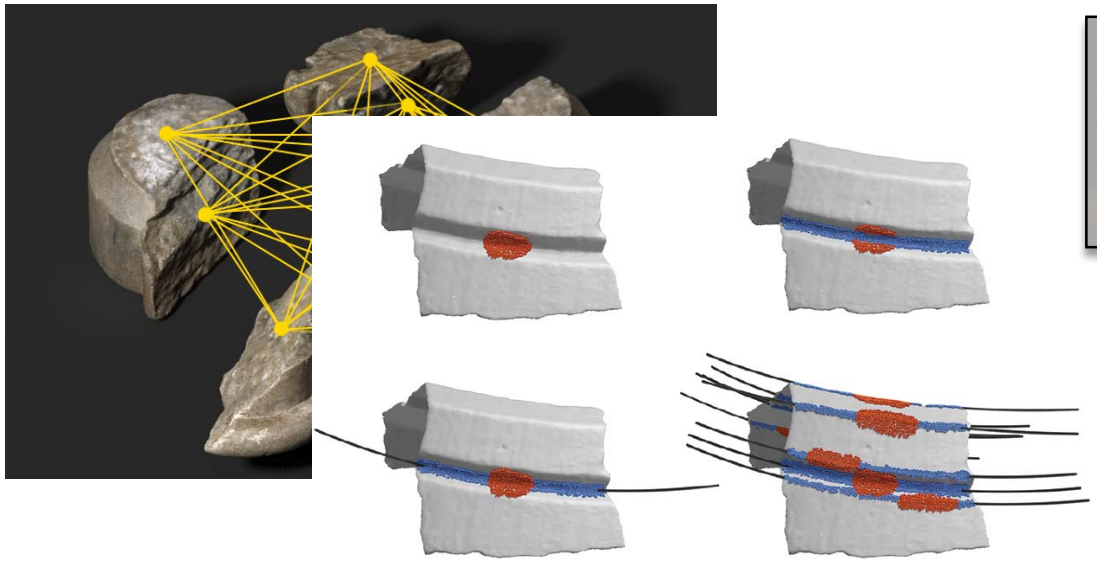
Roughness **R** at Vertex **p** and radius **r**

Set **N** of vertices within radius **r** around **p**

Norm of difference between normal **n** at p and normal $\mathbf{n_i}$ at vertex i in N

Workflow for Virtual Restoration

Surface Classification → **Fragment Reassembly** → Symmetry-based Completion → Template-based Completion → Merging & Annotation → Automated Inpainting → Missing Parts Computation



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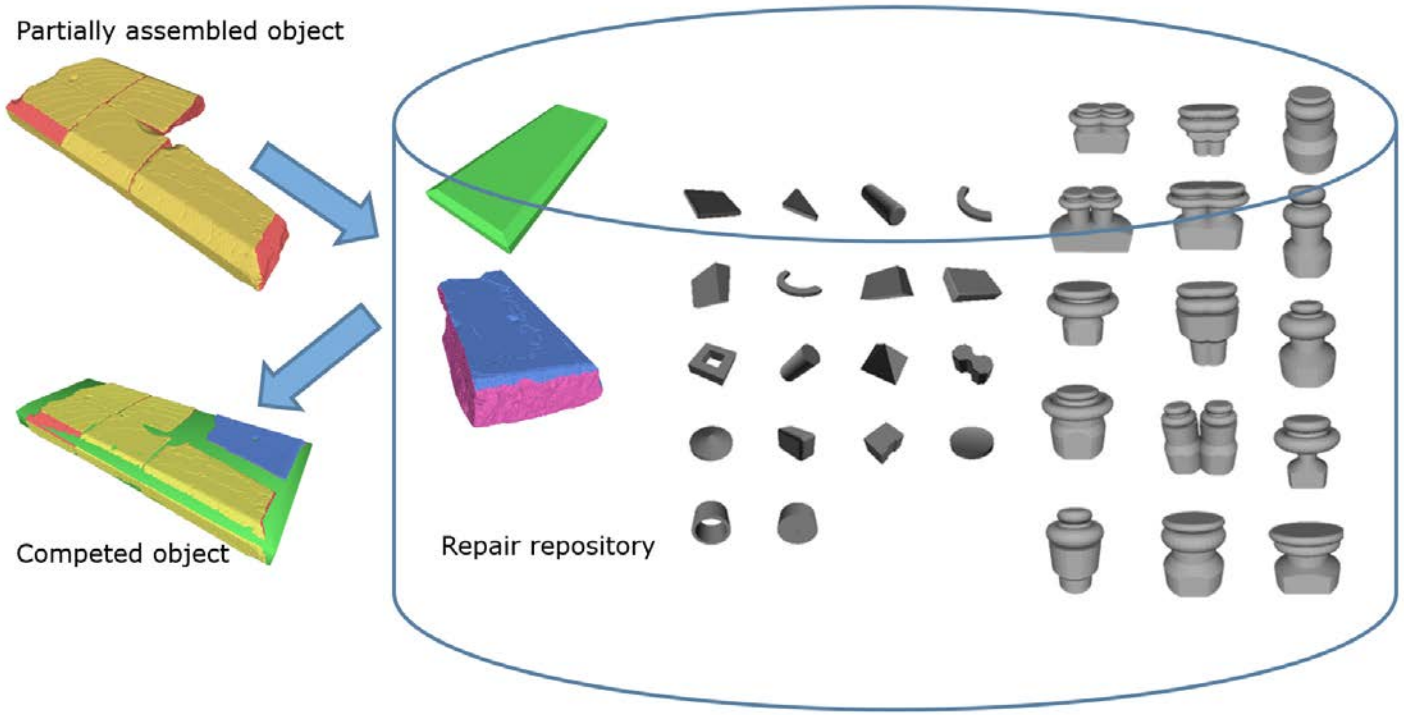

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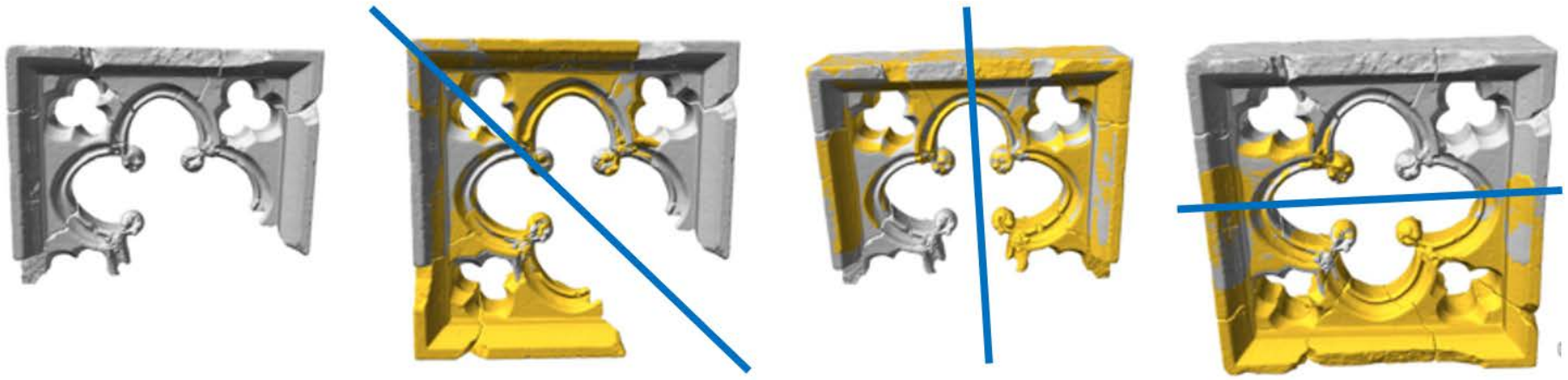

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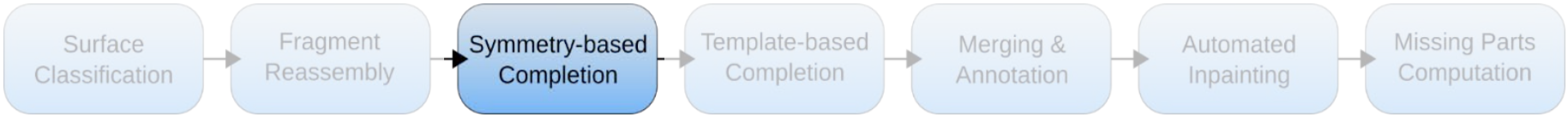

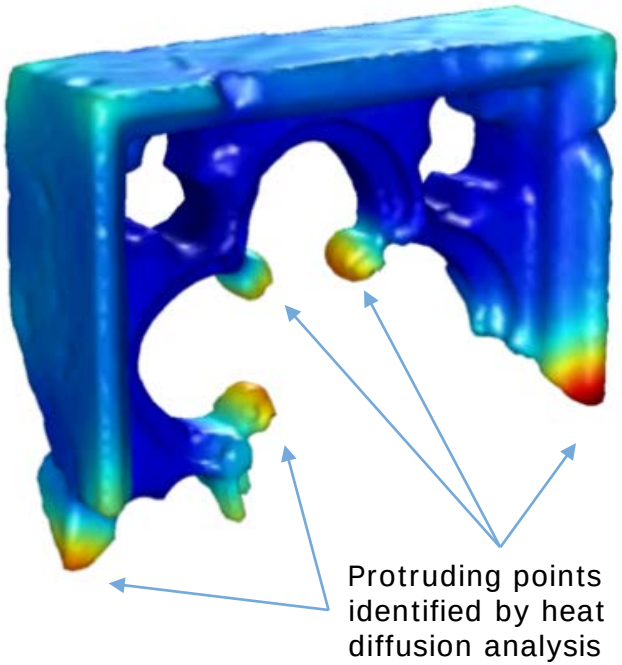

Heat kernel: heat flow from x to y at time t:

$$K_t(x,y) = \sum_{i=0}^{\infty} e^{-\lambda_i t}\phi_i(x)\phi_i(y)$$

Heat flow from x to x at time t:

$$h(x,t) = K_t(x,x) = \sum_{i=0}^{\infty} e^{-\lambda_i t}\phi_i(x)^2$$

Measure of retained heat at x at time t:

$$\mathcal{H}(x,t) = \int_0^t h(x,t)dt$$

Workflow for Virtual Restoration

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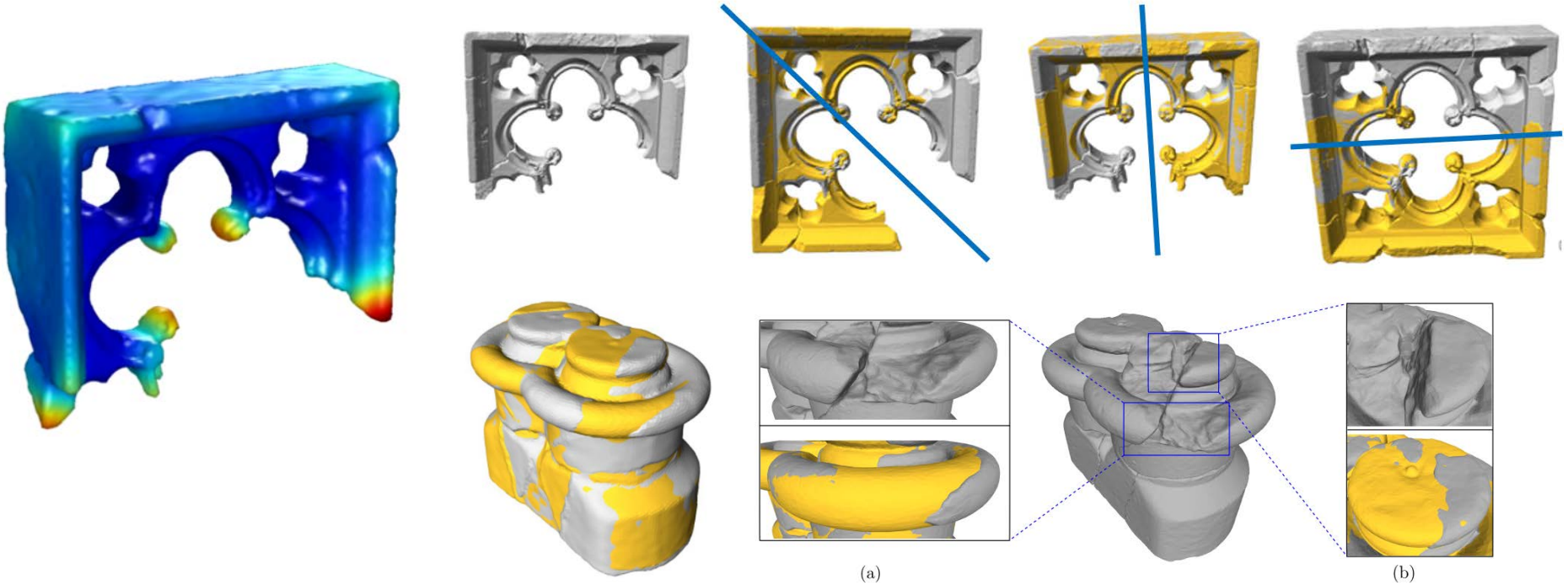

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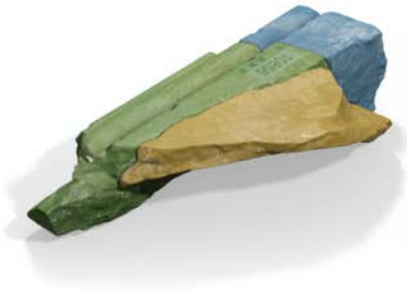
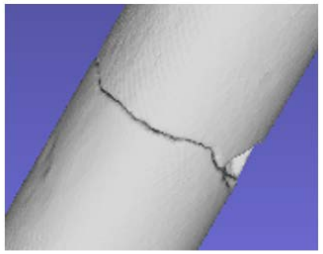
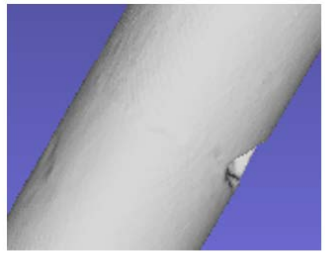




Input

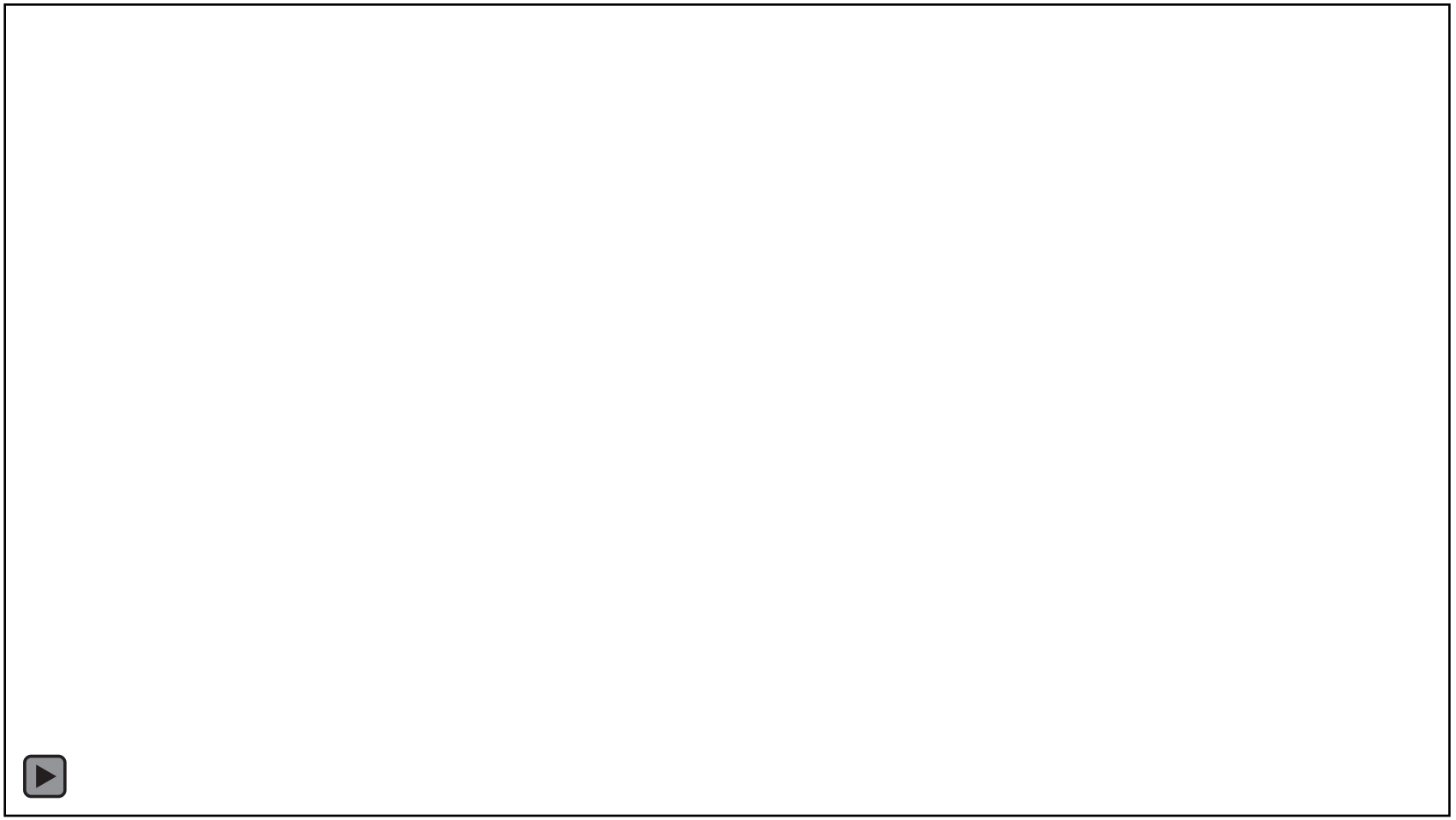


Watertight output

Virtual Shape Completion with AR Technology (Hololens)

Courtesy of:
Dr. Pavlos Mavridis (3D restoration), Dr. Volker Settgast (Holonens experiment)

(autoplay)



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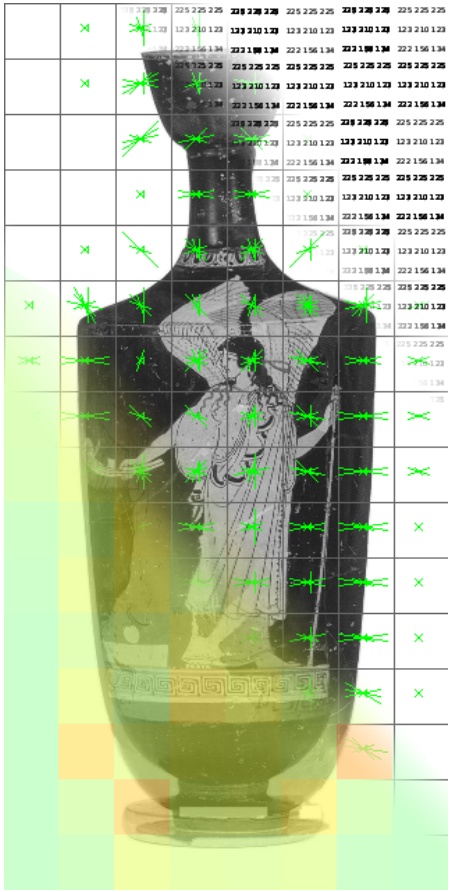


FWF Research Project 2018 – 2021
https://www.tugraz.at/institute/cgv/research/projects/crosssave-ch/

Crossmodal Search and Visual Exploration of 3D Cultural Heritage Objects (CrossSAVE-CH)

Motivation

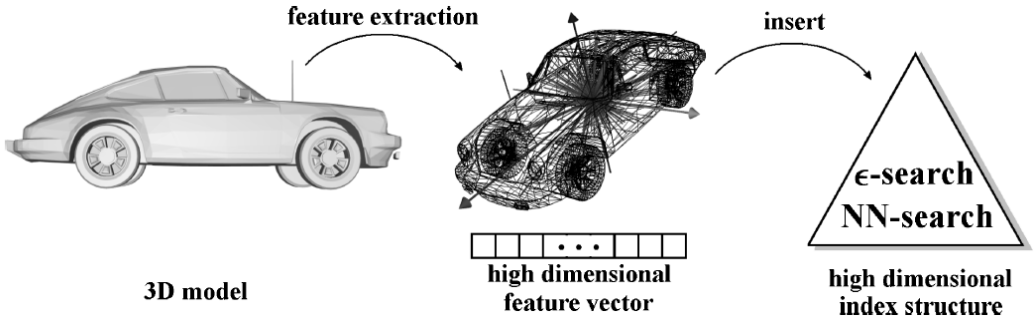
- In cultural heritage research, often **objects need to be compared based on shape and image** properties
  - For example, for painter and potter attribution in vessels; exploring trading routes, stylistic influence etc.
- Problems in practice
  - Object documentation often is given in different modalities (3D, 2D, sketch, diagram, textual description, …)
  - Documentation distributed and/or not fully digitized

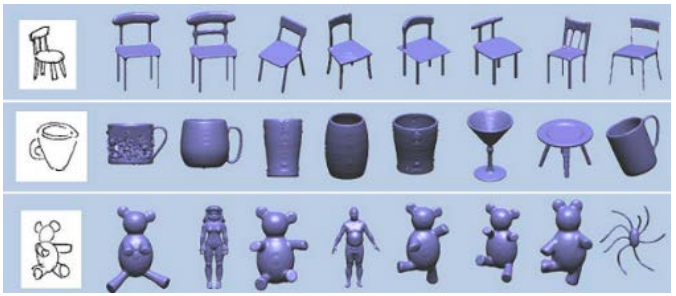
In this project we want:

- ***to research shape- and image-based search techniques***
- ***to build a crossmodal search engine, including document and shape visualization***
- ***to apply and evaluate the techniques in Archaeologically relevant use cases and on real data (3D objects, CVA publications, web repositories etc.)***

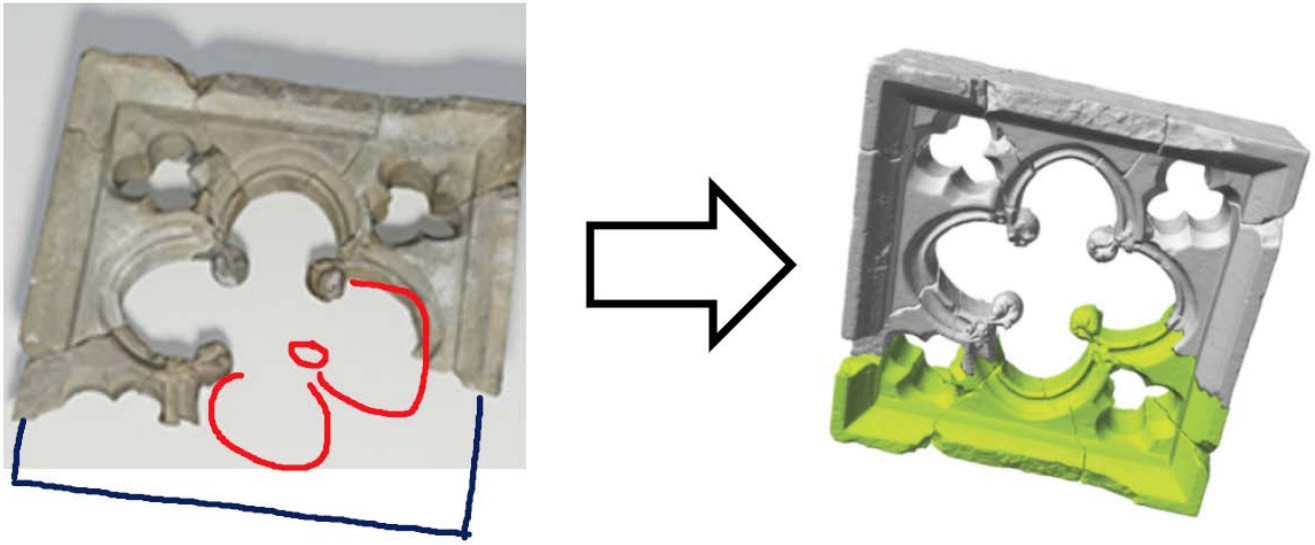
3D Object Retrieval

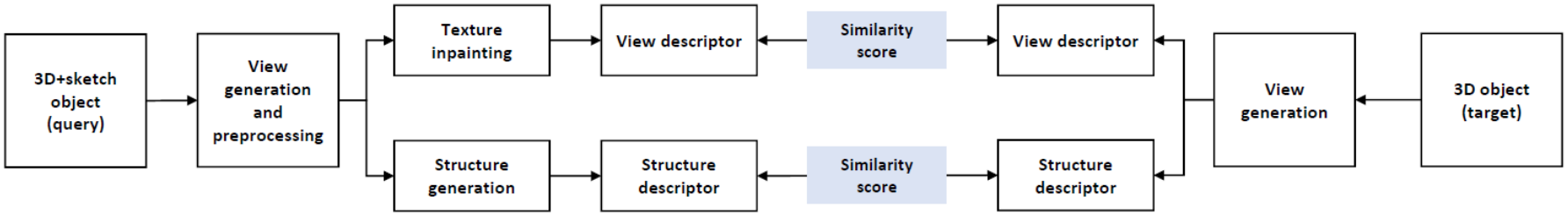
- Search for similar 3D objects given a query
  - Example object
  - User sketch
- Problem: Definition of similarity function
- Our approaches
  - Feature-based retrieval
  - Sketch-based retrieval



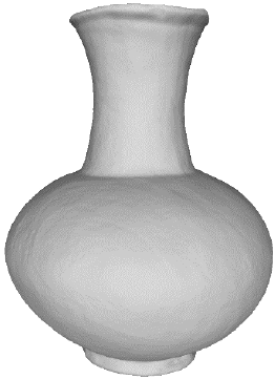


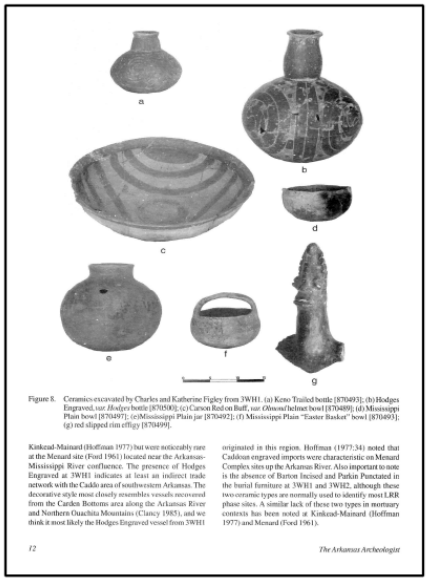
Work Package 1: Searching for 3D Objects with Hybrid 3D+Sketch Queries

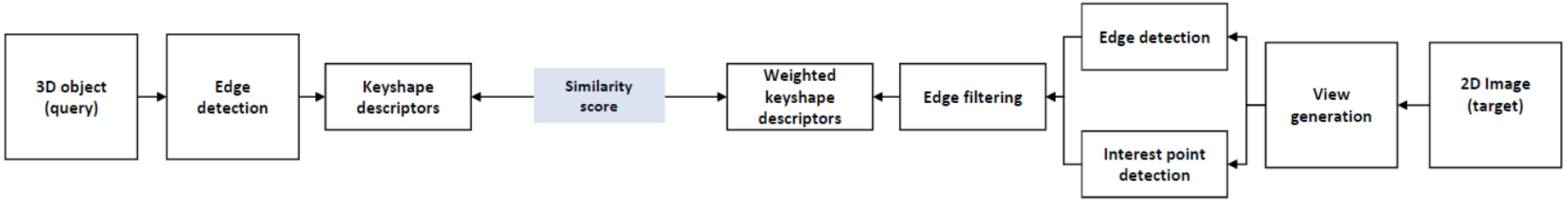




Work Package 2: Finding Occurrences of 3D Objects in Images

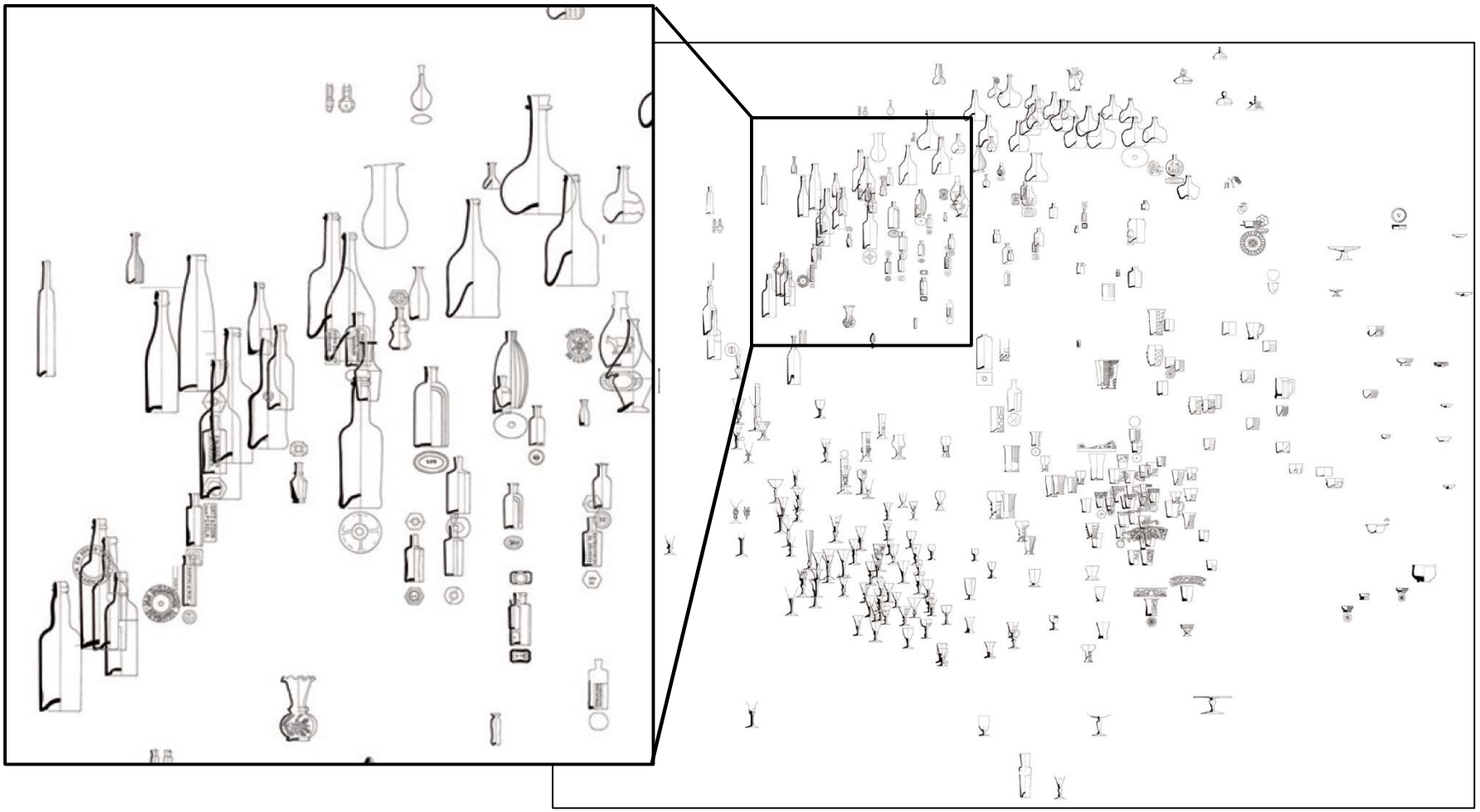






We want to test/compare feature engineering with deep learning approaches

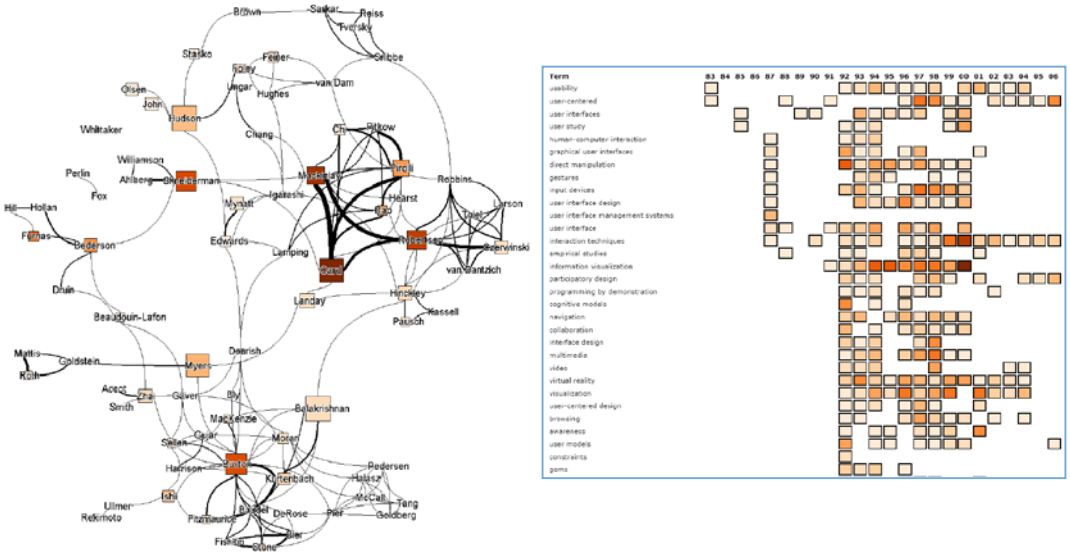
4.3 Work Package 3: Interactive Prototype and Result Visualization



van der Maaten et al., CAA 2006

4.3 Work Package 3: Interactive Prototype and Result Visualization

Topic treemap
https://github.com/topics/treemap



Authorship networks and topic/timeline matrix
Henry et al., IJCHI 2010

DEMO (Stefan Lengauer)

S. Lengauer, A. Komar, A. Labrada, S. Karl, E. Trinkl, R. Preiner, B. Bustos, and T. Schreck: Sketch-Aided Retrieval of Incomplete 3D Cultural Heritage Objects. Proc. Eurographics Workshop on 3D Object Retrieval 2019. (accepted)

Retrieval of Incomplete 3D Objects

Incomplete 3D Object

2D Target Search Space

Ranked Results

Sources

- 3D Objects
  - Attic black-figured lekythoi, 5th century BC.

Attic black-figured lekythoi, 5th century BC.
(courtesy of Landesmuseum Kärnten)

Sources

- 3D Objects
  - Attic black-figured lekythoi, 5th century BC.
- 2D Images from CVA Volumes
  - CVA Berlin XIII
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  - CVA Athens V
  - ...

Attic black-figured lekythoi, 5th century BC.
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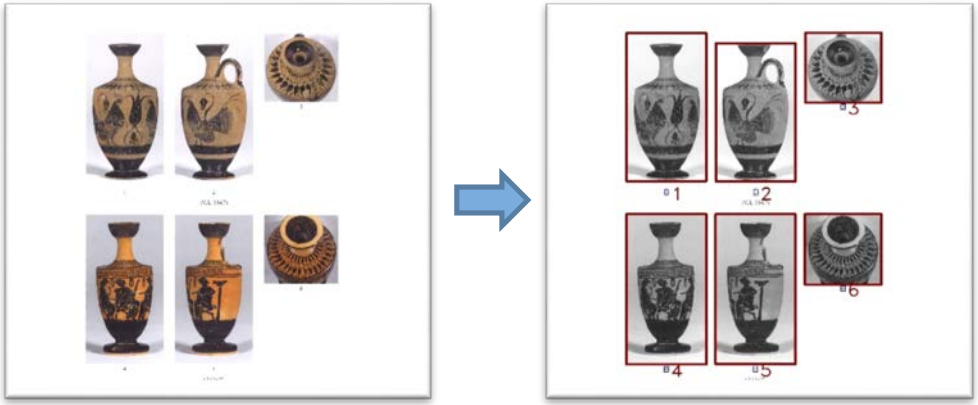

Zimmerman-Elseify "Corpus Vasorum Antiquorum Berlin, Antikensammlung 17", Deutschland 102. München, 2018

Sources

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  - CVA Athens V
  - ...
- Extraction
  - Image Segmentation
  - Number registration with OCR

Attic black-figured lekythoi, 5th century BC.
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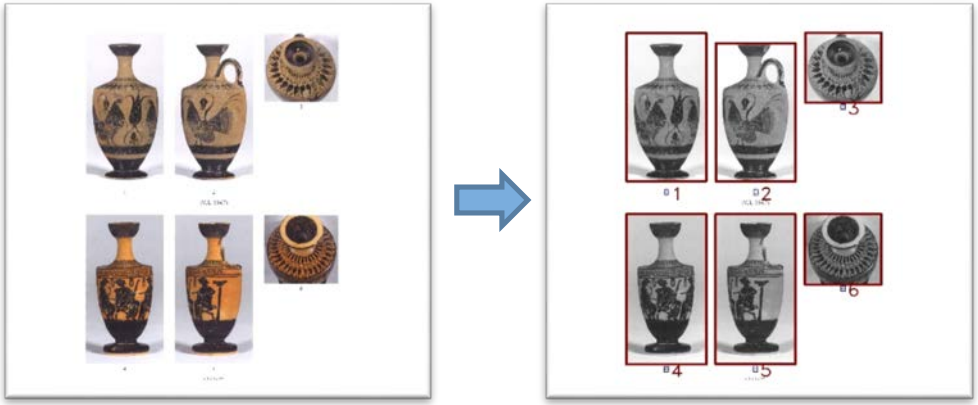
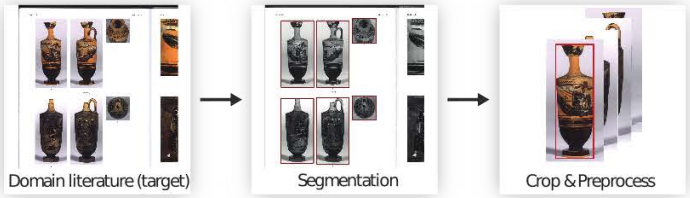


Zimmerman-Elseify "Corpus Vasorum Antiquorum Berlin, Antikensammlung 17", Deutschland 102. München, 2018

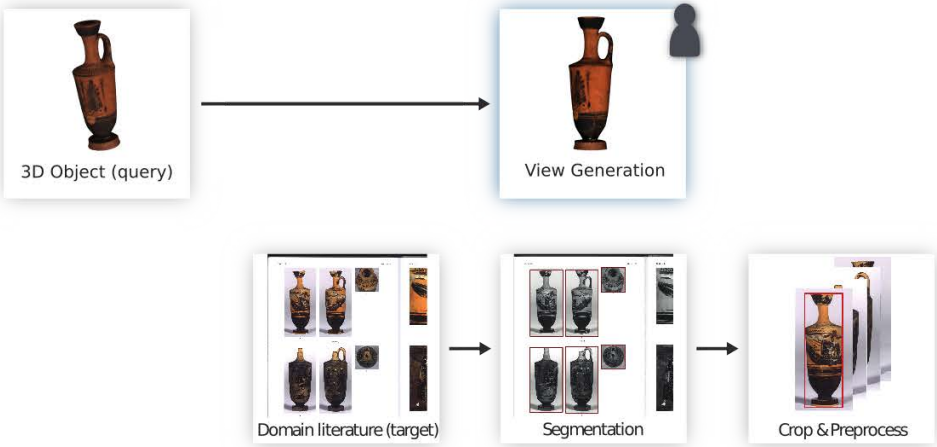
Pipeline

- 2D Search Space Preprocessing
  - Segmentation, Cropping



Pipeline

- 3D Input
  - View generation

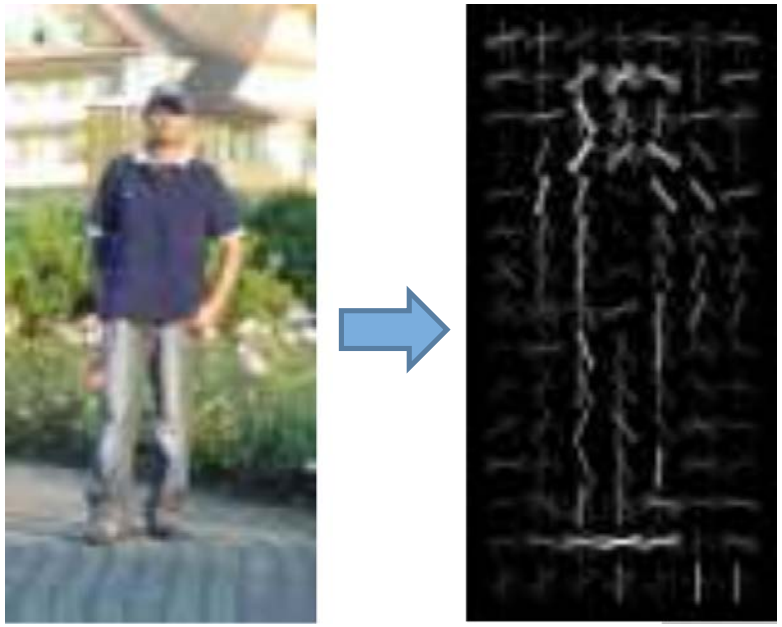


Retrieval

- View-based approach
  - Transformation of 3D object to common 2D base modality
  - Appropriate view determined by user

Retrieval

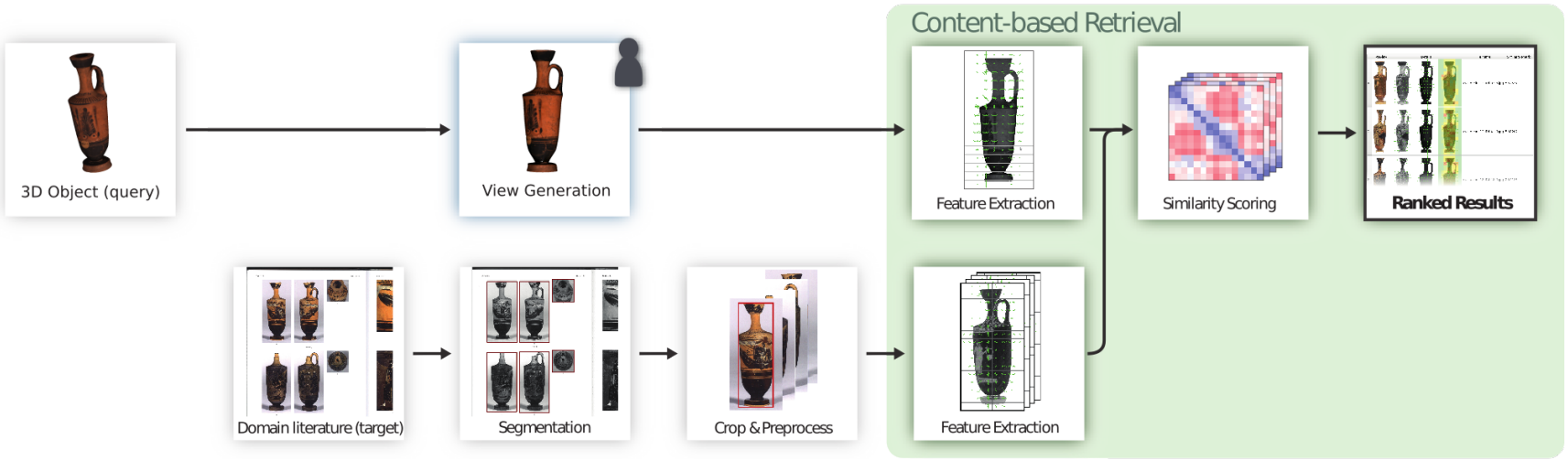
- View-based approach
  - Transformation of 3D object to common 2D base modality
  - Appropriate view determined by user
- 2D shape features
  - Histogram of oriented gradients (HOG)
  - Region-based gradient orientation and strength



Dalal, Navneet, and Bill Triggs. "Histograms of oriented gradients for human detection." *international Conference on computer vision & Pattern Recognition (CVPR'05)*. Vol. 1. IEEE Computer Society, 2005.

Pipeline

- Retrieval Process
  - Returning a list of results, raked by similarity



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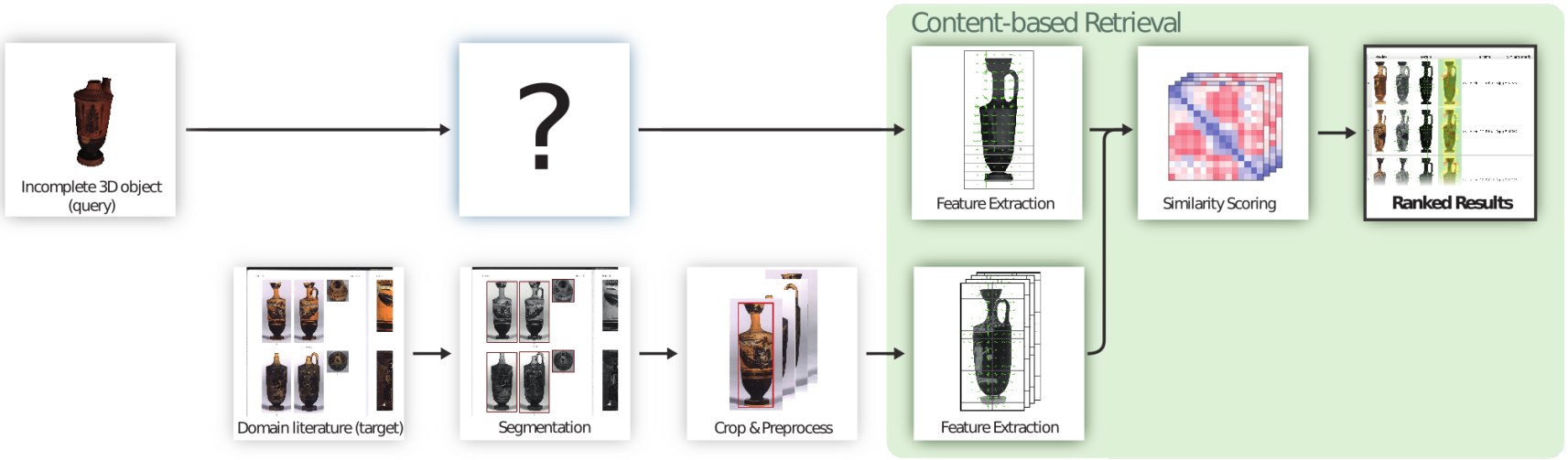
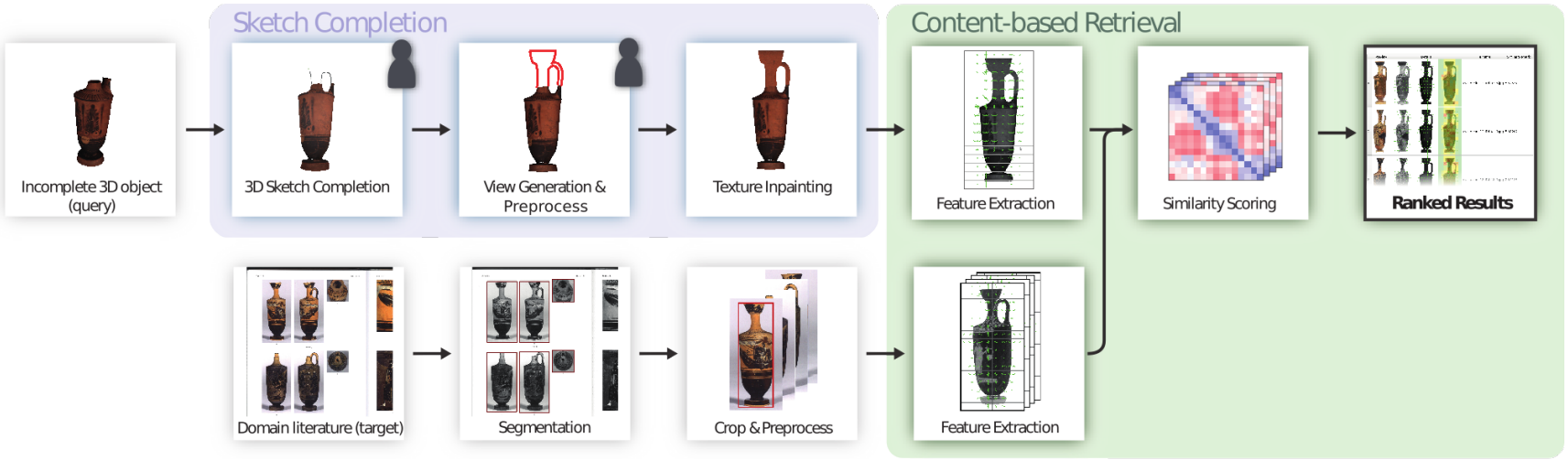


Unsatisfying retrieval results with incomplete object
Approach: Compensate for missing parts with User-Sketch

Pipeline

- Sketch-completion
  - Completion of the input by sketch and subsequent inpainting



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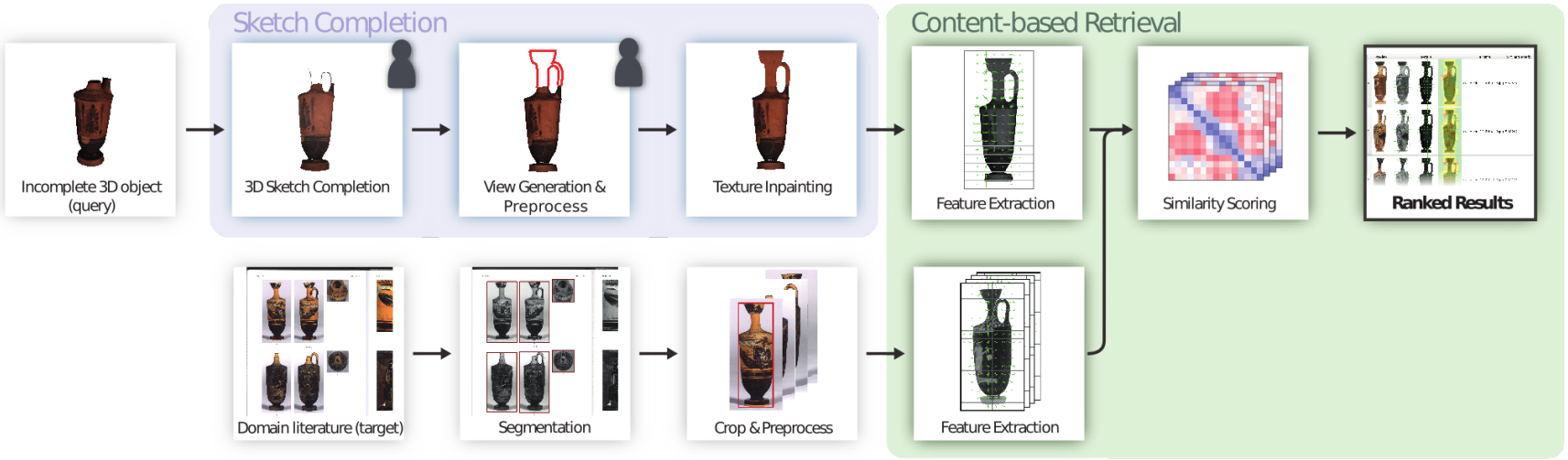
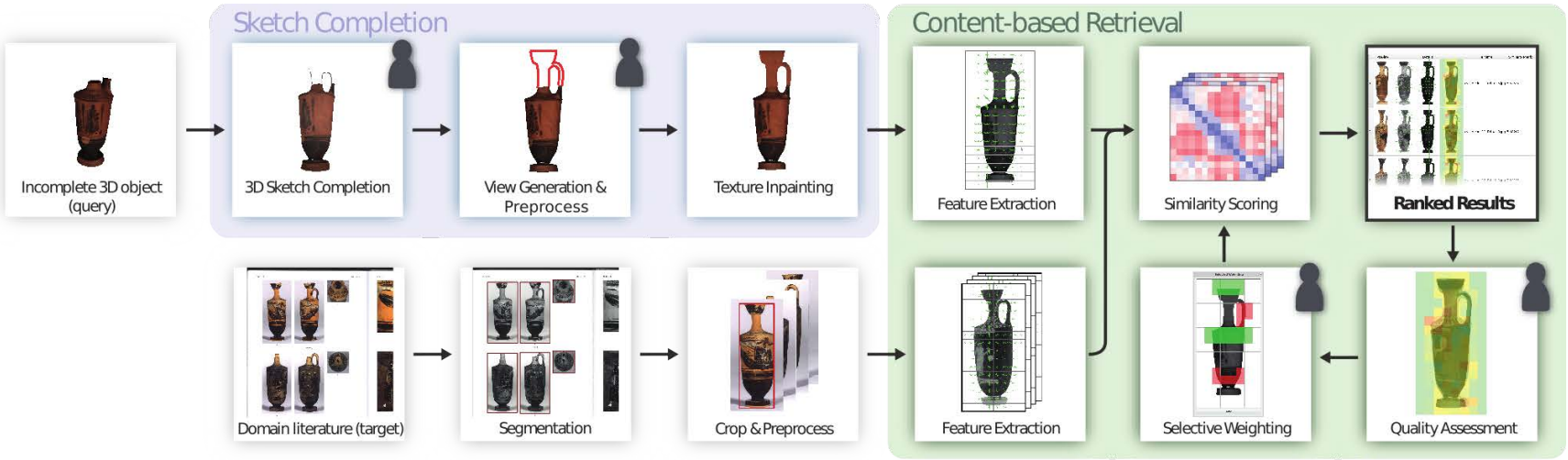


Some parts are “more relevant” for similarity than others
Approach: Allow the user to refine the query by selecting or deselecting certain areas

Pipeline

- Selective Weighting
  - User-specified interest areas through interface



Results

S. Lengauer, A. Komar, A. Labrada, S. Karl, E. Trinkl, R. Preiner, B. Bustos, and T. Schreck, **Sketch-Aided Retrieval of Incomplete 3D Cultural Heritage Objects**, Proc. Eurographics Workshop on 3D Object Retrieval 2019. (accepted)

Conclusion

- 3D digitization an opportunity to preserve cultural heritage artifacts
- Virtual restoration and distributed presentation/analysis
- Similarity search as key technology
- Sketch-based approaches interesting as intuitive interfaces for search, modeling and restoration
- Cross-modal linking of data to leverage 2D, 3D and textual research data archives

Thank you for your kind attention.

Questions or Comments?

Work supported by