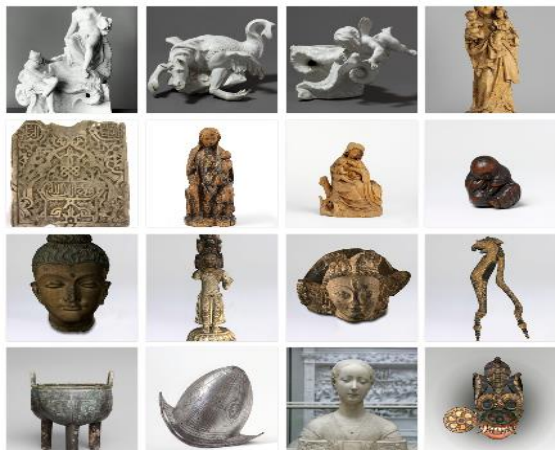


CultLab **3D**

Fast, Economic and Precise 3D Digitization of Cultural Heritage



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Why Digitization?



2003 Earthquake – Bam, Iran, world's largest clay buildings

Fire – Herzogin Anna Amalia Library Weimar 2004



Why Digitization?



2009 Collapse – City archives Cologne, 30 shelf-km destroyed

War – UNESCO World Cultural Heritage Timbuktu, Mali 2012



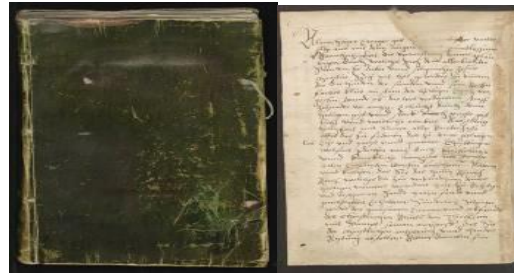
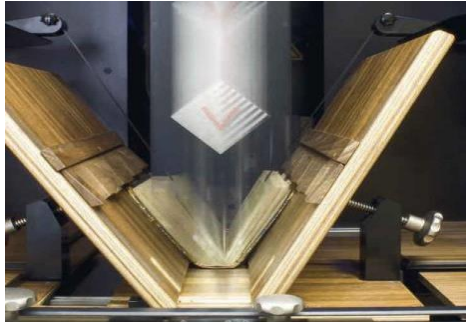
What has happened so far...

■ Digitization (German ‚Digitalisierung‘ / noun ‘Digitalisat’):

- Create a digital representation of real documents or artifacts

■ Two-dimensional cultural artifacts:

- Huge campaigns on national, European and worldwide level
Goal: digitization of antique scriptures, writings and paintings
e.g. German Digital Library (DDB), Europeana and Google Library Project, Microsoft Book Digitization Project
- Within the last 10 years, a market of device manufacturers and service providers has emerged, accounting to several 100 million EUR in size, worldwide



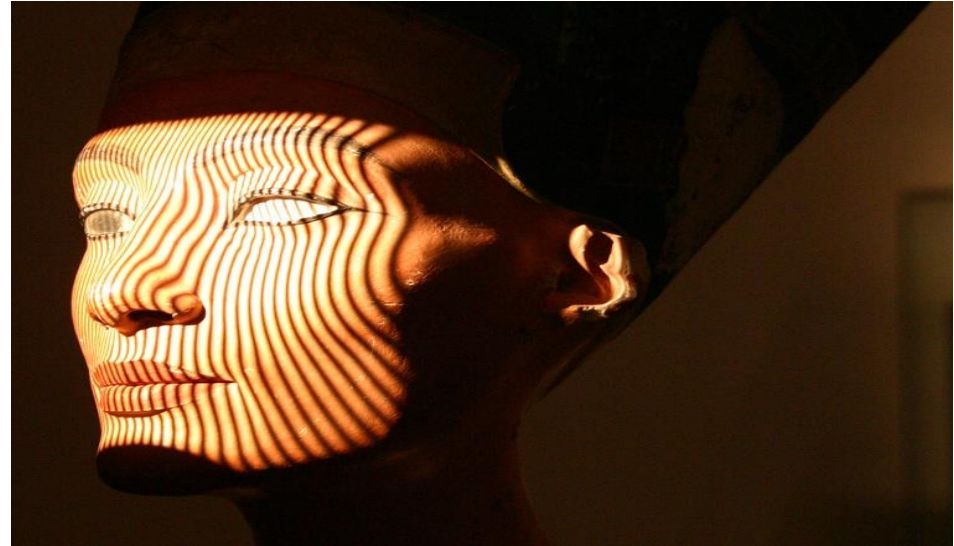
Collection of antiquities SMB
Inv.Nr. AvP VII 50

...and what about 3D?!

■ Three-dimensional cultural heritage:

- So far only prestige objects:

1999 Stanford, Michelangelo, David statue; **2002**, Luebke, Monticello; **2005**, Guidi, „Plastico di Roma antica“; **2009**, Skyarc, Kasumi Tombs Uganda, UNESCO world heritage; **2008, 2011**, Trigonart GmbH, Nofretete, Berlin



Staatliche Museen zu Berlin
Preußischer Kulturbesitz

Status: Digitization of documents and artifacts

■ Three-dimensional cultural heritage artifacts:

- Small artifact series (e.g. Saxony State Office for Archeology ~7000 3D artifacts digitized)
- But: no strategic, integral approach for digitization and classification of museum stock or new entrants, historic sites, monuments or historic edifices

■ Status May 2012 – ENUMERATE EU Project (2012-2014):

- Only few 3D artifacts digitized compared to other artifact classes (books, paintings, photos)
 - → **barely 1% of all digitized artifacts are 3D artifacts**
- **34% of museums hold a digitization strategy**
- **23% of museums hold a long-term preservation strategy for digitizations**

So far: manual 3D digitization of artifacts

- Digitization using e.g.:
 - PolyMetric 3D Scanner PT-M (4 MPixel cameras, 35mm lenses) – resolution down to 15µm
 - Manual (re-)positioning of scanner = 85% of time expenditure...



Rongorongo tablet
Ethnological Museum Berlin

3D digitization of the Berlin Rongorongo tablet

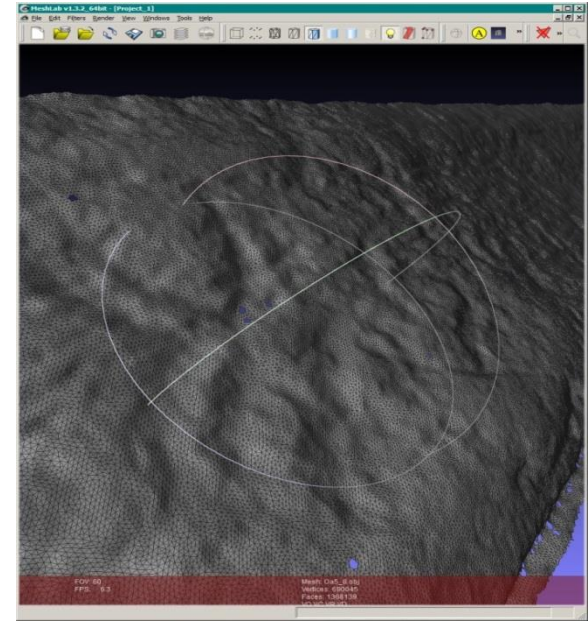
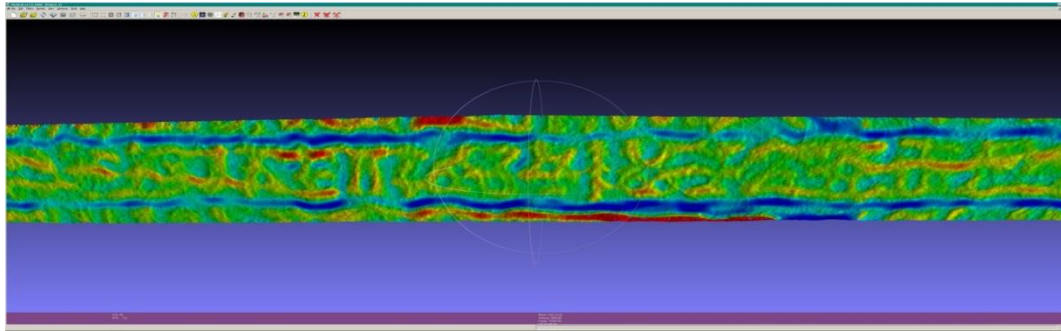


Competence Center
Cultural Heritage Digitization

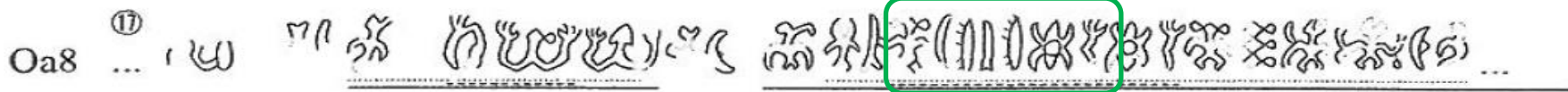
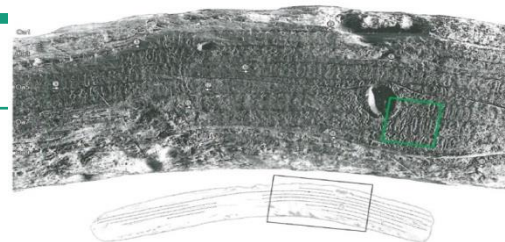
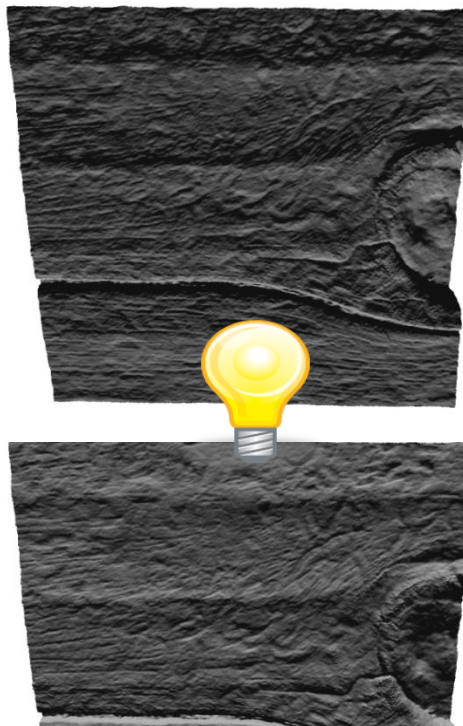
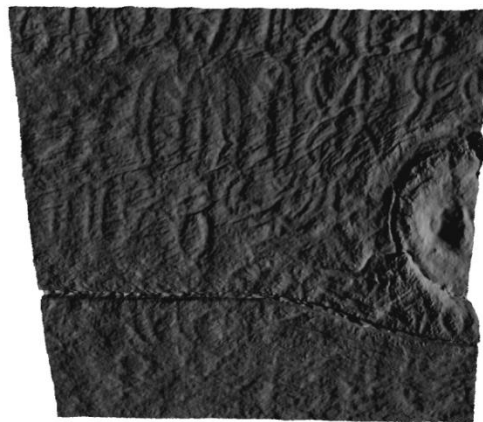


Berlin Rongorongo tablet

- 300 scans / 300 textures @ resolution 15 μ m
- Final computation in highest resolution
 - Machine:
2 x Xeon 3.2Ghz – 256GB RAM – 32 Cores
 - Computation time: 36 hours
 - Model size: 300 million triangles



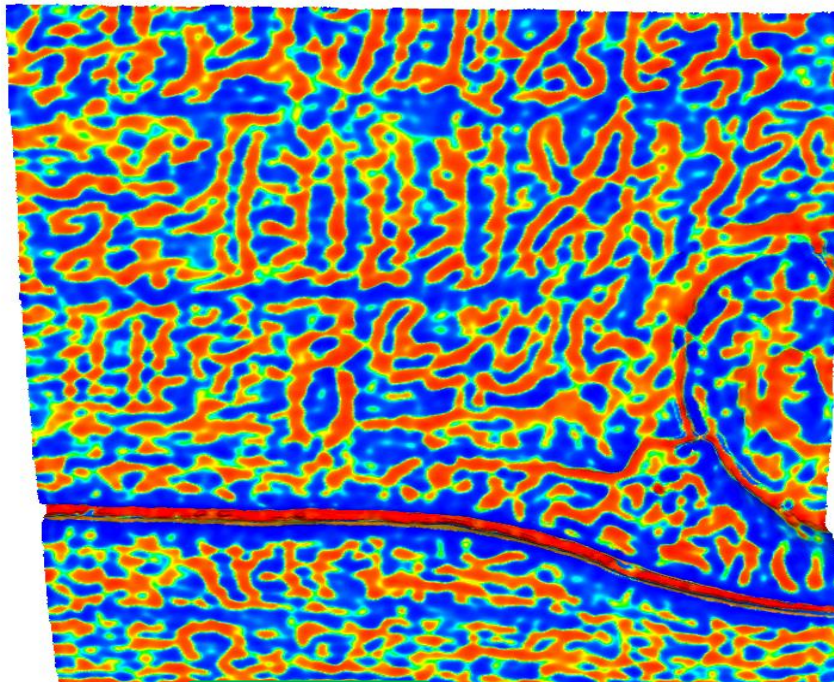
Controllable illumination



Surface analysis of backside illuminated from right

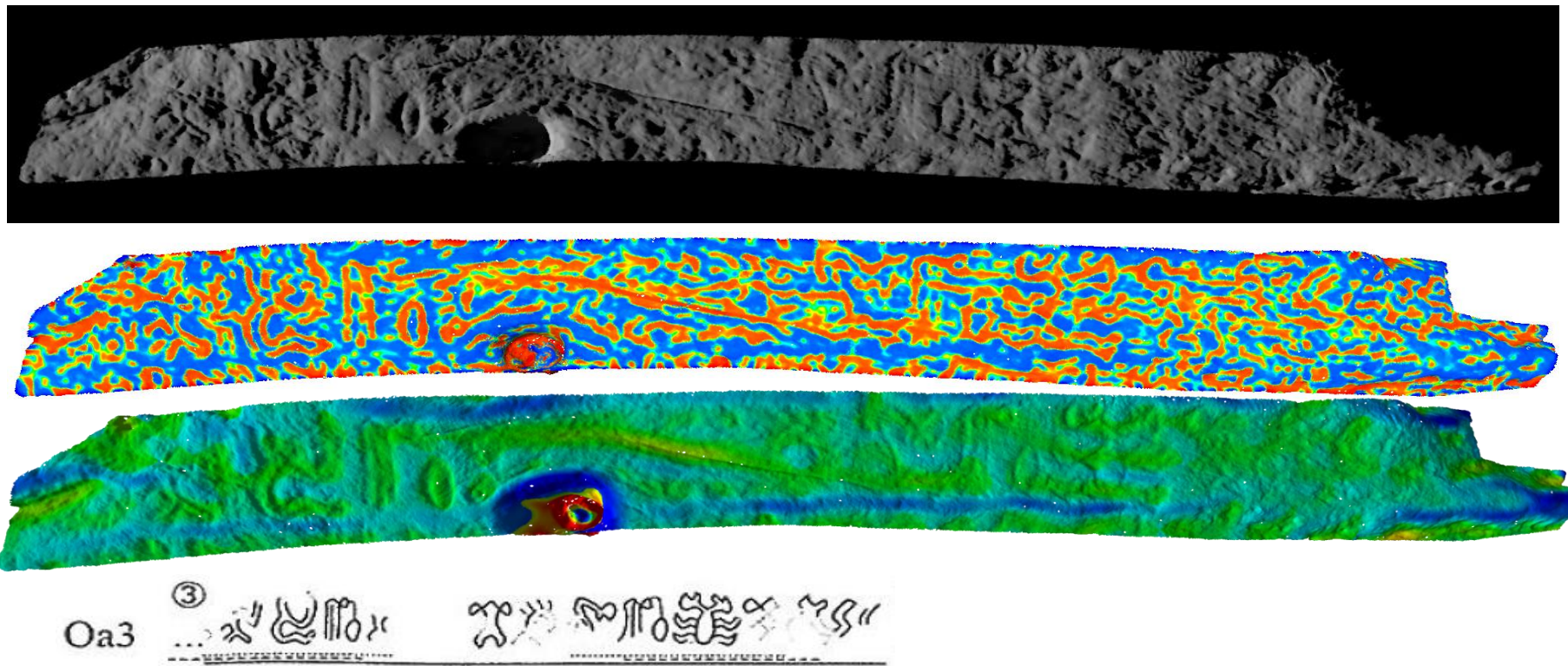


3D surface analysis with curvature filter

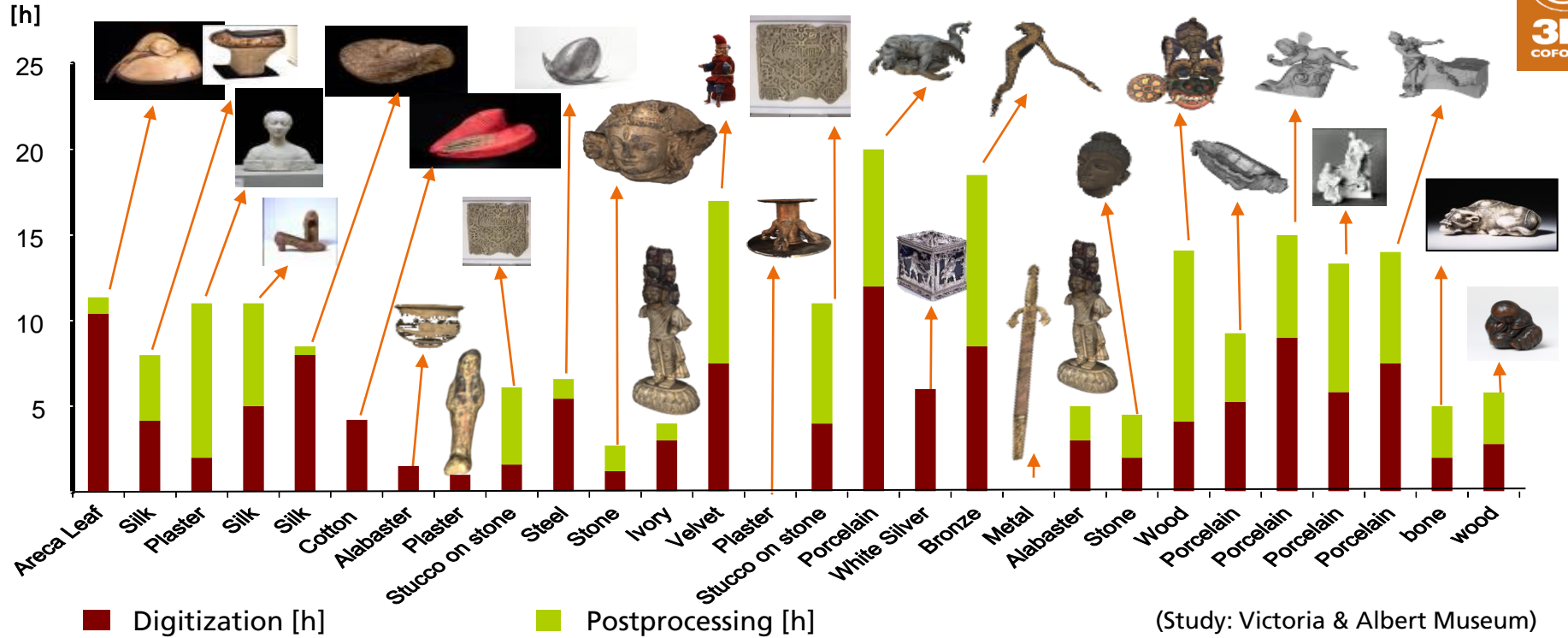


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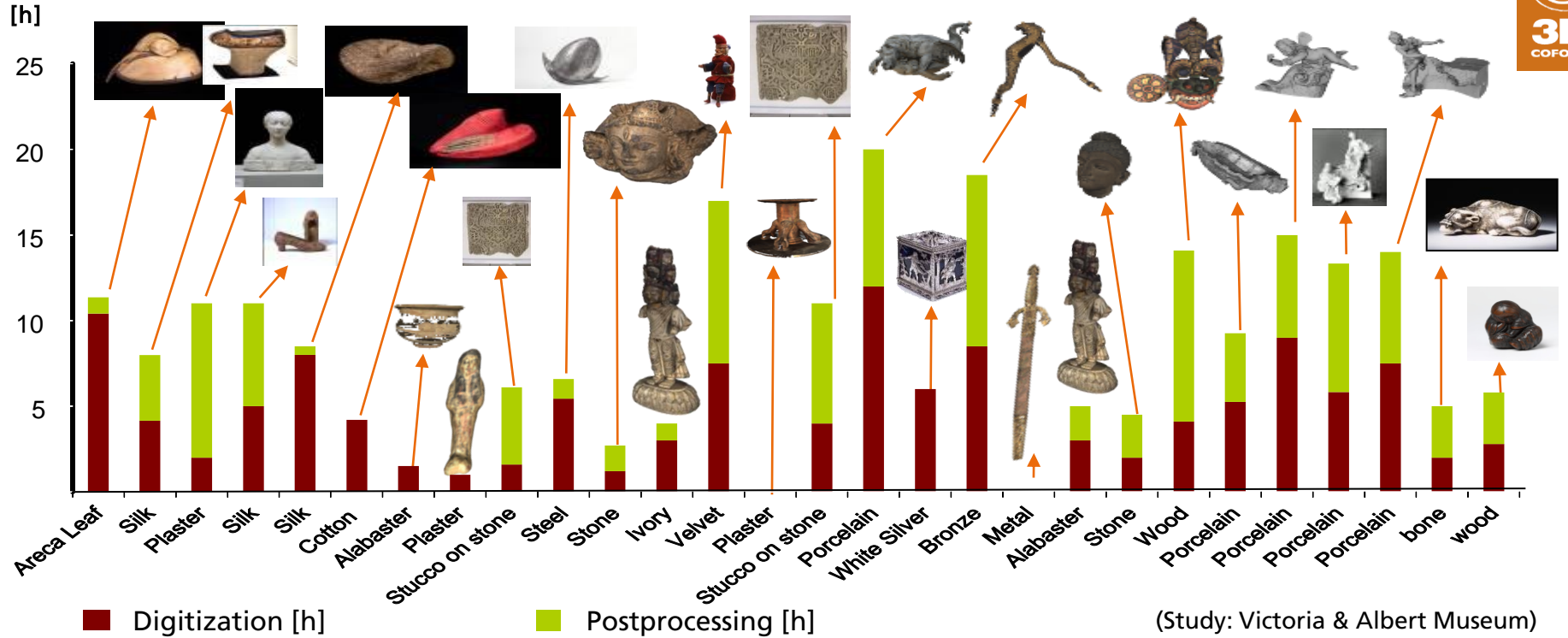
Surface analysis



Time expenditure today - V&A study: geometry and texture



Time expenditure today - V&A study: geometry and texture



Time expenditure today - V&A study: geometry and texture



What is missing? (e.g. from the perspective of the Berlin Museums)

- ~6 million artifacts
- 120,000 new entrants per year
- Quick estimation of effort...
 - 3D digitization of only the new entrants...
 - $120,000 / 365 \text{ days} / 24 \text{ h} / 60 \text{ min} =$
 - $0.228 \text{ objects/min} = 4.38 \text{ min/object!!!}$
- *Not feasible!*
Required: automated, scalable and economic 3D digitization processes!



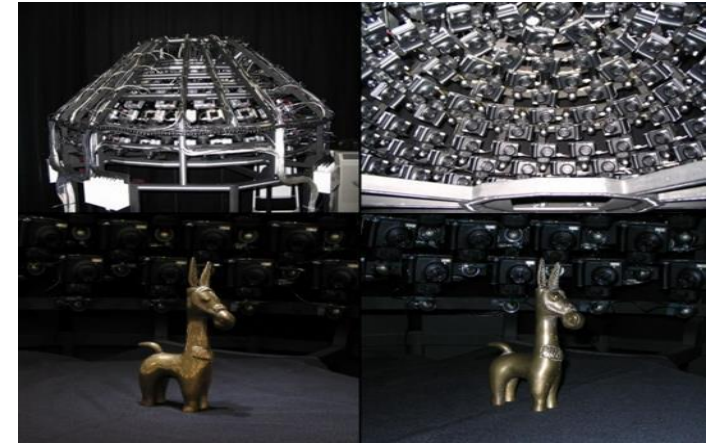
Staatliche Museen zu Berlin
Preußischer Kulturbesitz



- Cultural artifacts of worldwide heritage
- Back to 6000 BC
- More than 175 years museum history

First attempts of speeding up the process

- DOME:
 - University of Bonn, Prof. R. Klein
 - 151 Cameras and light sources
 - Geometry, texture and material property acquisition
- ORCAM:
 - DFKI, Prof. D. Stricker
 - Geometry, texture and material property acquisition
- Drawback:
 - Occlusions cannot be scanned
 - Processing time per artifact takes hours
 - Post-processing takes hours
 - Manual artifact placement and removal



Challenges

- Improved / simplified applicability of the technology
 - Geometry, texture, optical material properties acquisition
 - Cost reduction
 - Automatization
 - Scalability
- Improved workflows
 - Interdisciplinary knowledge transfer
 - Guidelines and best practices
- Projects with critical mass



Rongorongo tablet
Ethnological Museum Berlin

Our Vision: Fully automated 3D Scanning Pipeline *CultLab*^{3D}

- **Pass 0: New entries arrive at a museum archive / depot**
 - Place series of artifacts on conveyor tablets
 - Place conveyor tablets on conveyor belt system
- **Pass 1: Dome-like coarse scanner** (patent pending)
 - Acquisition of geometry, texture and optical material properties using photogrammetric approaches (MVS, PS,...)
 - Pre-classification of incoming artifacts for semantically supported 3D centered annotation
 - Iterative scan planning for consecutive pass in which occlusions are resolved

Our Vision: Fully automated 3D Scanning pipeline *CultLab*^{3D}

- **Pass 2: Compliant robotic arms with 3D scanners on end effectors at turntable**
 - Resolve remaining occlusions based on iterative scan planning (pass1)
 - Add more detail to full 3D scan and semantic classification of artifacts
- **Pass 3: Storage of real artifacts and virtual 3D models**
 - Move artifacts on conveyor tablets to storage vault
 - Post-process final 3D virtual models, annotate and store them in a Cloud-based Data storage vault (→ Fraunhofer Cloud)

Does this exist yet?

- Yes. *Visit us on...*

www.digitalheritage2013.org



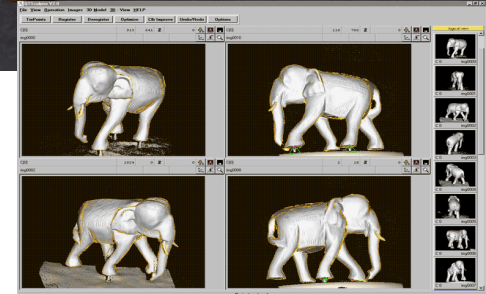
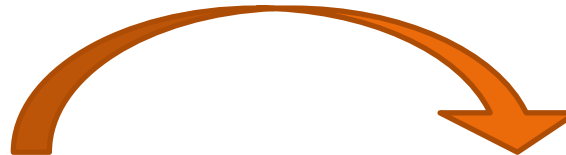
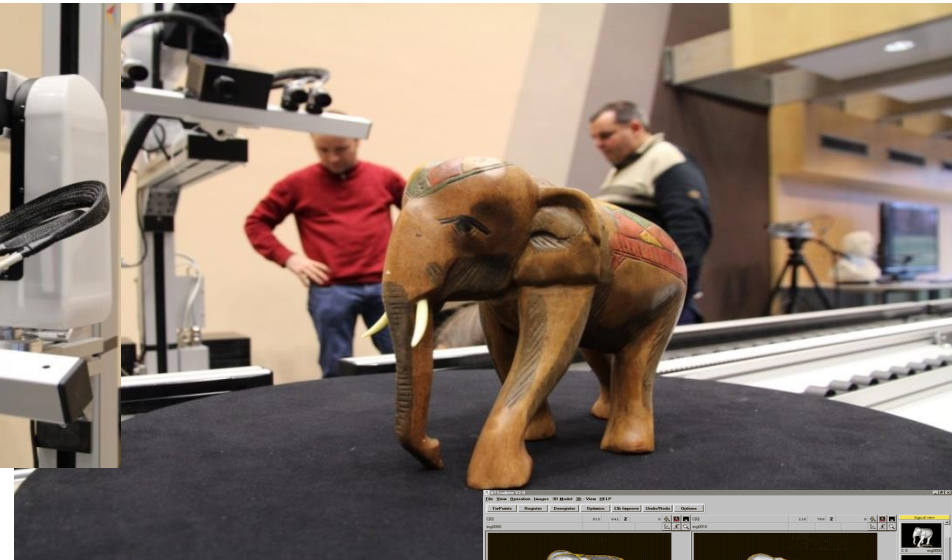
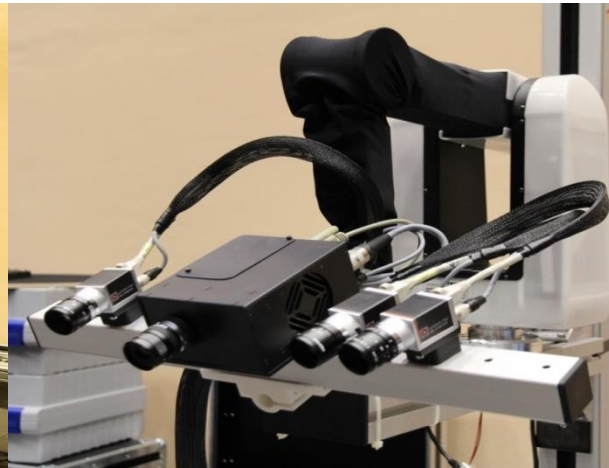
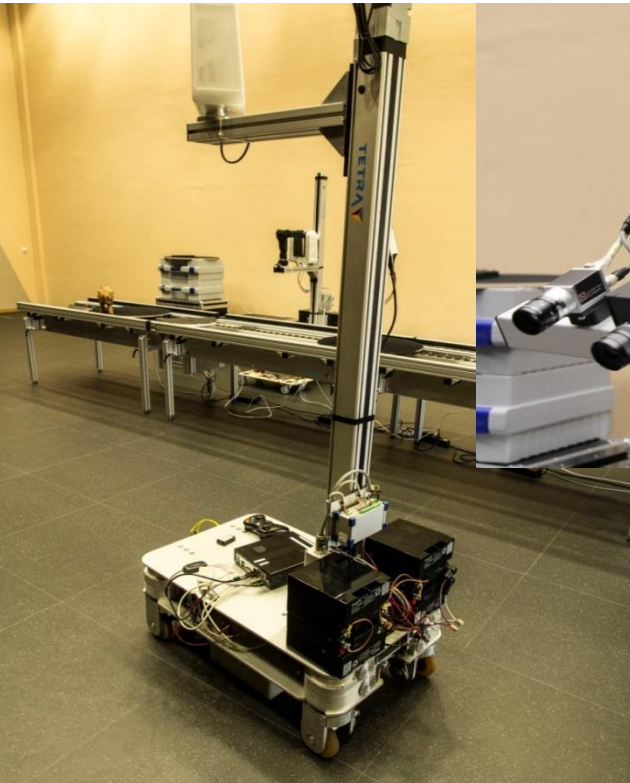
Built Heritage

Culture &
Traditions

Museums &
Collections

Libraries &
Archives

Art &
Creativity



Goals of *CultLab*^{3D}

- Economic and fast digitization of 3D artifacts to the price of 2D
- True-to-original replicas of artifacts (geometry, texture, material properties) in different levels of detail for:
 - Archiving systems of museums / research / replication
 - Tourism and culture applications
 - Game industry
- Novel possibilities of applications for museums:
 - Hybrid exhibitions
 - Parallel availability of artifacts

Advantages of *CultLab*^{3D}

- Flexibility regarding artifact sizes
 - Automated acquisition pipeline (objects up to size 60x60cm)
 - Efficient coarse-scanner
 - On-demand scanning of remaining occlusions/cavities
- Autonomous object-centric full acquisition
 - Any object size under 3m height
- More to come for increased flexibility in...
 - Sizes
 - Material complexities

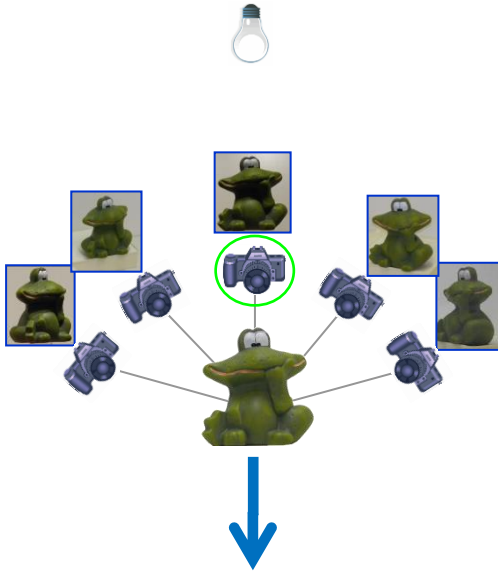
Excursion: what if my MVS reconstruction is incomplete?

Multi-View Stereo (MVS) + Photometric Stereo (PS) ...to complete 3D geometry

Multi-View Stereo + Photometric Stereo

Multi-view Stereo (MVS)

- different perspectives
- same light position





PS(E): Orientation Consistency

„Two points with the **same surface orientation** must have the **same or similar appearance** in an image“

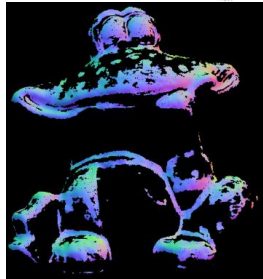
- Hertzmann, A. 2005. Example-Based Photometric Stereo: Shape Reconstruction with General, Varying BRDFs.



- For each **missing** surface point p in MVS geometry:
- Determine n best matching (most similar in appearance) points with **present** reconstruction (normal)
 - Combine normals and move to p

Fill missing regions by appropriately transferring available normals

Example = MVS geom.



(Normal map)

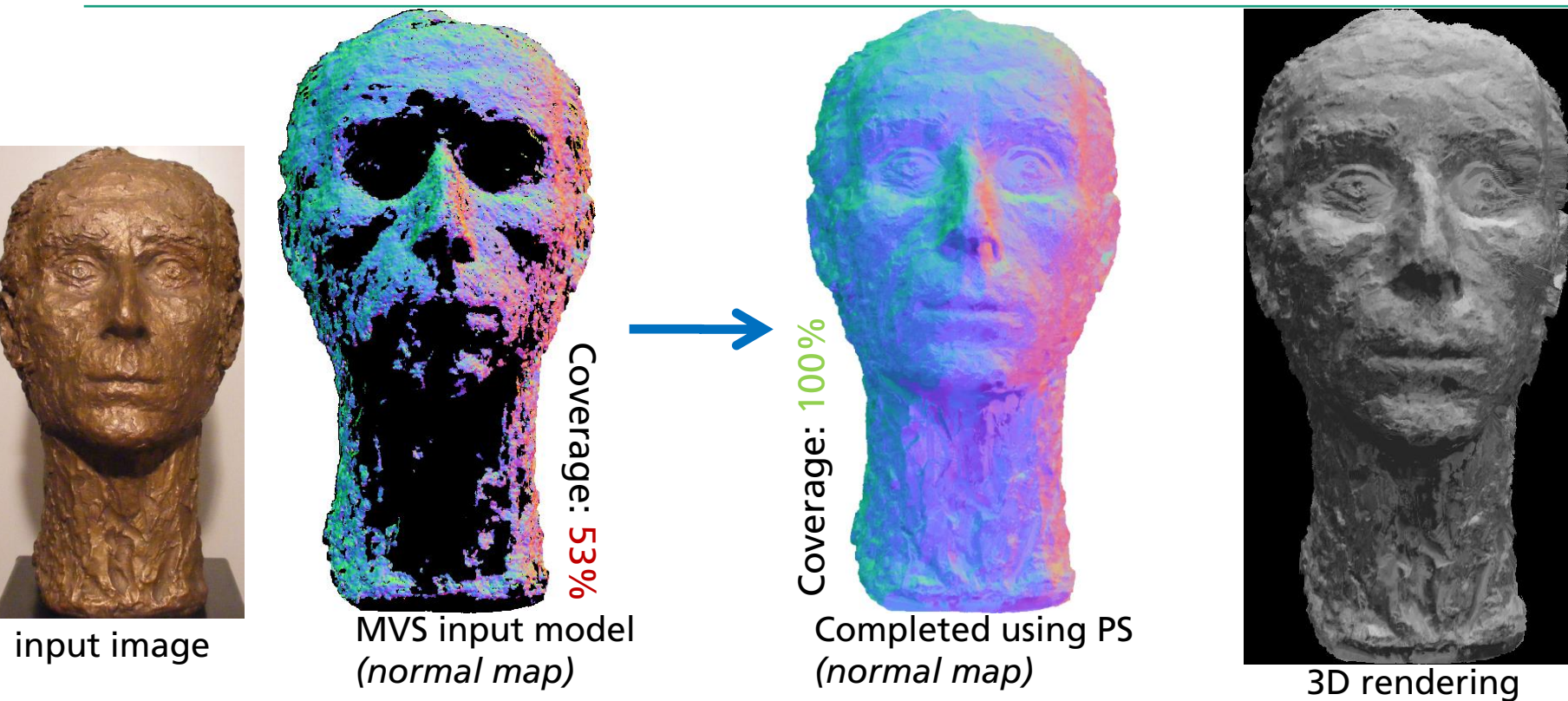


Optimization:

Matching over all points
(not only transfer MVS to missing)



Result based on lab-capturing



Results based on Real World data (webcam, 640x480 pix.)



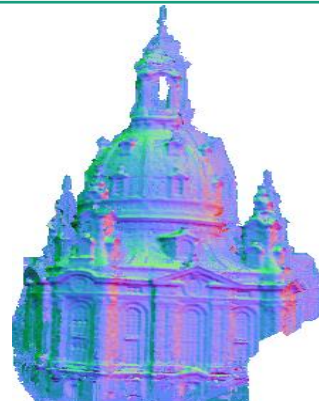
input image
(webcam, 640x480)



MVS input model
(3D rendering)



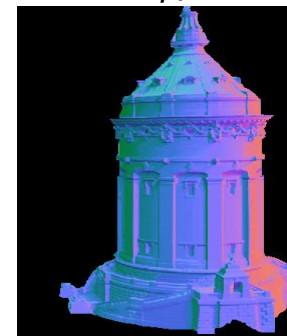
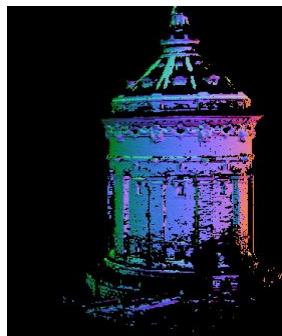
(normal map)



Completed using PS
(normal map)



3D rendering



Removing the Example from Example-Based Photometric Stereo

Jens Ackermann¹, Martin Ritz², André Stork², and Michael Goesele¹

¹ TU Darmstadt

² Fraunhofer IGD

Abstract. We introduce an example-based photometric stereo approach that does not require explicit reference objects. Instead, we use a robust multi-view stereo technique to create a partial reconstruction of the scene which serves as scene-intrinsic reference geometry. Similar to the standard approach, we then transfer normals from reconstructed to unreconstructed regions based on robust photo-

*Removing the Example from Example-Based Photometric Stereo,
Trends and Topics in Computer Vision, p. 197-210, vol. 6554, Springer, 2012*

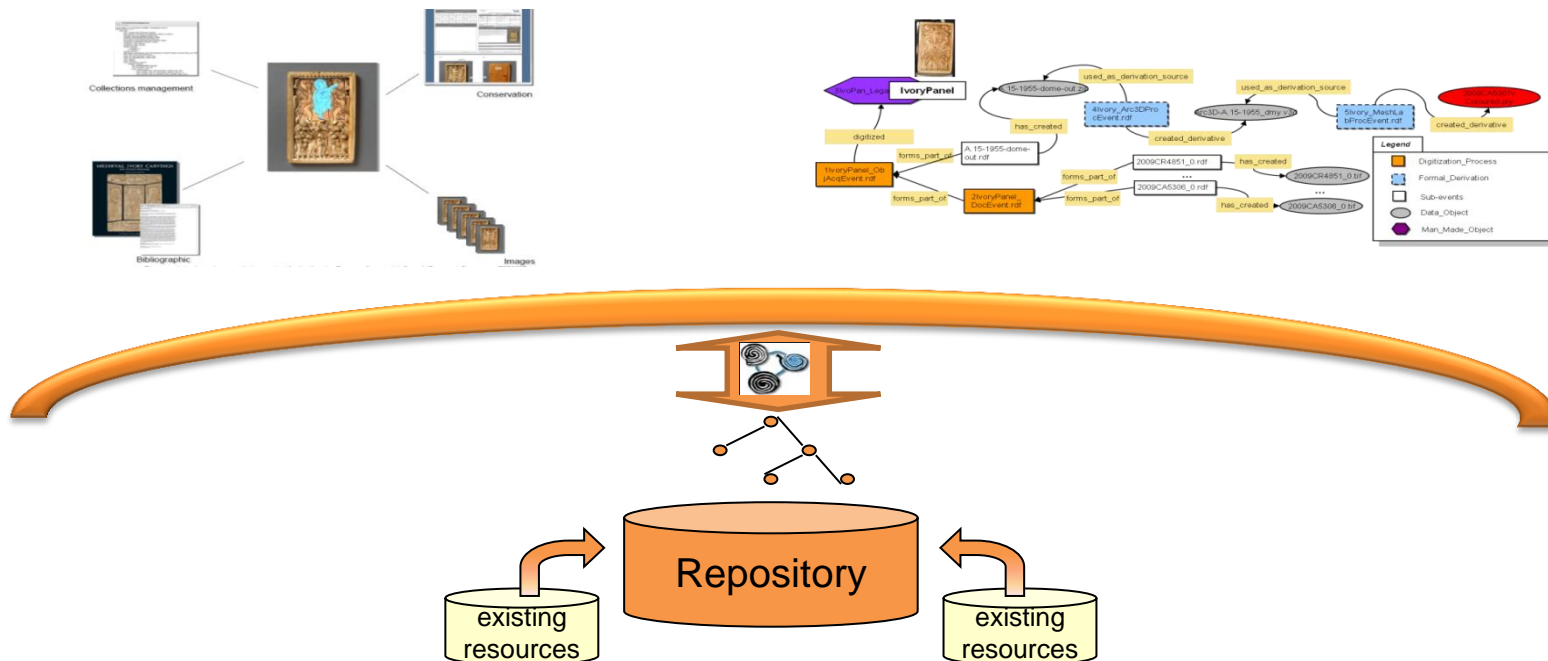
Enriching digitized artifacts – 3D centered documentation

3D Internet as a means of presentation and exploration

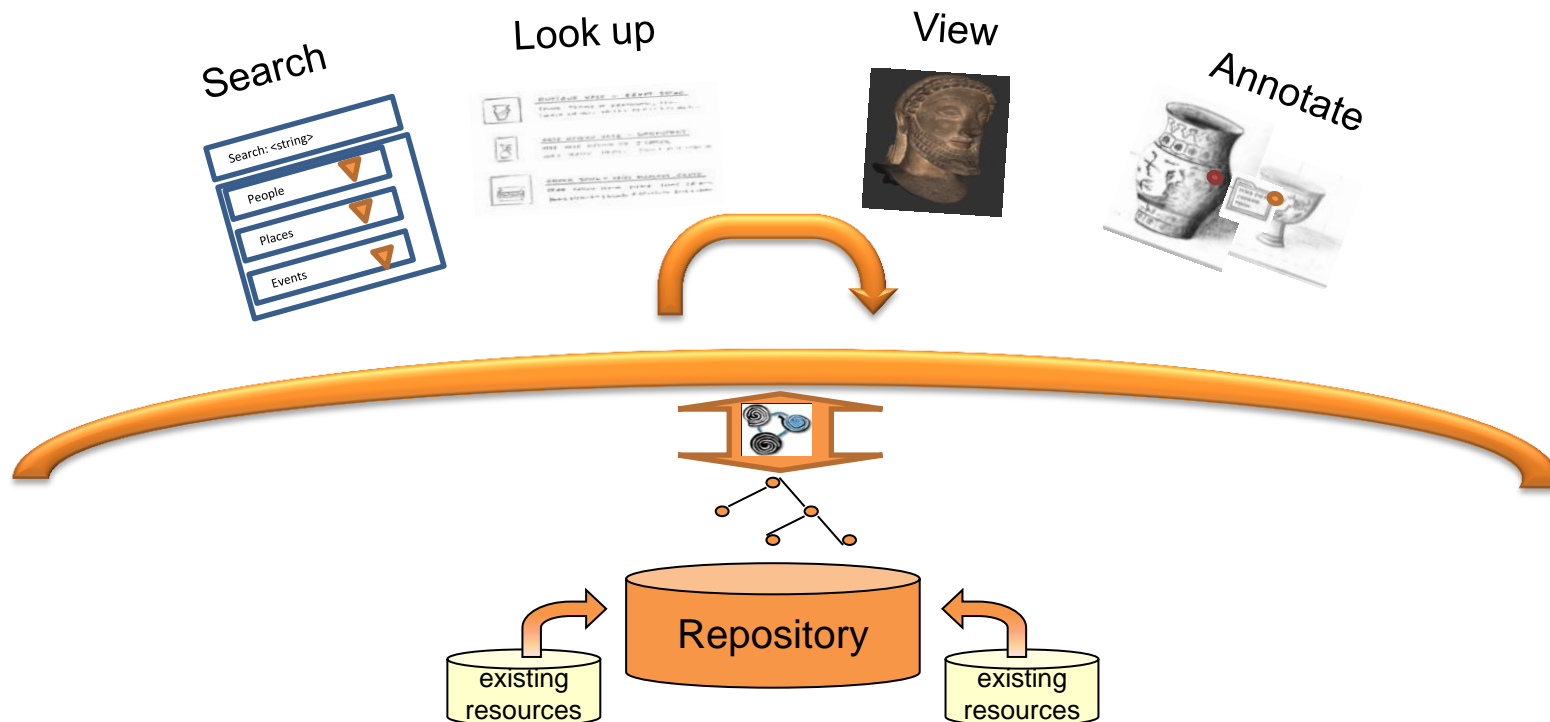
3D centered documentation



Fusing 3D/2D media-, meta- und provenience data



3D centered documentation



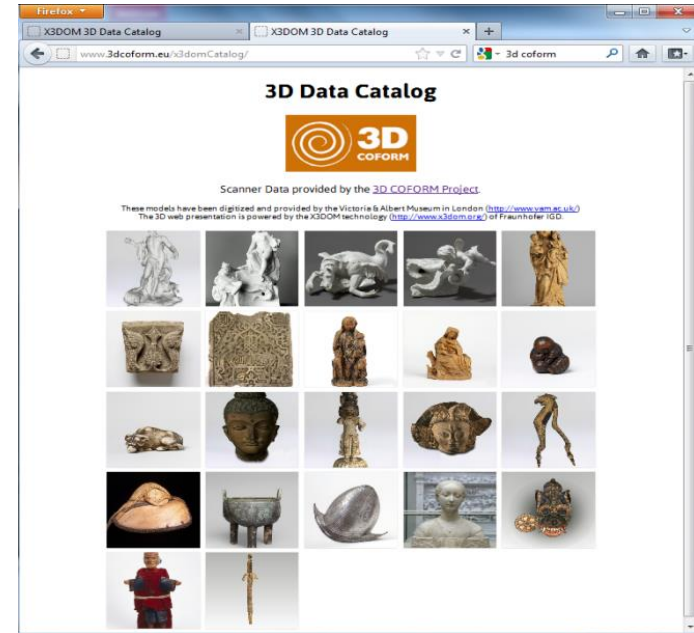


Interactive Semantic Enrichment of 3D CH Collections

accepted for EG VAST 2012

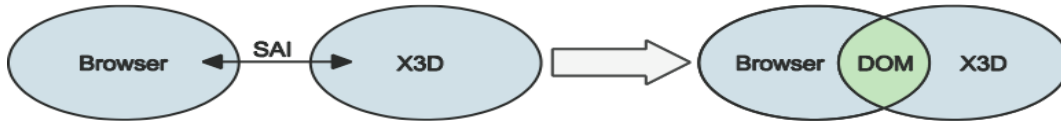
3D in the web browser

- From web sites to web applications – Improved user experience
 - Today: Adobe Flash-based web sites
 - Tomorrow: Immersive in-browser 3D
- Increased interest for 3D
 - Product presentation
 - Visualization of abstract information (e.g. time diagrams, multi-dimensional data)
 - Immersive applications in culture and tourism



*Example 3D-COFORM:
browser for historic 3D objects*

3D Internet: X3DOM – Declarative (X)3D in HTML5



- $X3DOM := X3D + DOM$
- DOM-based integration framework for declarative 3D graphics in HTML5
- Seamless integration of 3D content into the web browser

Example: 3D artifacts in Europeana

Home Explore Help About Us Follow Us My Europeana Choose a language

europæana
think culture

Explore Europe's cultural collections

3d [Help](#)

[Return to search results](#) [Previous](#) [Next](#)

3D model of Loaves and Fishes

Creator: [Cultural Informatics Research Group, University of Brighton](#) | [Contributor: Cultural Informatics Research Group, University of Brighton ; Karina Rodriguez Echavaria](#)

Date: 2012-02-21

Geographic coverage: [long -0.14188856887817 lat 50.826027910088506](#)

Type: 3D | [Translate details](#)

Subject: [Loaves and Fishes](#) | [Refers to Christ feeding the 5000 with but five loaves and two fish. \(Matthew 14:13-21, Mark 6:31-44, Luke 9:10-17 and John 6:5-15\)](#) | [Relation: http://www.publicsculpturesofsussex.co.uk/object?id=182](#)

Data provider: [Public Monuments and Sculpture Association](#) | [Provider: 3D-COFORM consortium](#) | [United Kingdom](#) | [Cite on Wikipedia](#)

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Identifier: uuid:4a08db76-318d-4e1b-88c3-ed38c825e692

Format: model/ply

Language: en


Provenance: Public Monuments and Sculpture Association

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Europeana

3D Model

Loaves and Fishes [more information on Loaves and Fishes](#)



Drag mouse to rotate
Drag mouse with shift pressed to zoom

render as flat

3D web presentation

Thank you for your attention.

CultLab ^{3D} 

**Fast, Economic and Precise
3D Digitization of
Cultural Heritage**



**Competence Center
Cultural Heritage Digitization**

Visit us on...

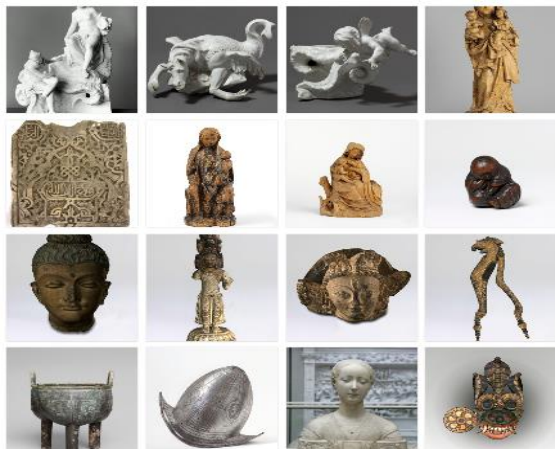
DIGITAL HERITAGE

INTERNATIONAL CONGRESS 2013
28 Oct - 01 Nov, Marseille, France

Thank you for your attention.

CultLab ^{3D} 

Fast, Economic and Precise 3D Digitization of Cultural Heritage



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Web: <http://www.igd.fraunhofer.de>

Thank you for your attention.



Competence Center Cultural Heritage Digitization