

Crossmodal Search and Visual Exploration of Digital Cultural Heritage Objects

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3D Modelling and Processing

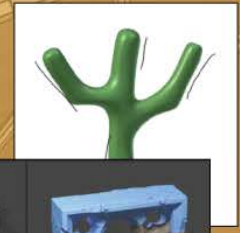
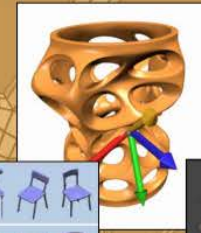
Computer Aided Geometric Design

Procedural Modelling

Physics-based Modelling

3D Object Retrieval

3D Restoration

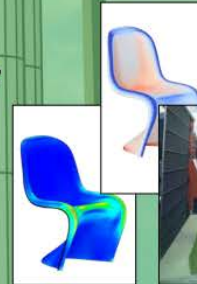


Simulation and Analysis

Analysis and Visualization of Geometric Information

Isogeometric Analysis

Virtual Reality



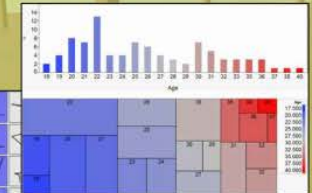
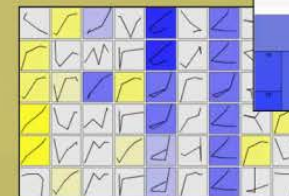
Visual Analytics and Digital Libraries

Visual-Interactive Data Exploration

Search Interfaces and

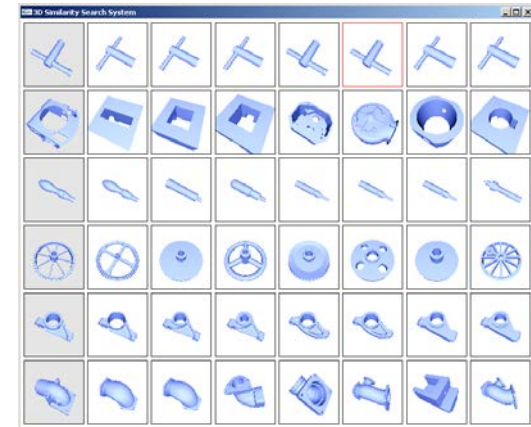
Semantic Annotation

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/>]



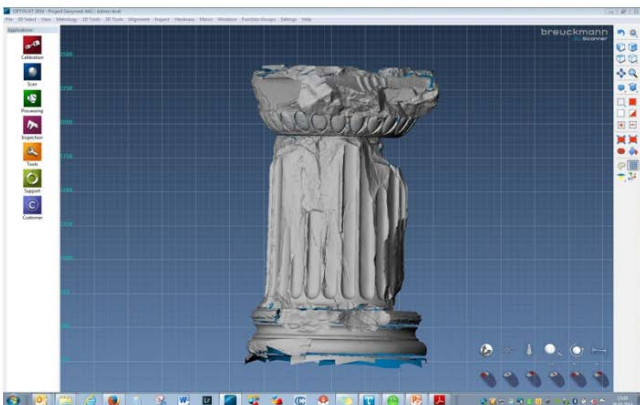
Probado3D Repository
[<http://www.probado.de/>]



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



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



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



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



Kinect Sensor
(Microsoft)



3D Technology in Cultural Heritage


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



3D Technology in Cultural Heritage

- **Documentation and presentation**
- Long term preservation
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- ...


Virtual Hampson Museum



The
Virtual Hampson Museum
- Who is James K. Hampson?

Hampson Archeological Museum State Park

About the Project What is Nodena? Browse the Collection 3D Nodena Village 3D FAQ Who is Hampson? Home




Dr. James Kelly Hampson

The amazing materials at the Hampson Museum State Park were made possible by the efforts and dedication of Dr. James K. Hampson. Dr. James Kelly Hampson was born in Memphis, Tennessee on July 9, 1877. In 1898 he graduated from the College of Medicine, now the Medical School at the University of Tennessee. He then attended the New York Polyclinic School and went on to practice medicine for over 25 years in Memphis, and at Nodena and Fort Smith, Arkansas. Dr Hampson died on October 8, 1956.

Dr. Hampson coupled his interest in science and background in medicine with an interest in archaeology and this resulted in the excavation of over 1,000 burials at Nodena alone. Dr. Hampson took great care to ensure that the materials he found were not scattered far and wide into various public and private collections as was common with other sites in the region at the time. Additionally he worked with a number of professional archaeologists including Walter B. Jones of the Alabama Museum of Natural History; **Samuel C. Dellinger of the University of Arkansas**, who Hampson generously permitted to excavate Nodena; and Stephen Williams of Harvard, who Hampson permitted to extensively study his collection in 1953.

Modern Arkansas laws now make the disturbance of human burials without a permit illegal and permits are issued only when impacts from construction or other damage are unavoidable. But in the first half of the 20th century excavation of human remains was unfortunately all too common. While other excavators in this time were often not much better than looters, Dr. Hampson carried out his work with care and attention, drawing on his medical training and experience, and he collaborated with professional archaeologists. According to Williams, "Dr. Hampson brought an inquiring mind and a sound knowledge of the scientific method to the subject of archaeology... his methods equaled those of his professional colleagues working in the area at the same time."

For more on Dr Hampson see:




The First Hampson Museum

Virtual Hampson Museum

Artifact Viewer - Internet Explorer
http://hampson.cast.uark.edu/artifact.php?IDart=1





Ark HM headpot Get Link



Ark HM headpot
Hampson ID: 0
Form: Headpot
Site: Shawnee Village

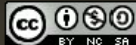
From Shawnee Village, this headpot is especially noteworthy for the incising on the face, which may represent tattooing. Headpots are a very rare and unique form of pre-historic Native American pottery found almost exclusively in northeast Arkansas and the adjacent boot heel region of Missouri. They are distinguished from other native North American pottery in that

Images



Download Formats
VRML (Lo) | 3D PDF (Lo) | OBJ (Lo) | OBJ (Hi)

Click on links above to download a 3D model of this artifact. Hovering over the link will give description of the 3D formats.



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Case Study: Pergamon Web



Case Study: Pergamon Web





3D Technology in Cultural Heritage

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

EU Project PREVIOUS (2013-16)

Restoration of 3D Archaeologic Data

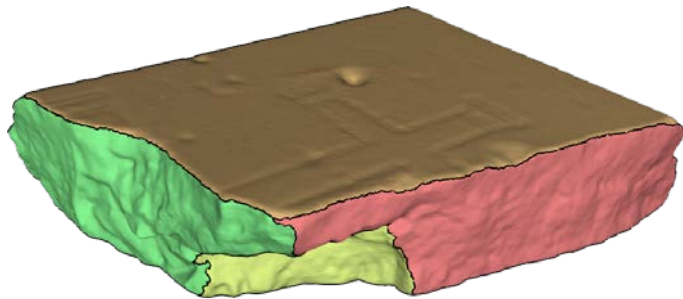
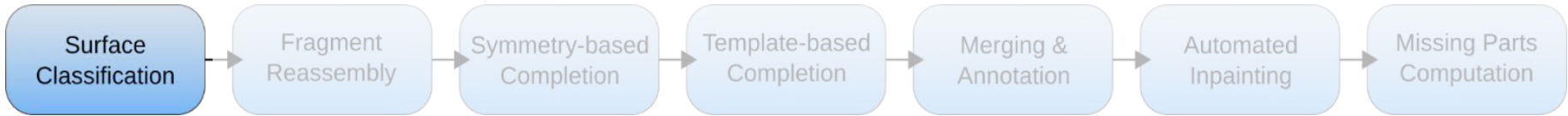


- Tools for Virtual Archaeology
- Work packages:
 - Predictive scanning
 - Degradation assessment
 - Fragment reassembly
 - Similarity-based object completion and repair



<http://www.precious.eu/>

Workflow for Virtual Restoration



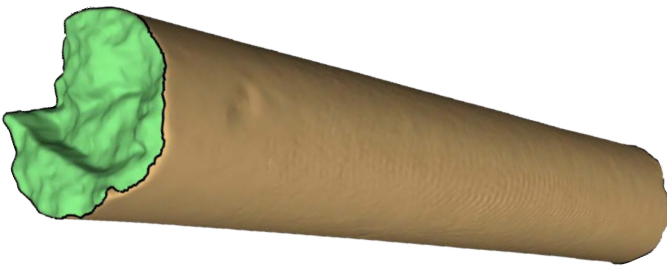
Fracture surface segmentation is done by clustering or region growing using roughness measure

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

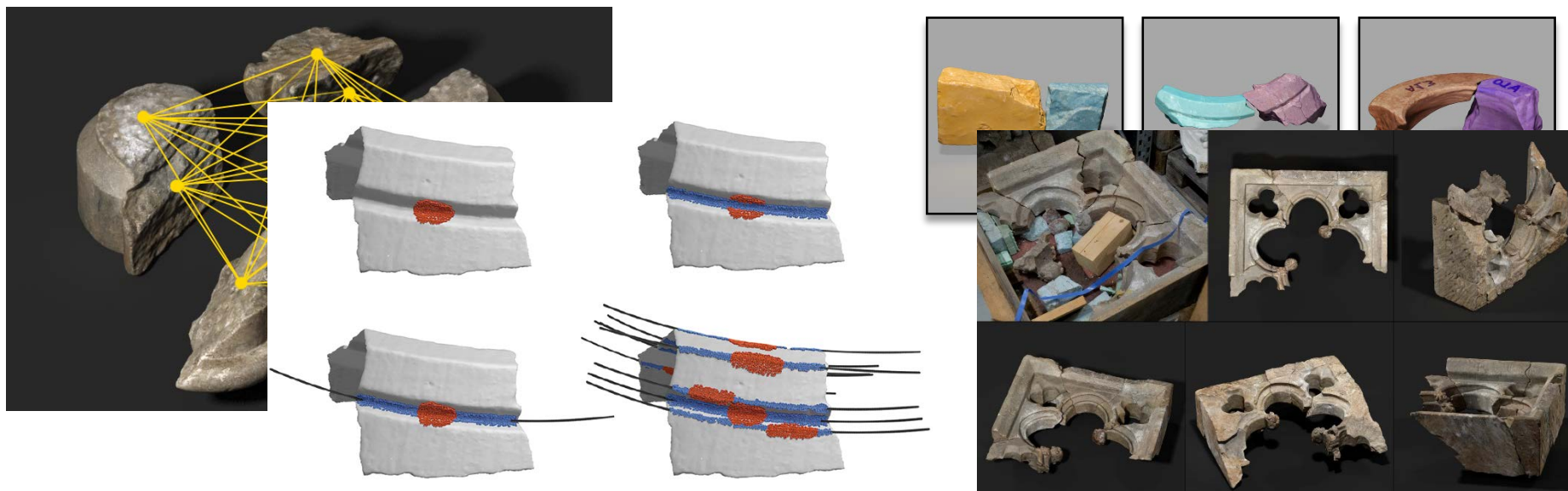
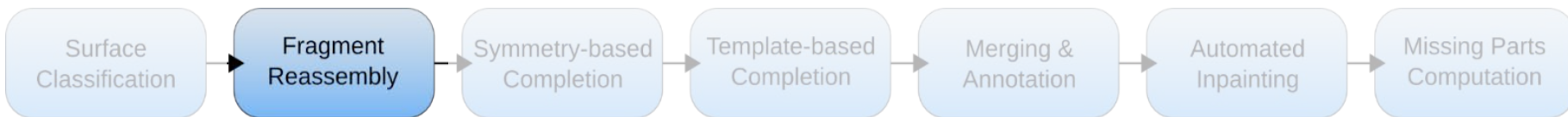
Roughness \mathbf{R}
at Vertex \mathbf{p}
and radius \mathbf{r}

Set \mathbf{N} of
vertices within
radius \mathbf{r}
around \mathbf{p}

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



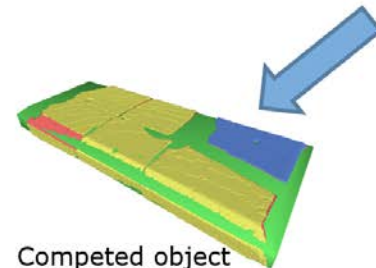
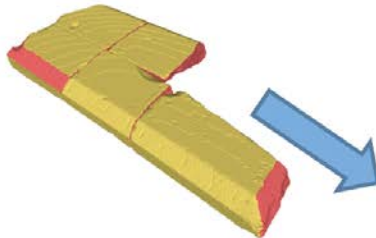
Workflow for Virtual Restoration



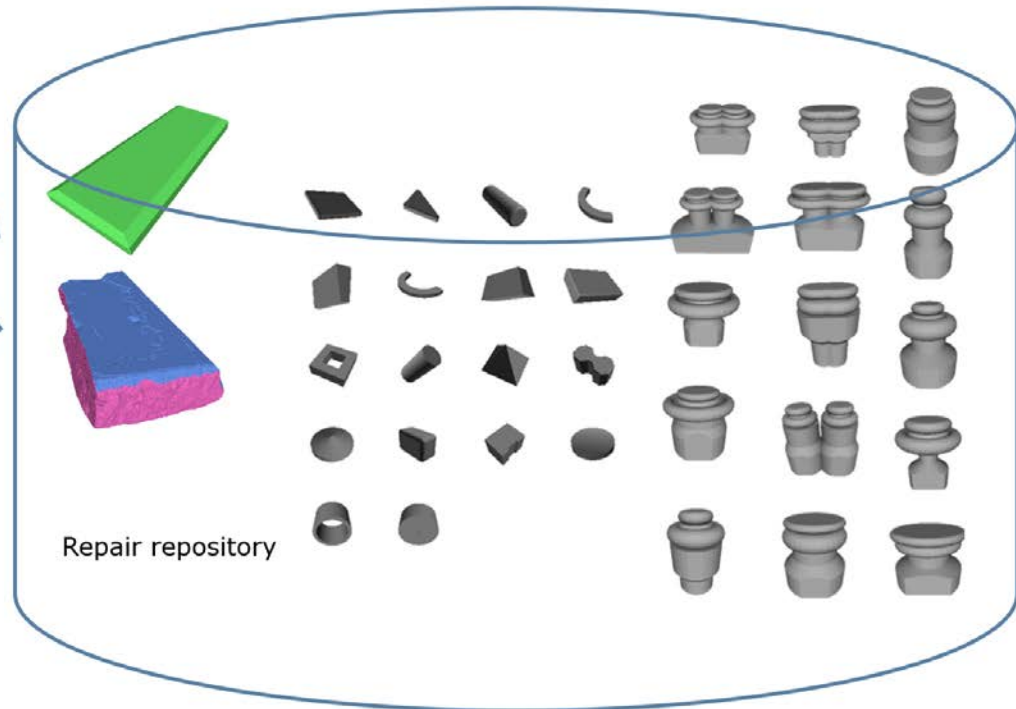
Workflow for Virtual Restoration



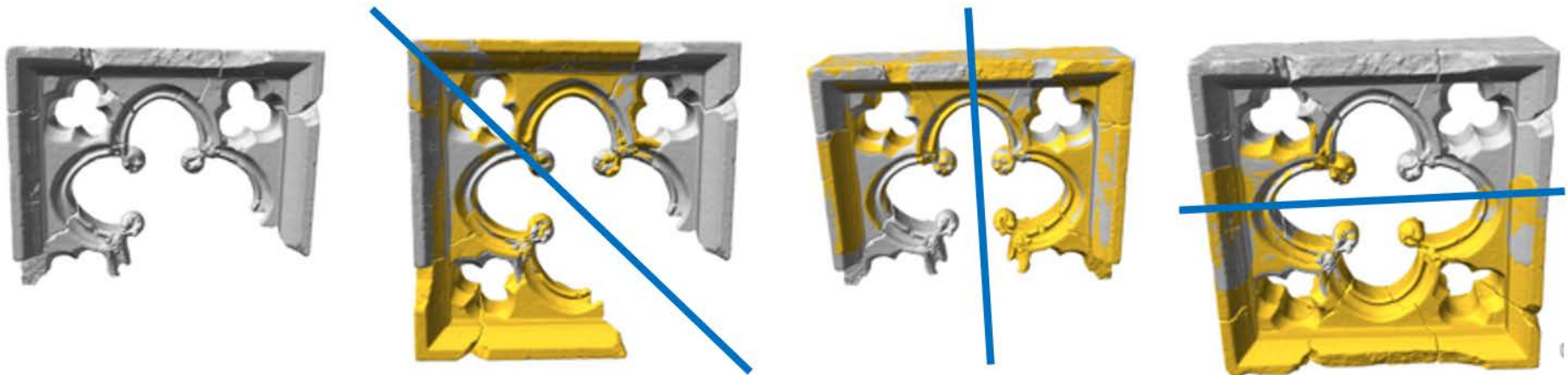
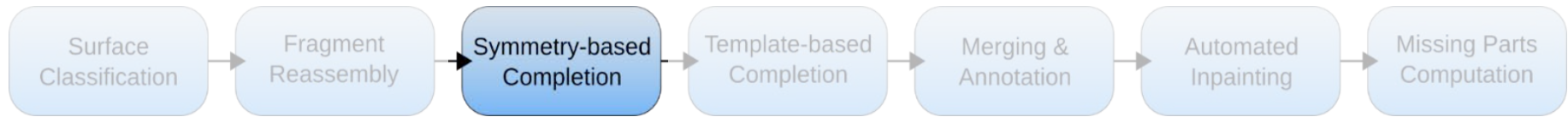
Partially assembled object



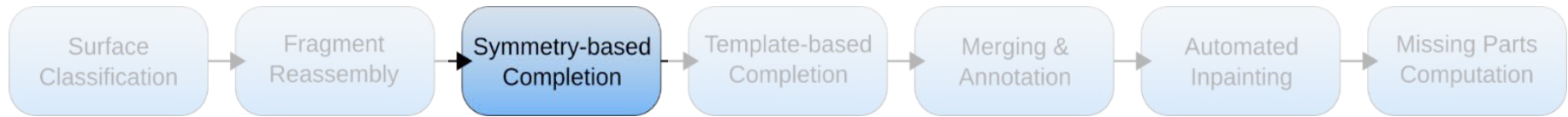
Completed object



Workflow for Virtual Restoration



Workflow for Virtual Restoration



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

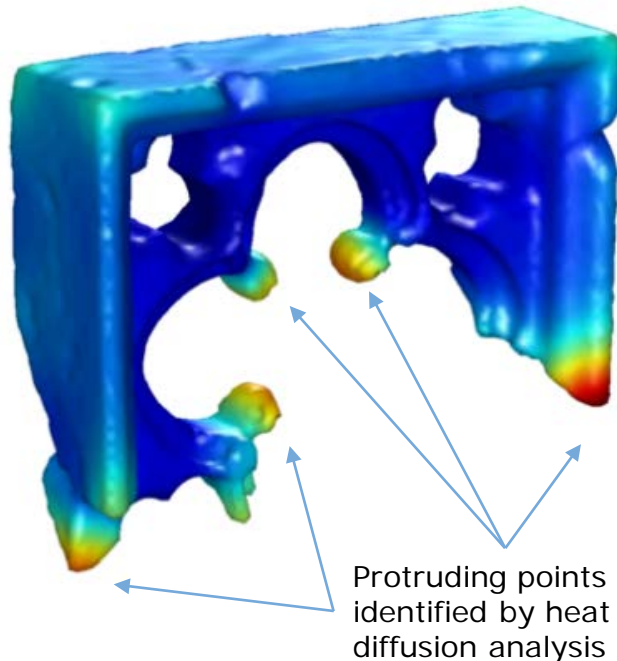
$$K_t(x, y) = \sum_{i=0}^{\infty} e^{-\lambda_i t} \phi_i(x) \phi_i(y)$$

Heat flow from x to x at time t :

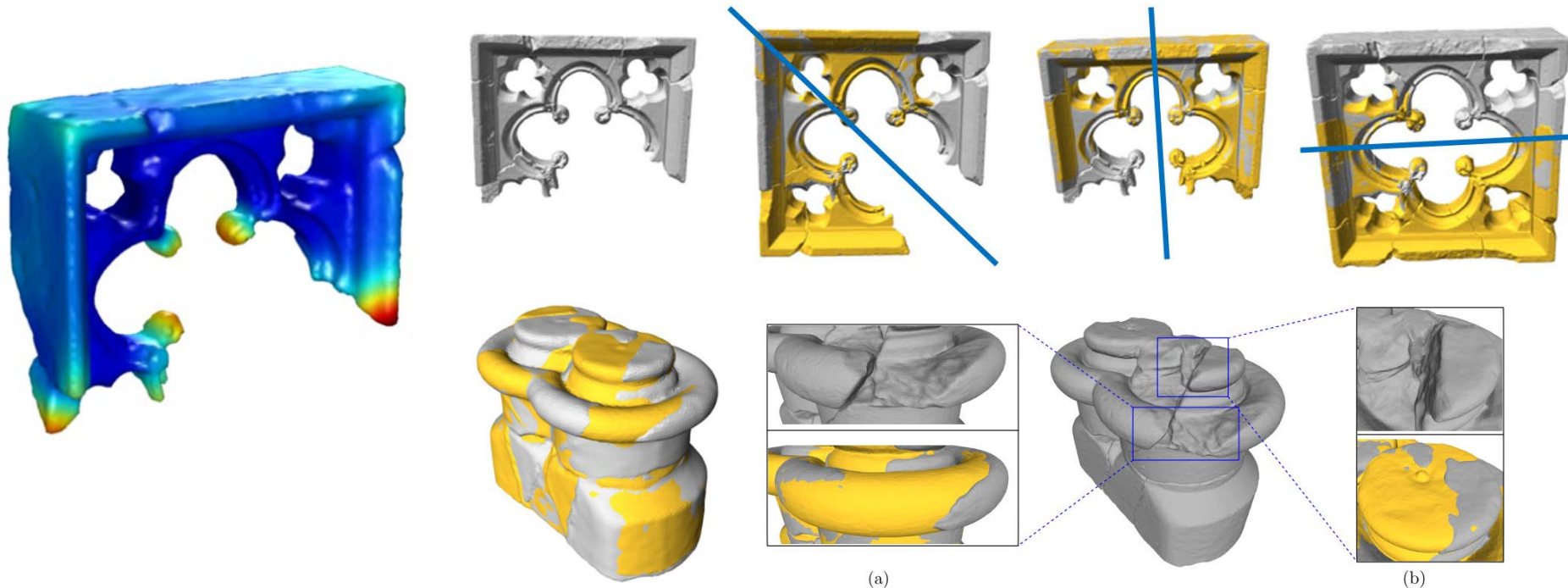
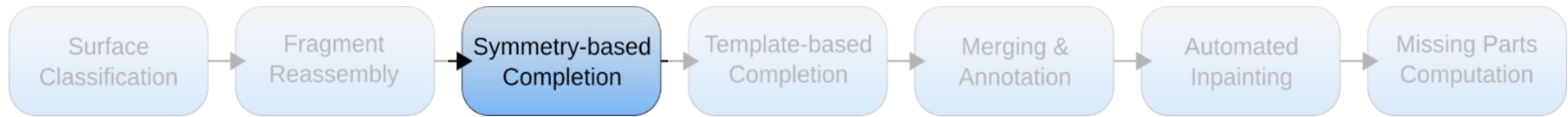
$$h(x, t) = K_t(x, x) = \sum_{i=0}^{\infty} e^{-\lambda_i t} \phi_i(x)^2$$

Measure of retained heat at x at time t :

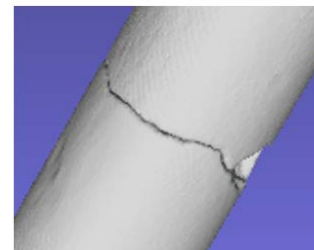
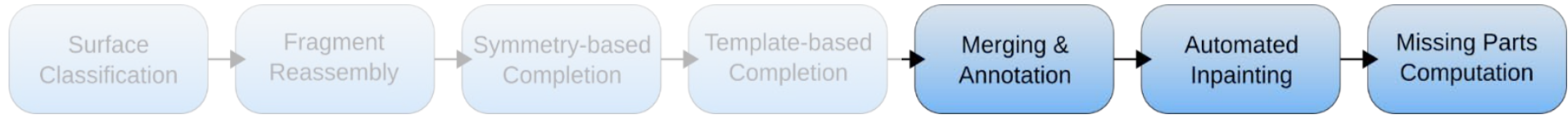
$$\mathcal{H}(x, t) = \int_0^t h(x, t) dt$$



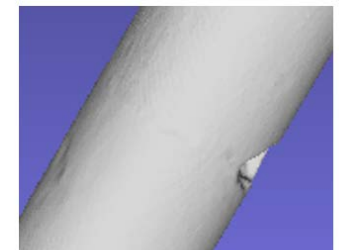
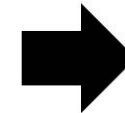
Workflow for Virtual Restoration



Workflow for Virtual Restoration



Input



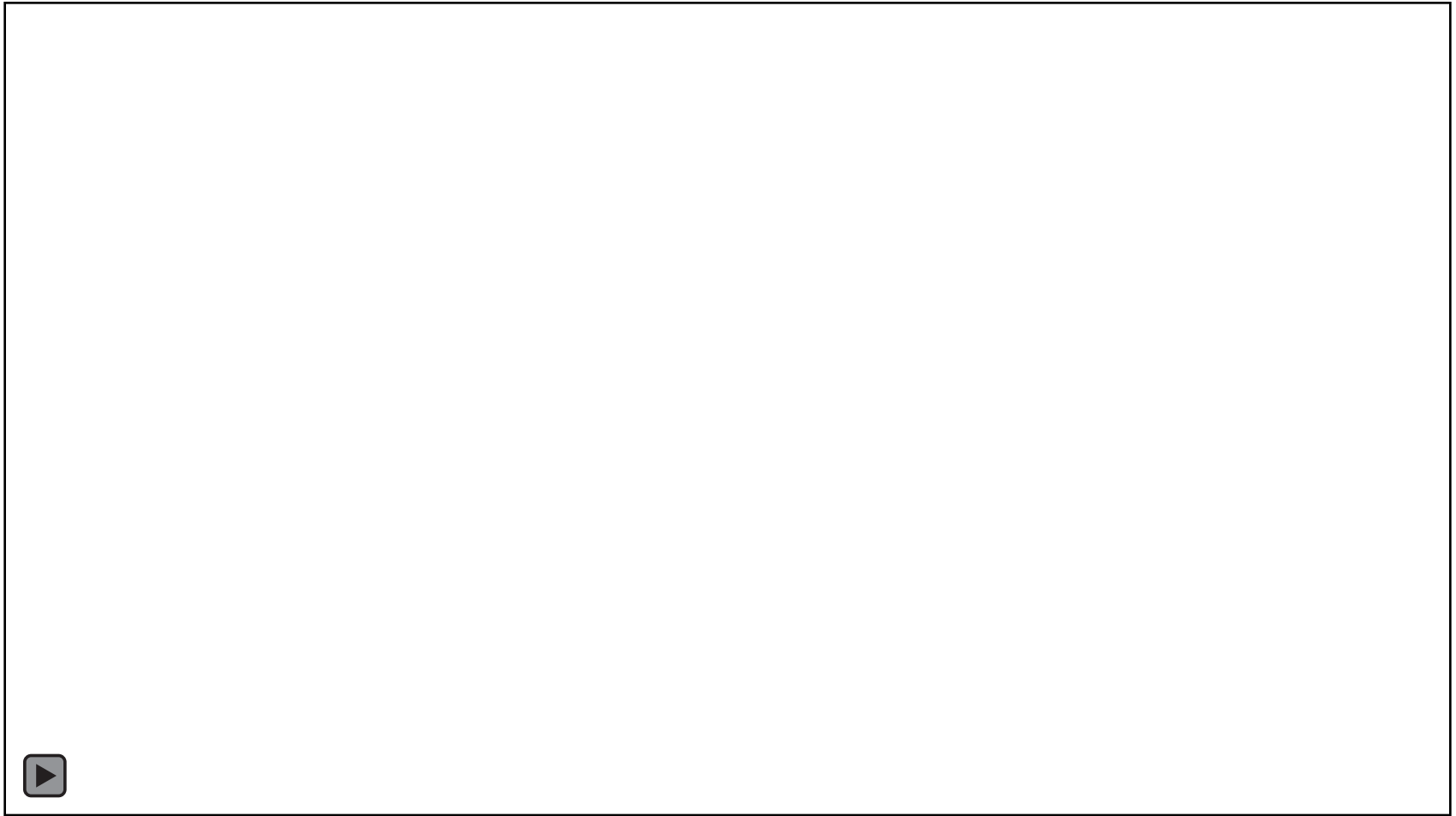
Watertight output

Virtual Shape Completion with AR Technology (Hololens)



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

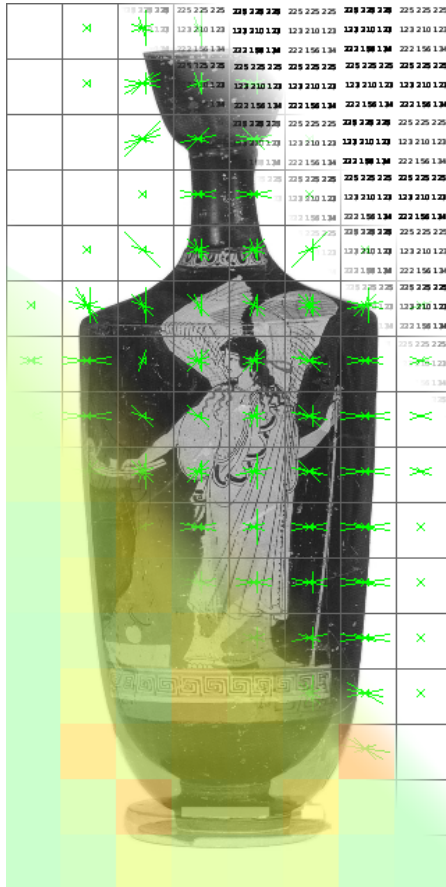
(autoplay)





3D Technology in Cultural Heritage

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



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

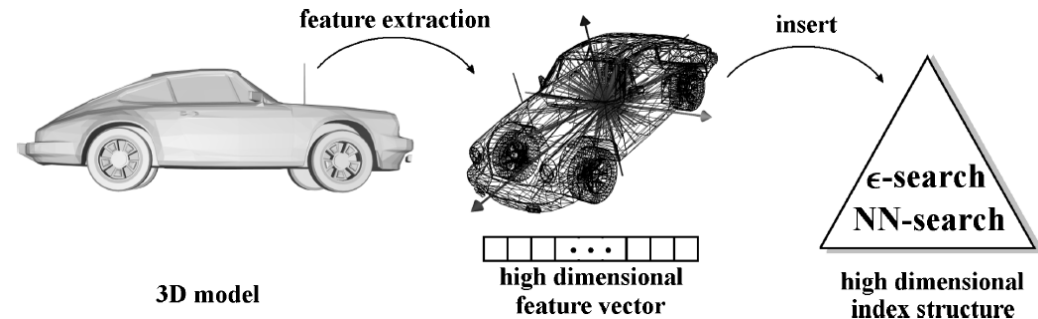
- In cultural heritage research, often **objects need to be compared based on shape and image** properties
 - For example, for painter and potter attribution in vessels; exploring trading routes, stylistic influence etc.
- Problems in practice
 - Object documentation often is given in different modalities (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

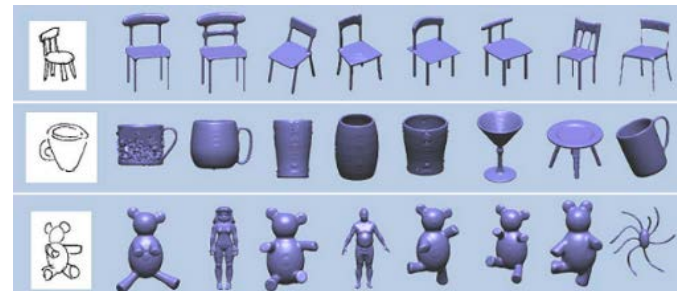
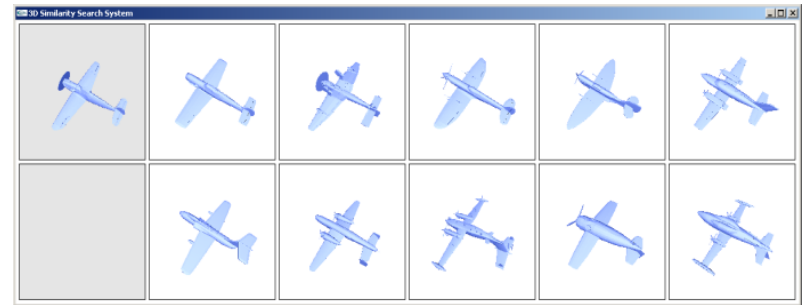
- Search for similar 3D objects given a query
 - Example object
 - User sketch



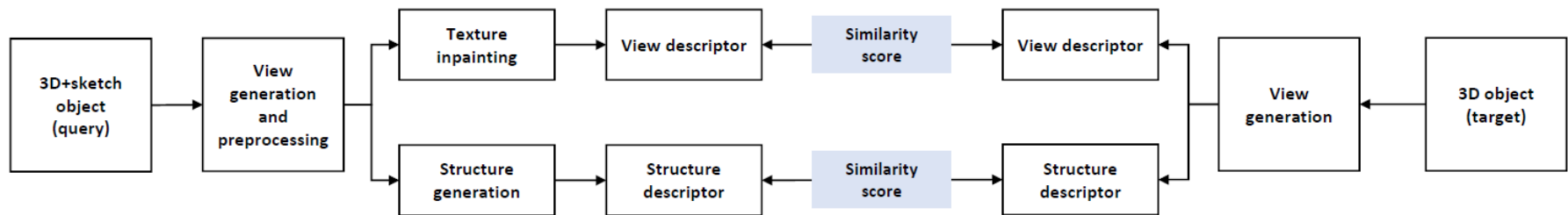
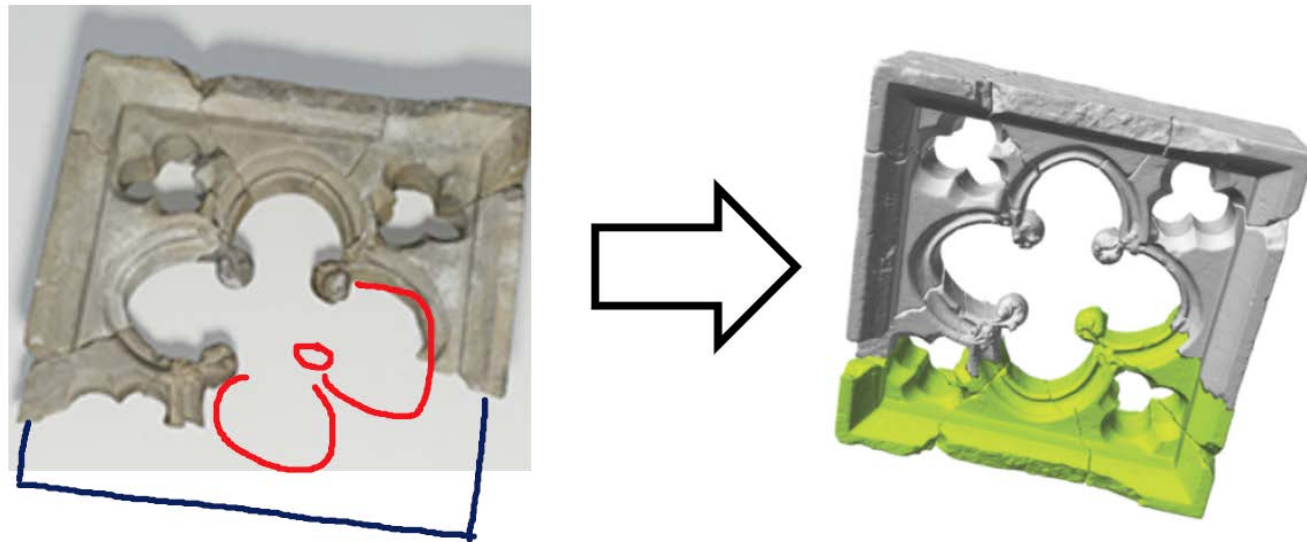
- Problem: Definition of similarity function

- Our approaches

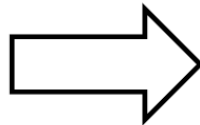
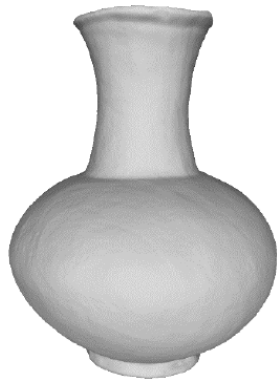
- Feature-based retrieval
- Sketch-based retrieval



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



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

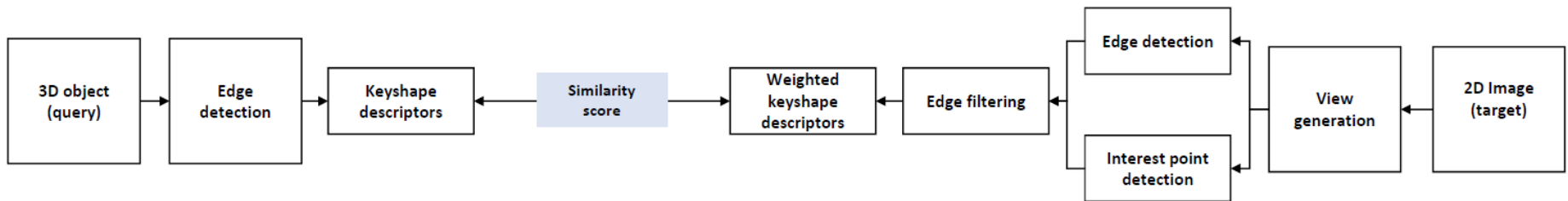
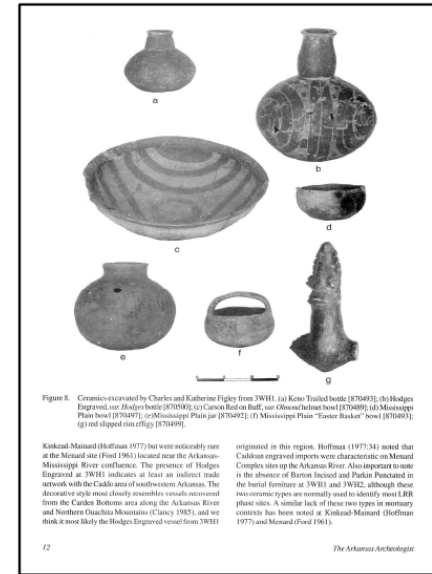


In archaeology [[edit](#)]

Chronologies based on pottery have been essential for dating Mississippian cultures. Along with [anthropologists](#) and [historians](#), [archaeologists](#) study of the pottery has provided one of the best insights into the culture. Because pottery is durable and often survives long after artifacts made from less durable materials have decayed past recognition,

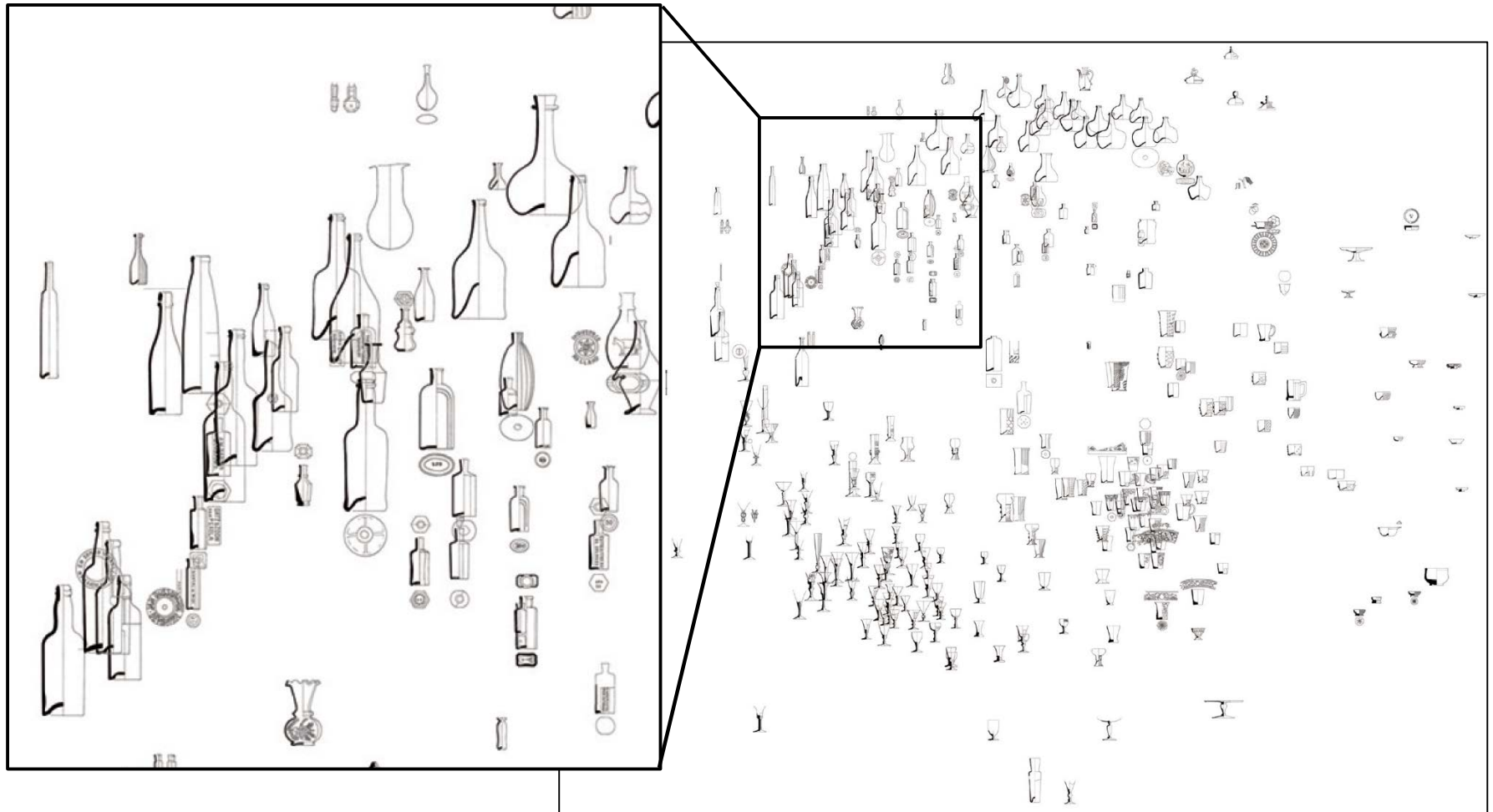


Non-local pottery found at [Moundville](#), showing trade with other groups



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

4.3 Work Package 3: Interactive Prototype and Result Visualization



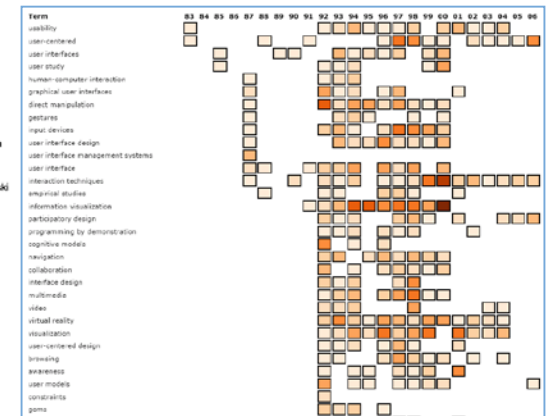
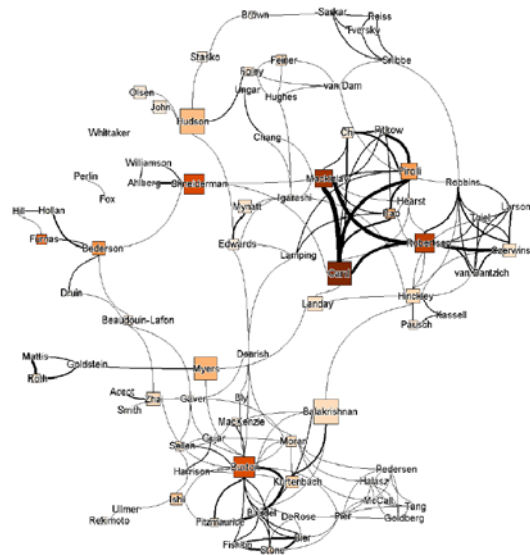
van der Maaten et al., CAA 2006

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.



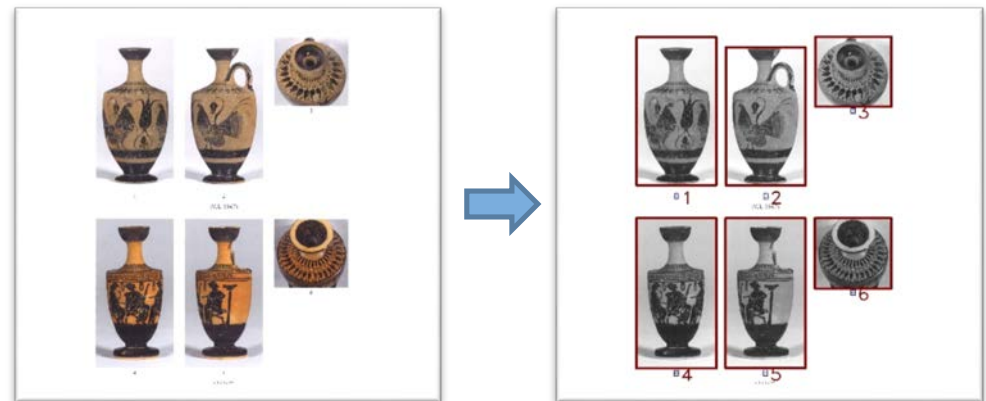
Attic black-figured lekythoi, 5th century BC.
(courtesy of Landesmuseum Kärnten)

Sources

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



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



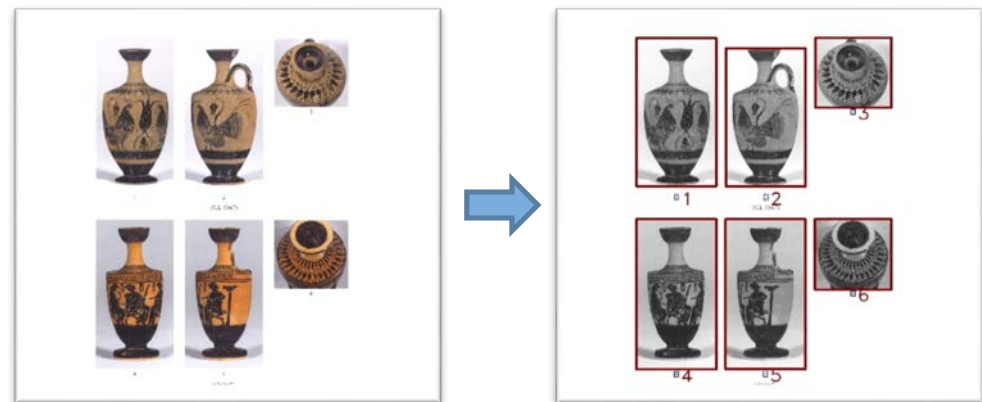
Zimmerman-Elseify "Corpus Vasorum Antiquorum Berlin, Antikensammlung 17", Deutschland 102. München, 2018

Sources

- 3D Objects
 - Attic black-figured lekythoi, 5th century BC.
- 2D Images from CVA Volumes
 - CVA Berlin XIII
 - CVA Berlin XVII
 - CVA Athens V
 - ...
- Extraction
 - Image Segmentation
 - Number registration with OCR



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



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

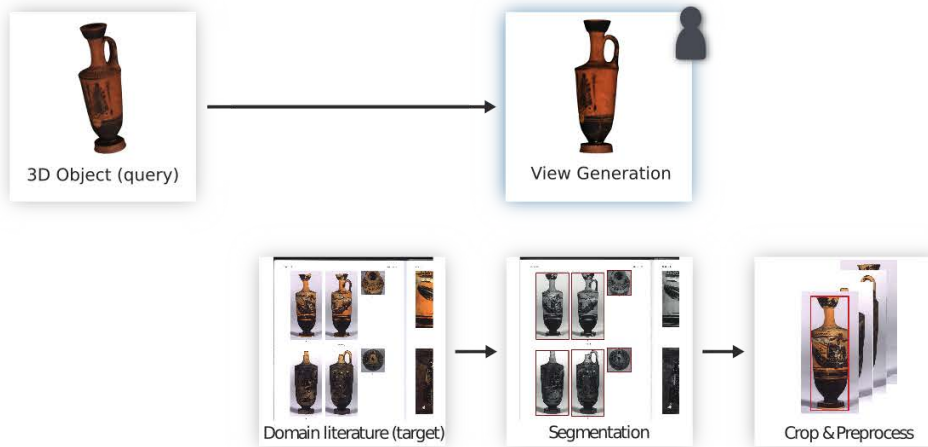
Pipeline

- 2D Search Space Preprocessing
 - Segmentation, Cropping



Pipeline

- 3D Input
 - View generation

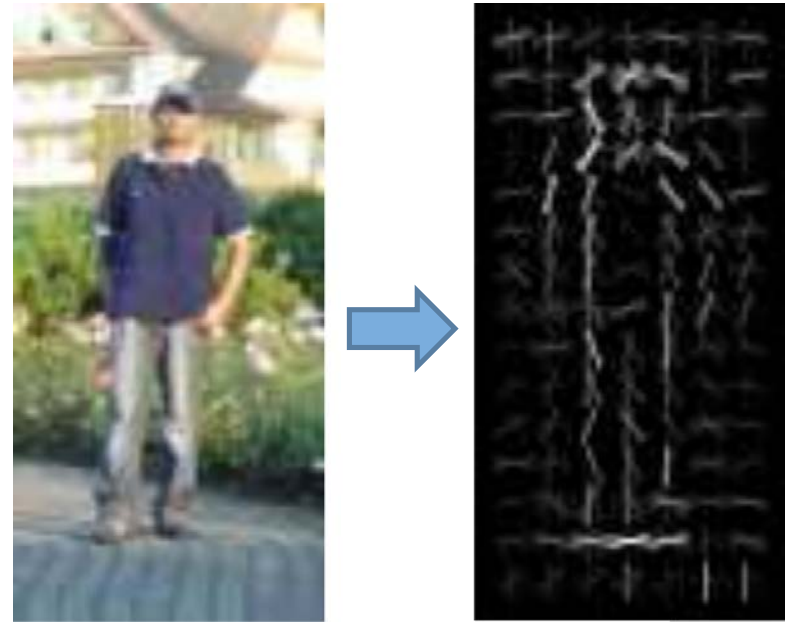


Retrieval

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

Retrieval

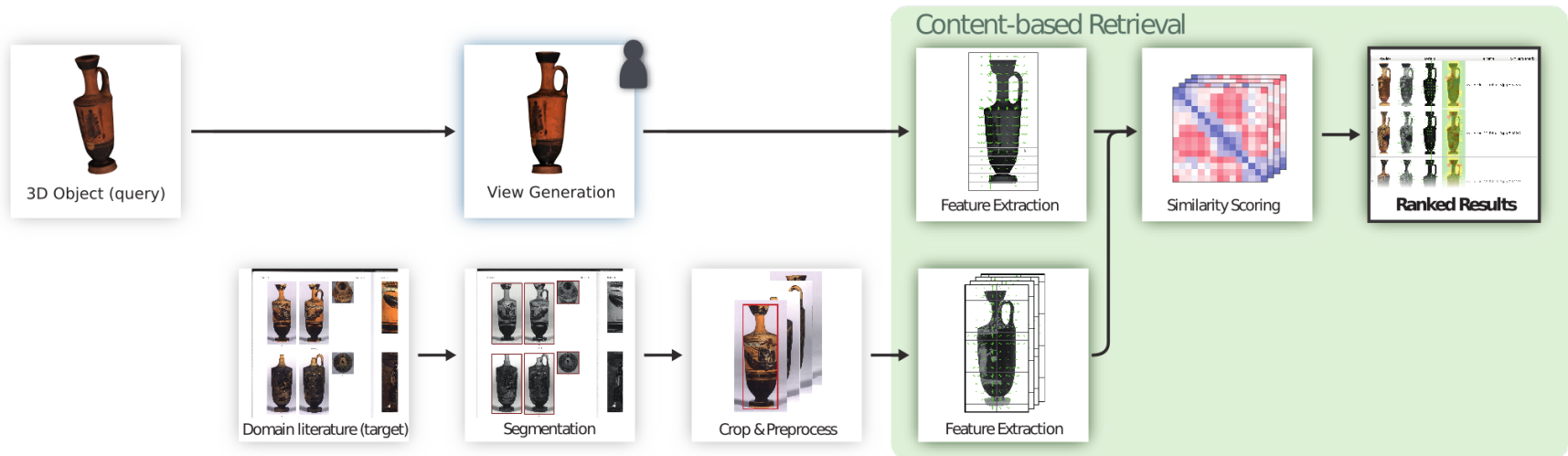
- View-based approach
 - Transformation of 3D object to common 2D base modality
 - Appropriate view determined by user
- 2D shape features
 - Histogram of oriented gradients (HOG)
 - Region-based gradient orientation and strength



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.

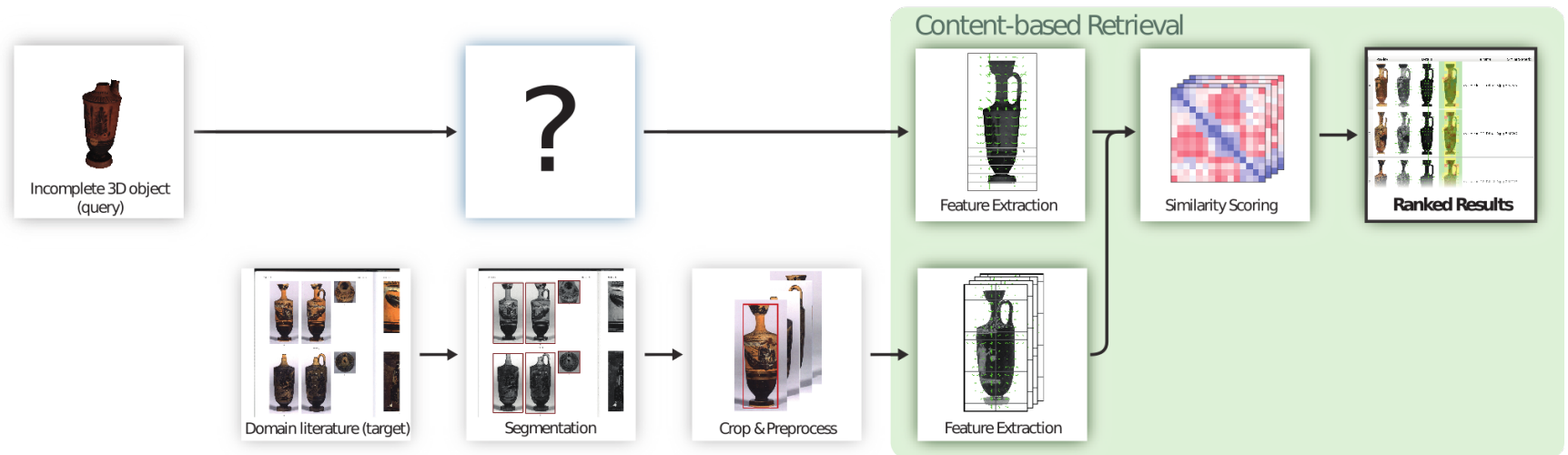
Pipeline

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



Pipeline

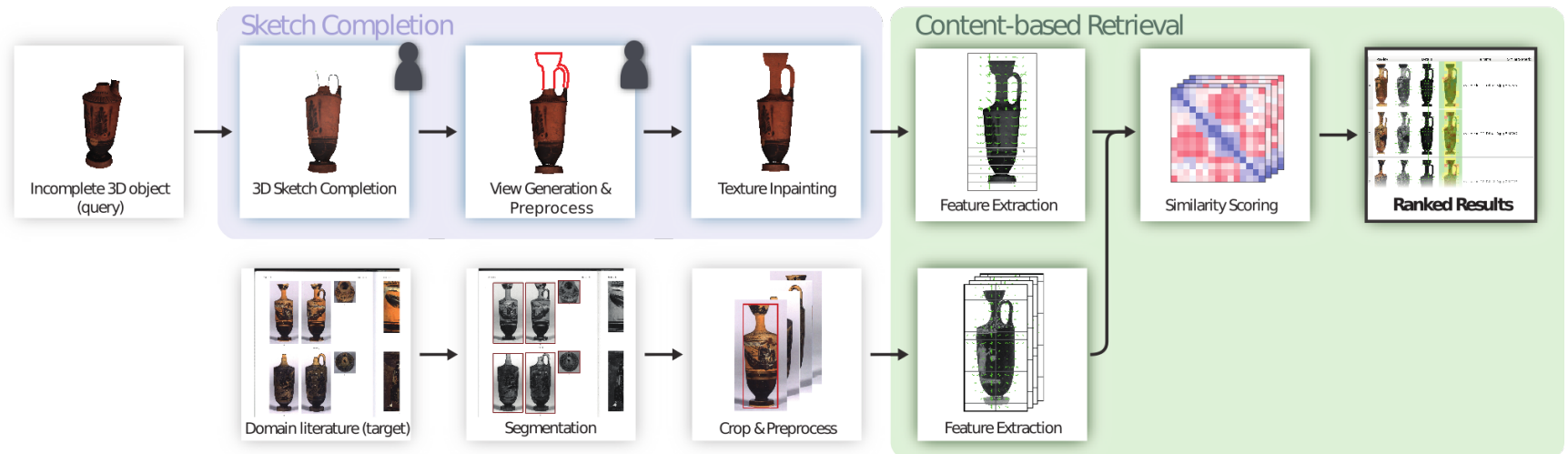
- Retrieval Process
 - Returning a list of results, ranked by similarity



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

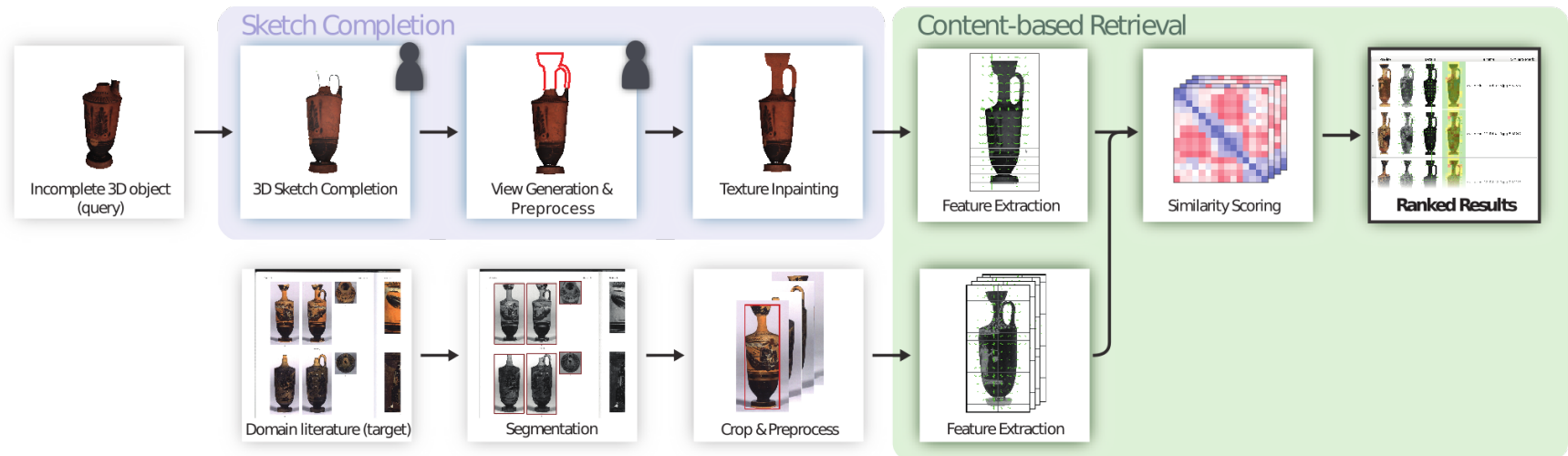
Pipeline

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



Pipeline

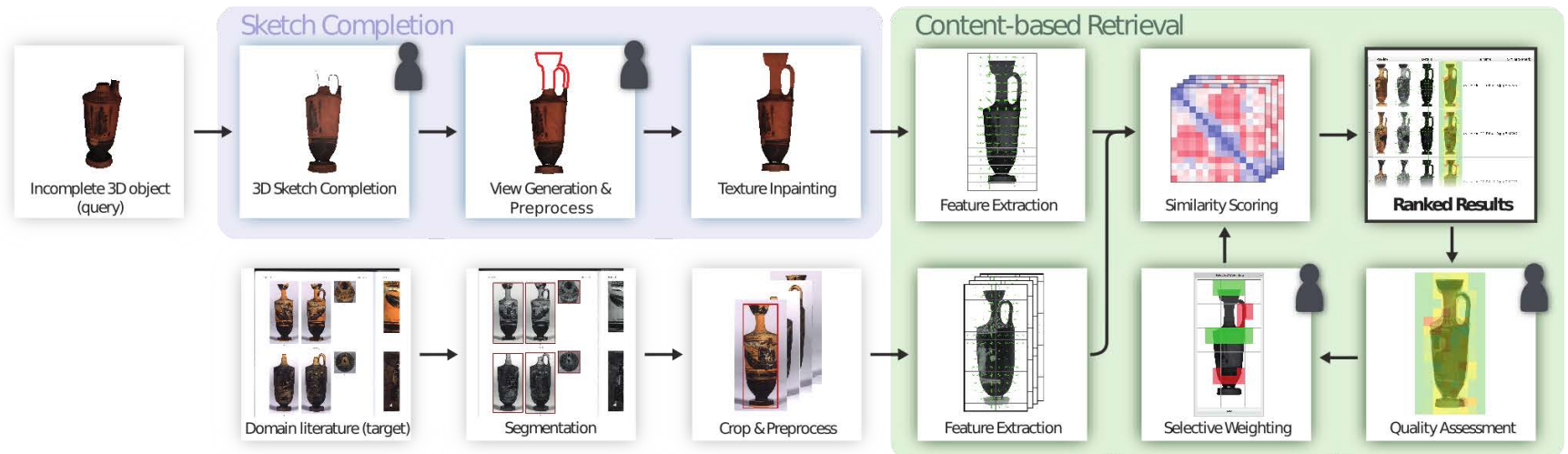
- Sketch-completion
 - Completion of the input by sketch and subsequent inpainting



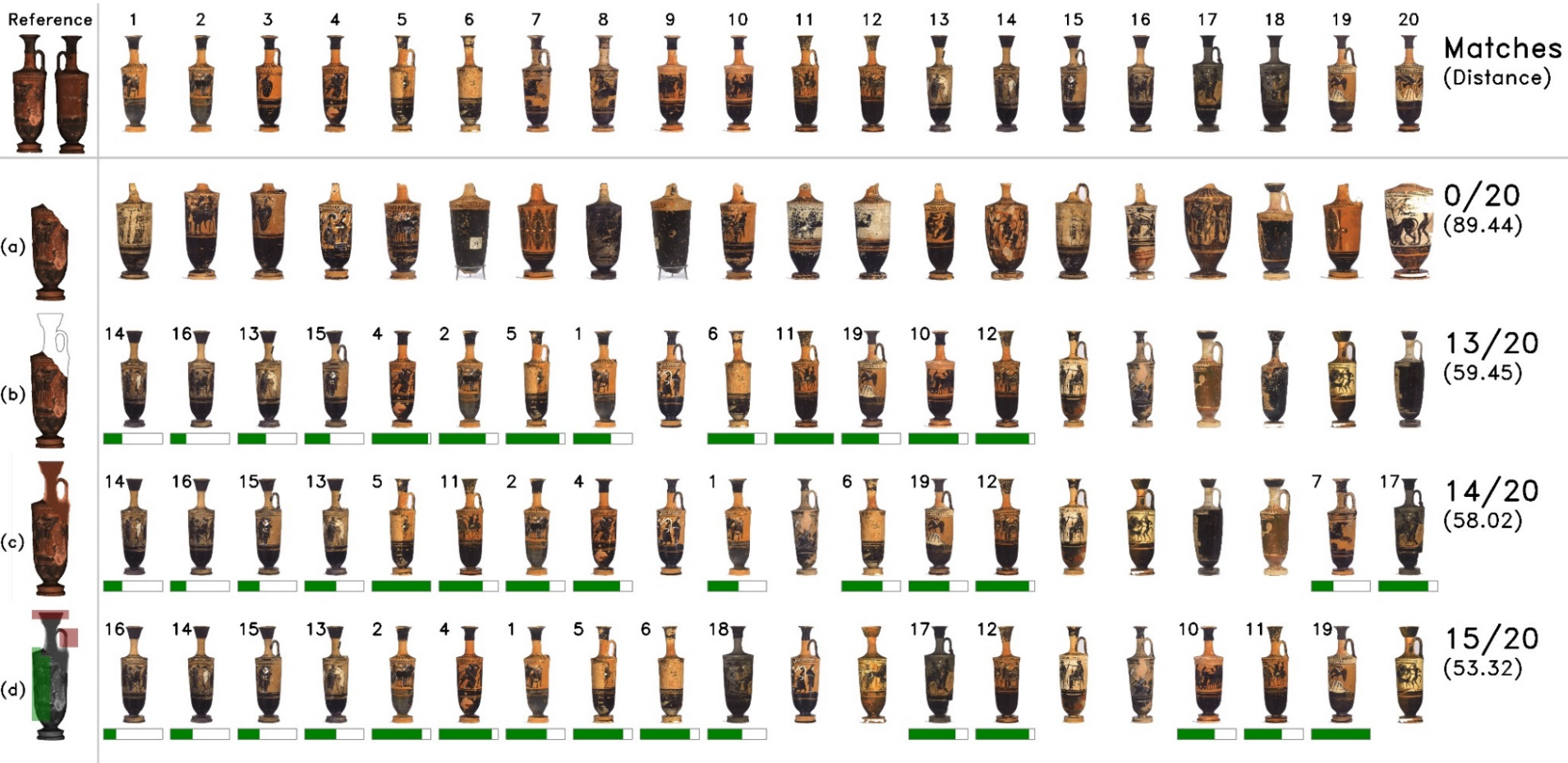
Some parts are “more relevant” for similarity than others
Approach: Allow the user to refine the query by selecting or deselecting certain areas

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

