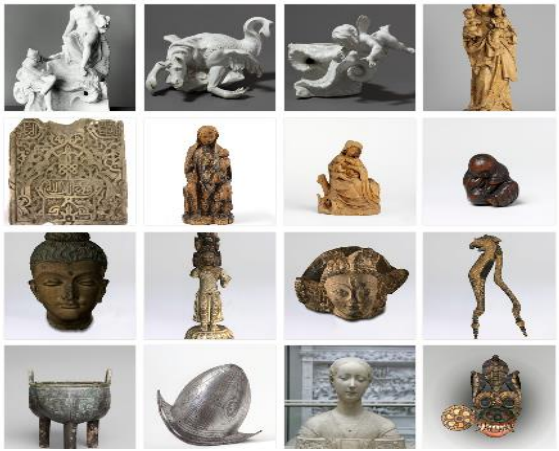
CultLab3D

Fast, Economic and Precise 3D Digitization of Cultural Heritage



Martin Ritz

Competence Center Cultural Heritage Digitization
Fraunhofer Institute for Computer Graphics Research

Fraunhoferstraße 5 - 64283 Darmstadt - Germany

eMail: Martin.Ritz@igd.fraunhofer.de
Web: http://www.igd.fraunhofer.de

TECHNISCHE UNIVERSITÄT DARMSTADT
TU Graz
Fraunhofer IGD

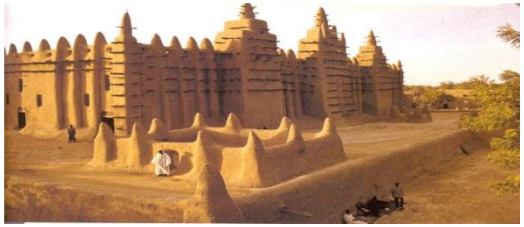
Why Digitization?

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

Fire – Herzogin Anna Amalia Library Weimar **2004**

Why Digitization?

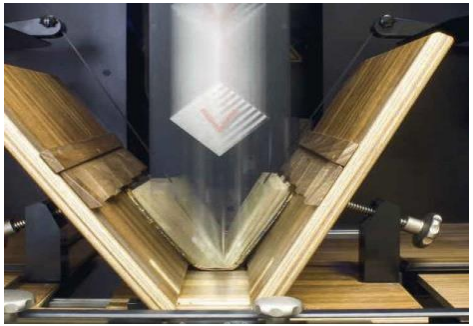
2009 Collapse – City archives Cologne, 30 shelf-km destroyed



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



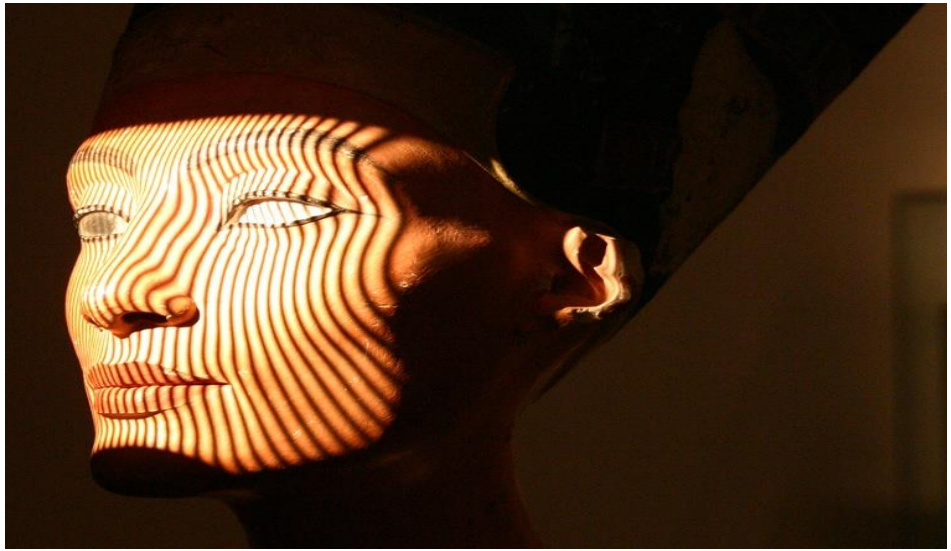
Collection of antiquities SMB
Inv.Nr. AvP VII 50

TECHNISCHE UNIVERSITÄT DARMSTADT
TU Graz
Fraunhofer IGD

…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



TECHNISCHE UNIVERSITÄT DARMSTADT
TU Graz
Fraunhofer IGD

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

TECHNISCHE UNIVERSITÄT DARMSTADT
TU Graz
Fraunhofer IGD

3D digitization of the Berlin Rongorongo tablet

Competence Center
Cultural Heritage Digitization

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

FROBENIUS-INSTITUT an der Johann Wolfgang Goethe - Universität

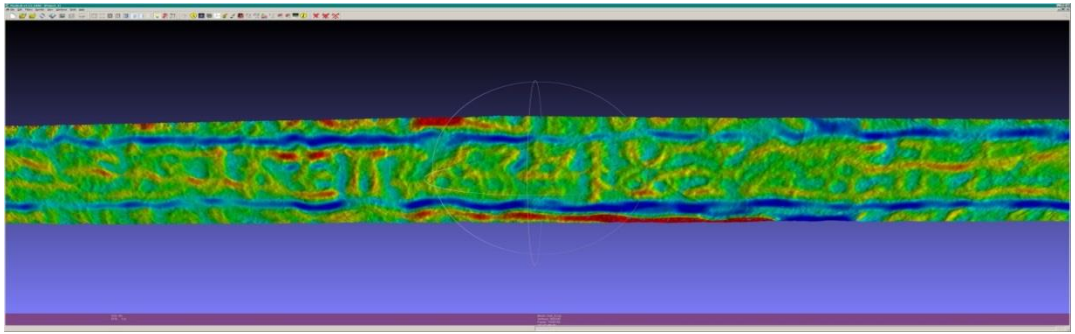
TECHNISCHE UNIVERSITÄT DARMSTADT

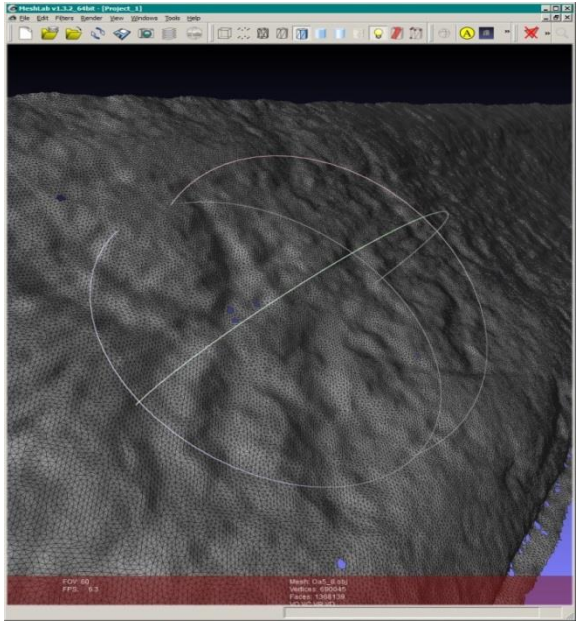
TU Graz

Fraunhofer IGD

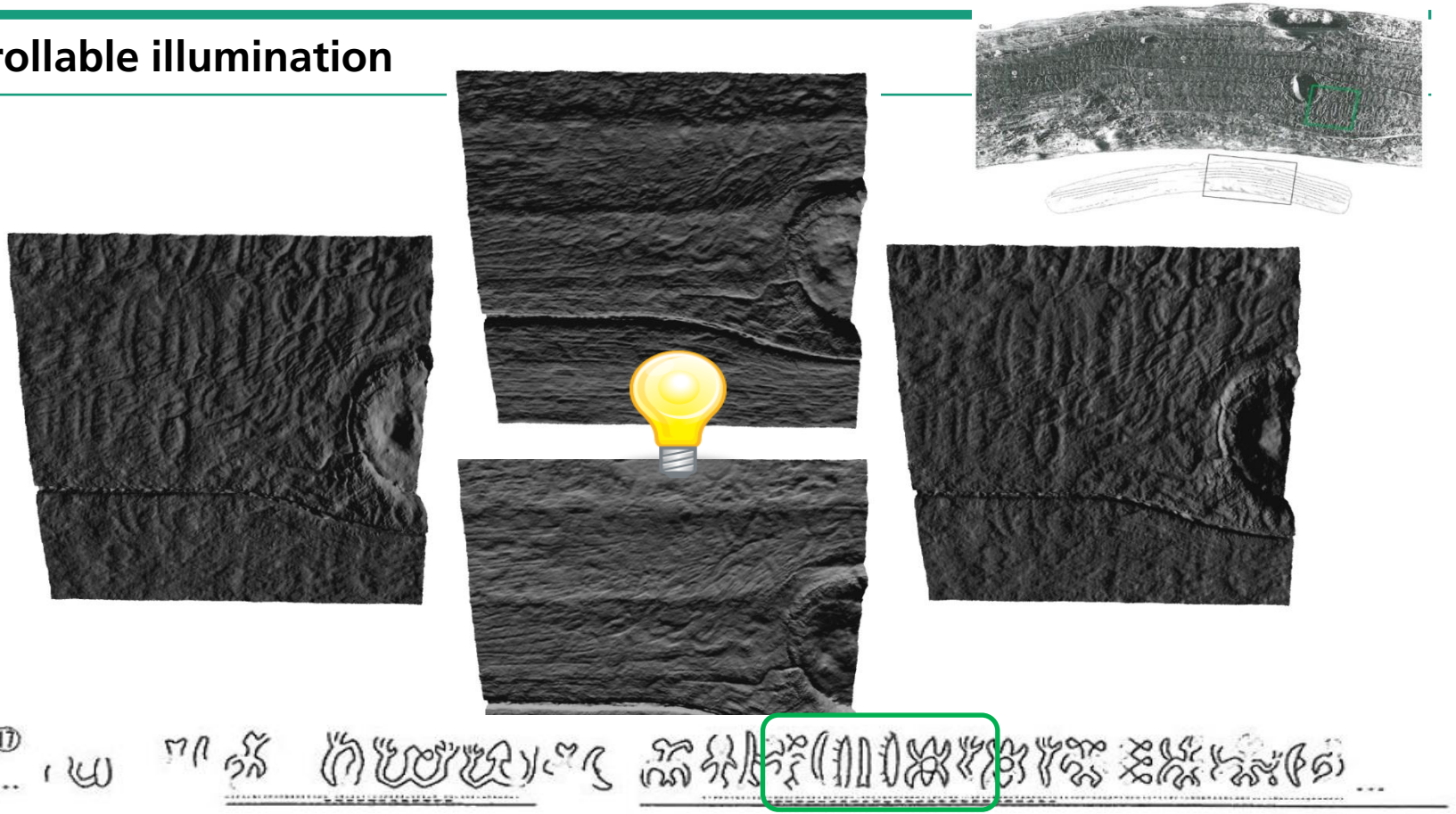
Berlin Rongorongo tablet

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

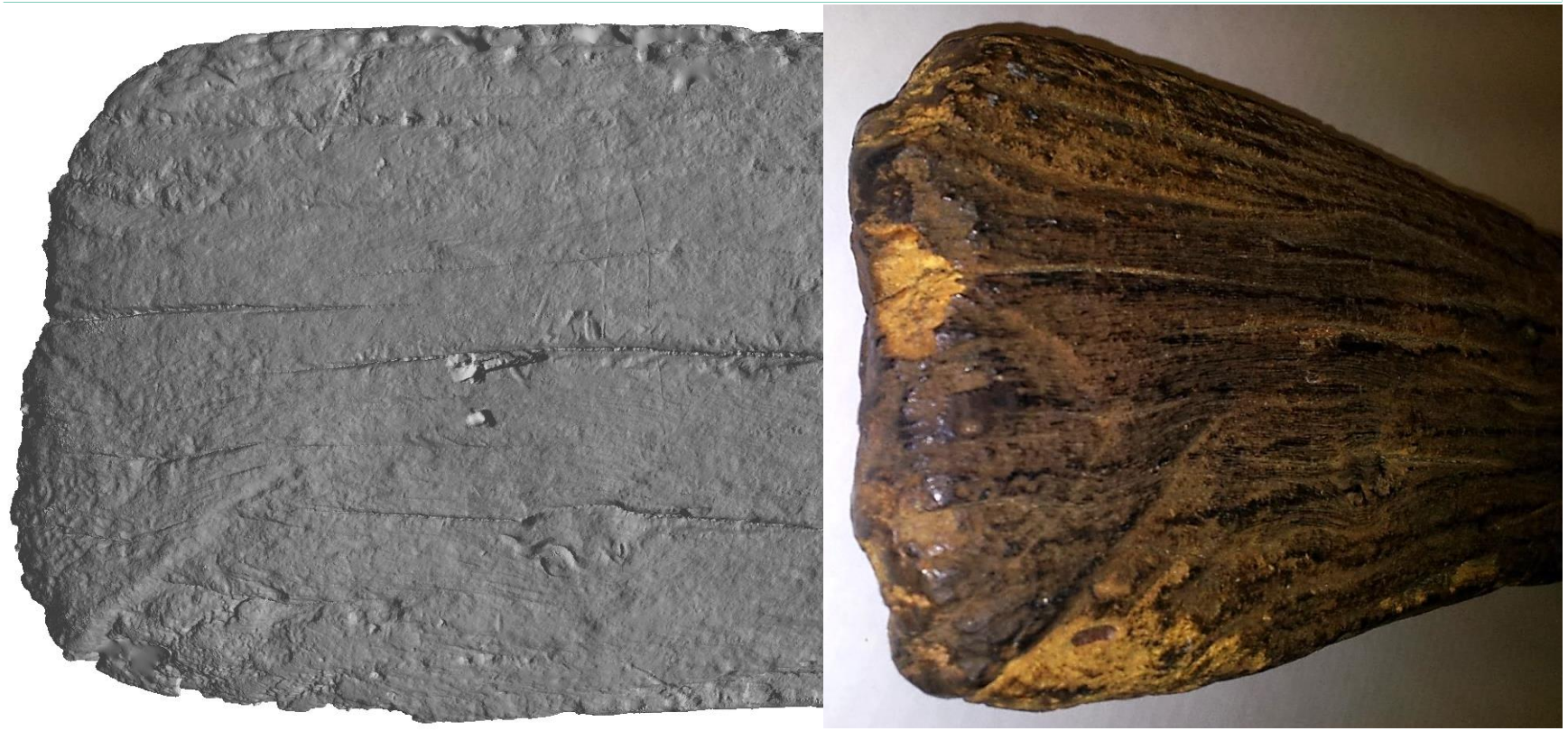




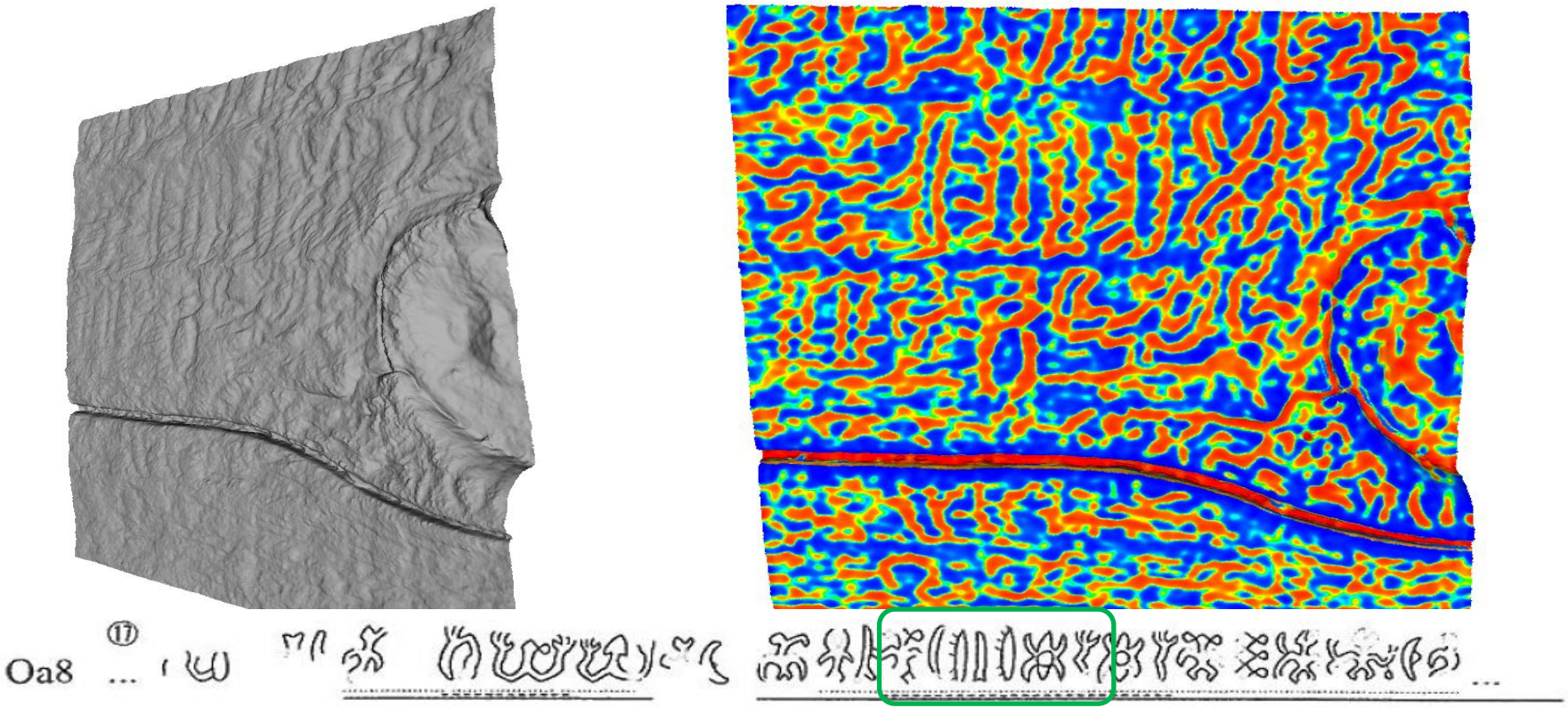
Controllable illumination



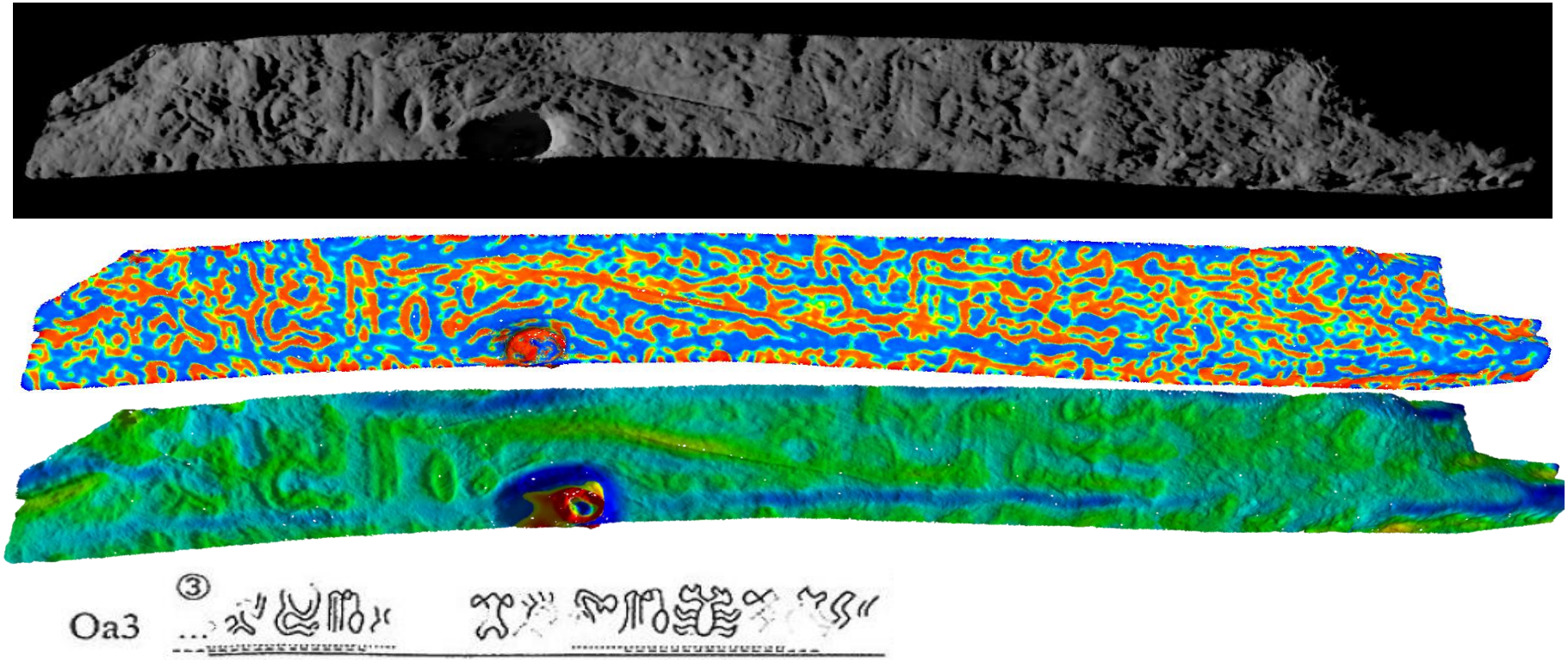
Surface analysis of backside illuminated from right



3D surface analysis with curvature filter



Surface analysis

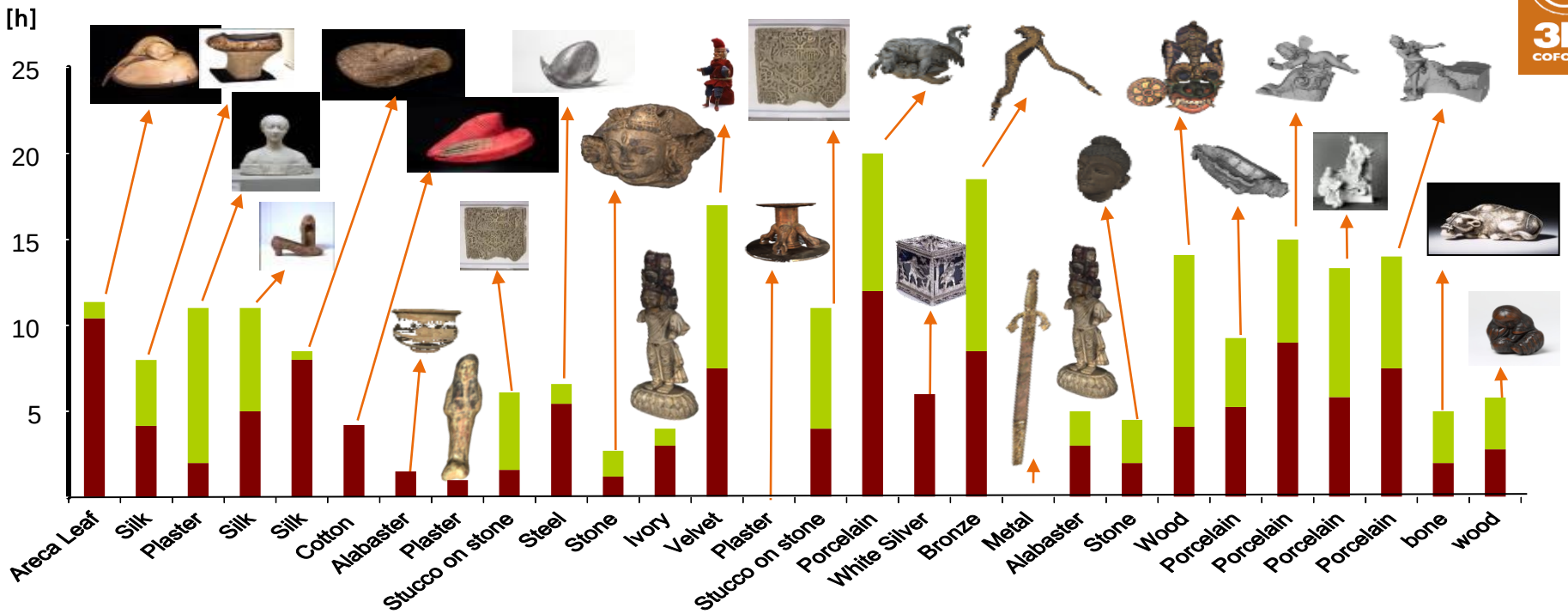


TECHNISCHE UNIVERSITÄT DARMSTADT

TU Graz

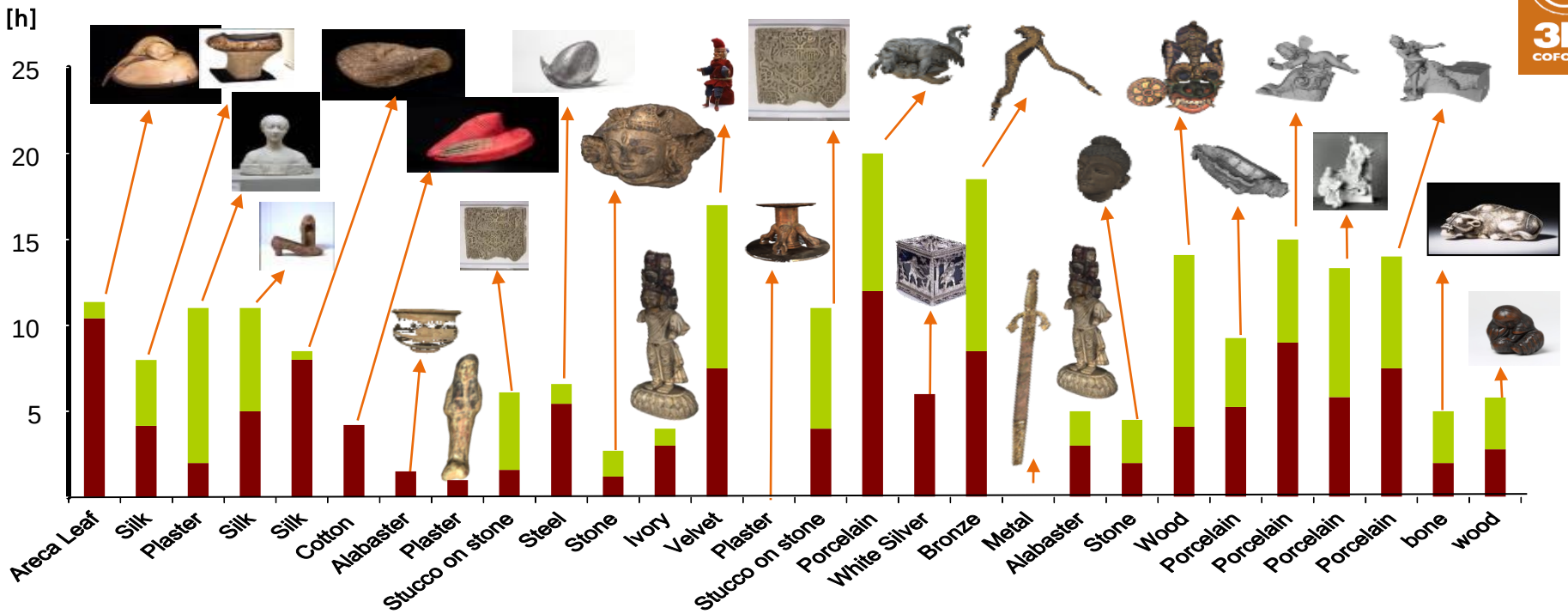
Fraunhofer IGD

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



(Study: Victoria & Albert Museum)

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



(Study: Victoria & Albert Museum)

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

(Study: Victoria & Albert Museum)

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 days / 24 h / 60 min =
    - 0.228 objects/min = 4.38 min/object!!!

- *Not feasible!*
  ***Required**: **automated, scalable** and **economic** 3D digitization processes!*

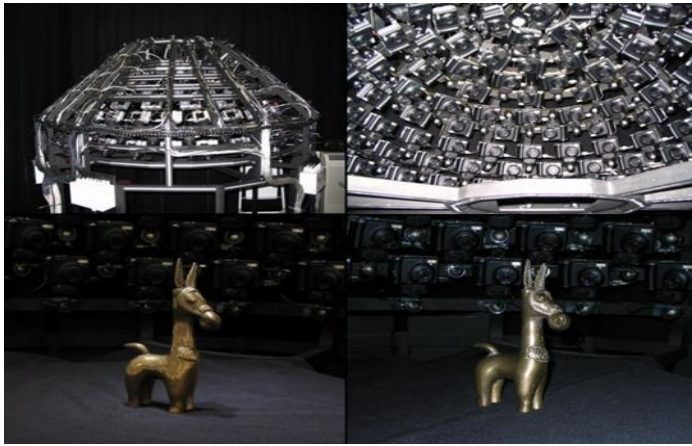
Staatliche Museen zu Berlin
Preußischer Kulturbesitz

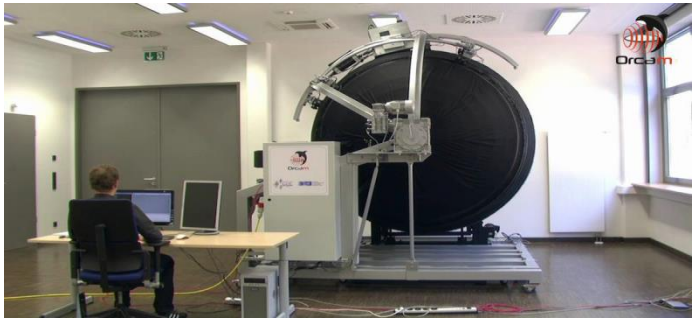
- Cultural artifacts of worldwide heritage
- Back to 6000 BC
- More than 175 years museum history

TECHNISCHE UNIVERSITÄT DARMSTADT TU Graz Fraunhofer IGD

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

CultLab3D

- **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

CultLab3D

- **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?

CultLab3D

- Yes.

Visit us on…

www.digitalheritage2013.org

Built Heritage

Culture & Traditions

Museums & Collections

Libraries & Archives

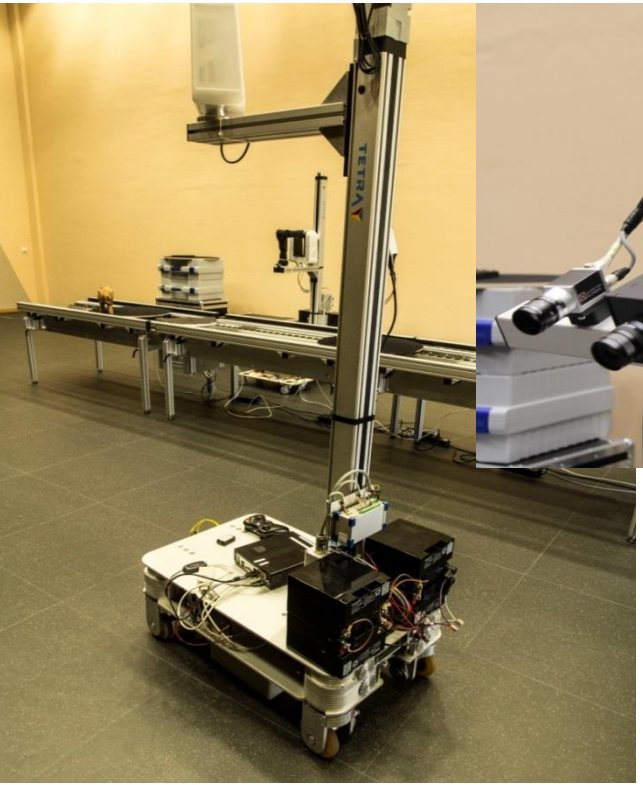
Art & Creativity

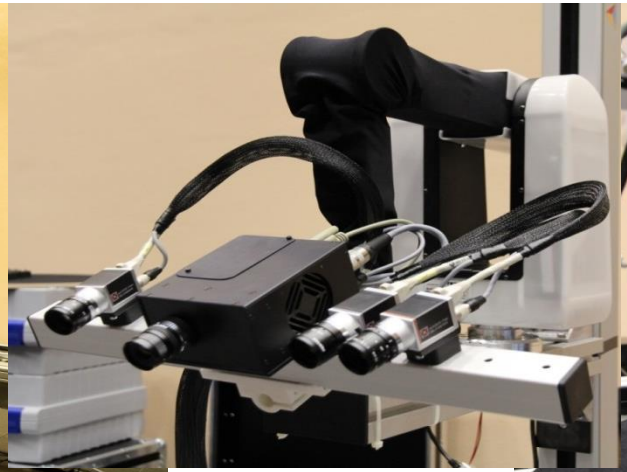
TECHNISCHE UNIVERSITÄT DARMSTADT

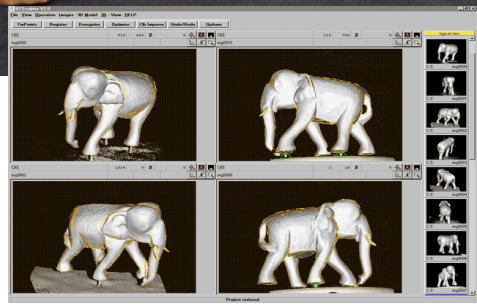
TU Graz

Fraunhofer IGD

CultLab 3D







TECHNISCHE UNIVERSITÄT DARMSTADT

TU Graz

Fraunhofer IGD

Goals of CultLab3D

- 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

Technologies used in CultLab3D (for coarse scanner)

Excursion: what if my MVS reconstruction is incomplete?

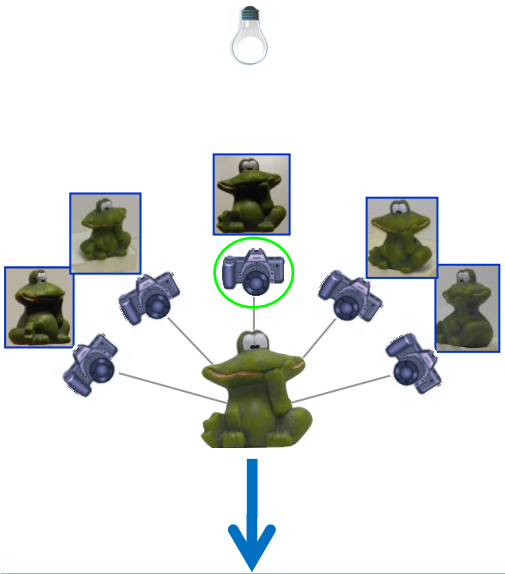
Multi-View Stereo (MVS) + Photometric Stereo (PS)

…to complete 3D geometry

Multi-View Stereo + Photometric Stereo

Multi-view Stereo (MVS)

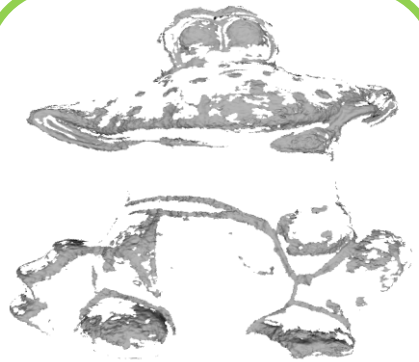
- different perspectives
- same light position

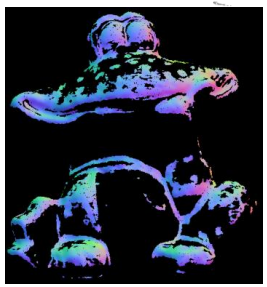


PS(E): Orientation Consistency

„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.

MVS geometry





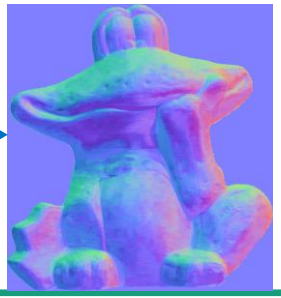
(Normal map)

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.

Optimization:

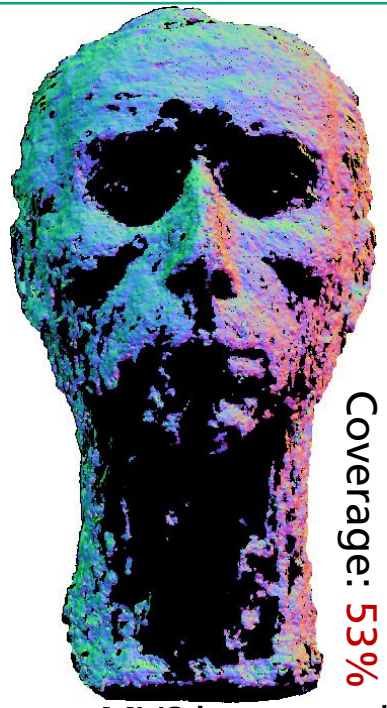
Matching over all points
(not only transfer MVS to missing)



TECHNISCHE UNIVERSITÄT DARMSTADT TU Graz Fraunhofer IGD

Result based on lab-capturing

input image



Coverage: 53%

MVS input model
(normal map)

Coverage: 100%

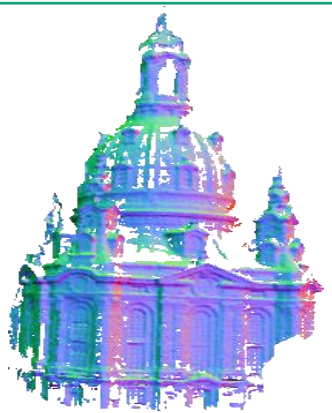
Completed using PS
(normal map)

3D rendering

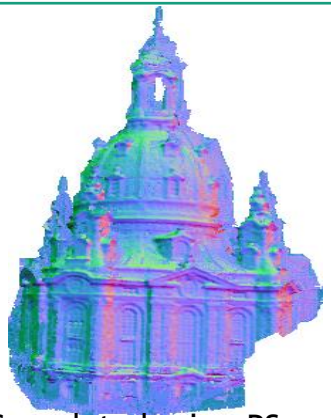
Results based on Real World data (webcam, 640x480 pix.)

input image
(webcam, 640x480)

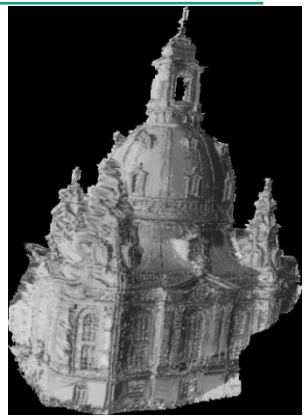
MVS input model
(3D rendering)



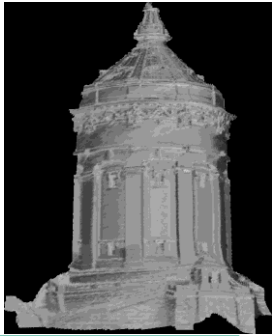
(normal map)



Completed using PS
(normal map)



3D rendering

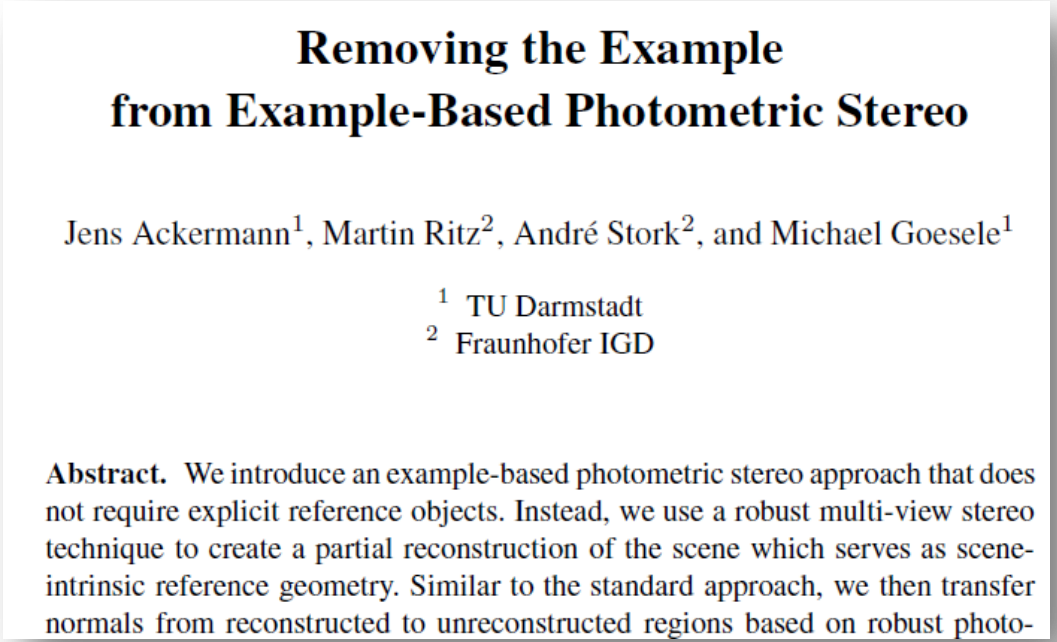


TECHNISCHE UNIVERSITÄT DARMSTADT

TU Graz

Fraunhofer IGD

Publication



Removing the Example from Example-Based Photometric Stereo

Jens Ackermann[1], Martin Ritz[2], André Stork[2], and Michael Goesele[1]

[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

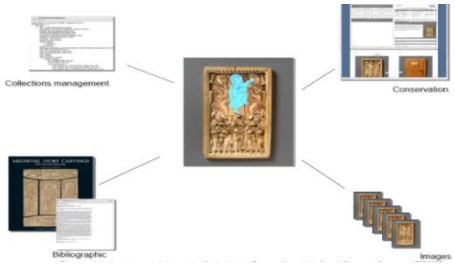
TECHNISCHE UNIVERSITÄT DARMSTADT TU Graz Fraunhofer IGD

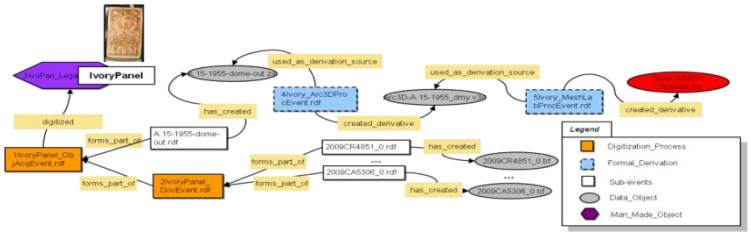
Enriching digitized artifacts – 3D centered documentation

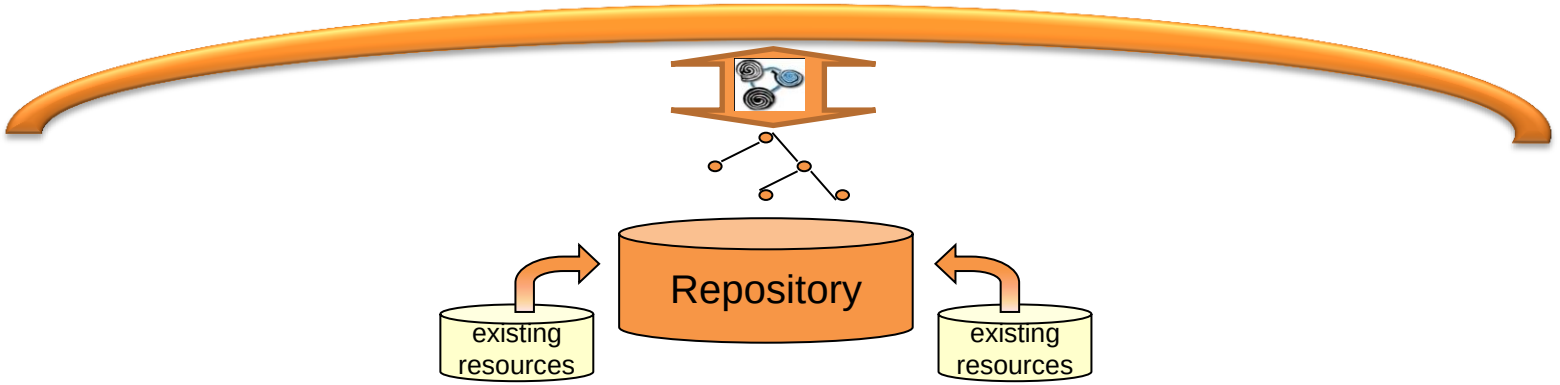
3D Internet as a means of presentation and exploration

3D centered documentation

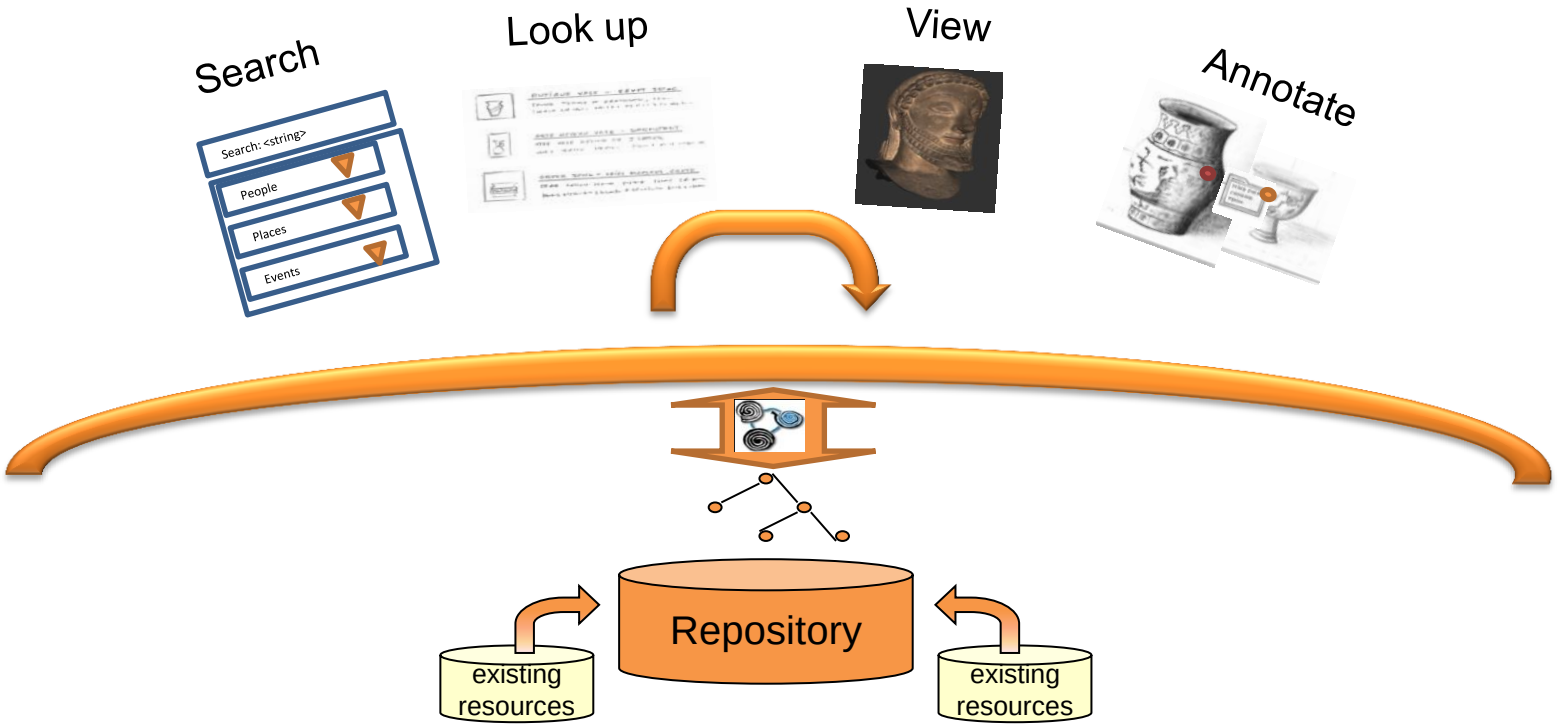
Fusing 3D/2D media-, meta- und provenience data







3D centered documentation



Example: 3D annotation tool 3D-COFORM IVB (Integrated Viewer-Browser)

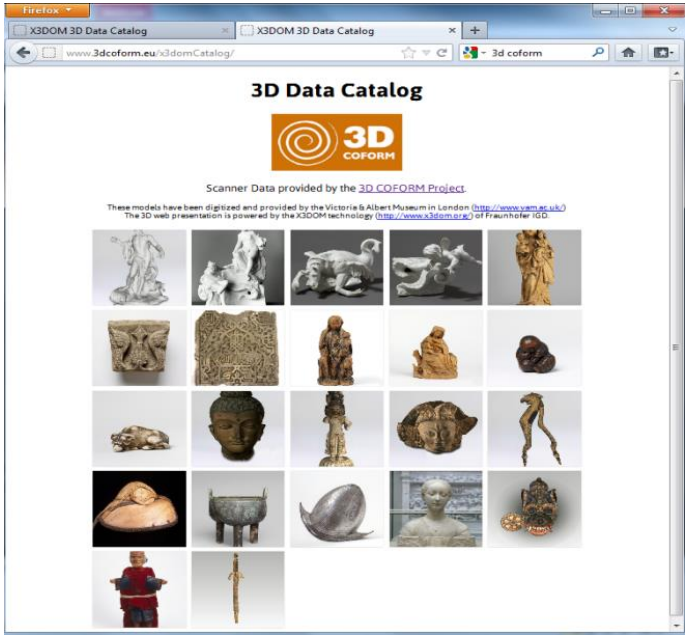
accepted for EG VAST 2012

TECHNISCHE UNIVERSITÄT DARMSTADT TU Graz Fraunhofer IGD

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

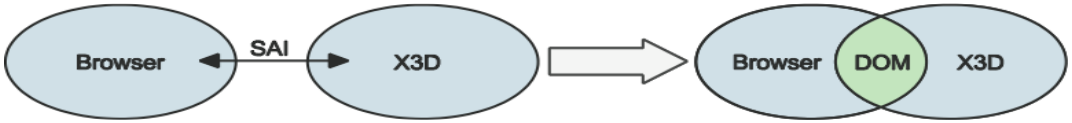
- Increased interest for 3D
  - Product presentation
  - Visualization of abstract information (e.g. time diagrams, multi-dimensional data)
  - Immersive applications in culture and tourism



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

TECHNISCHE UNIVERSITÄT DARMSTADT TU Graz Fraunhofer IGD

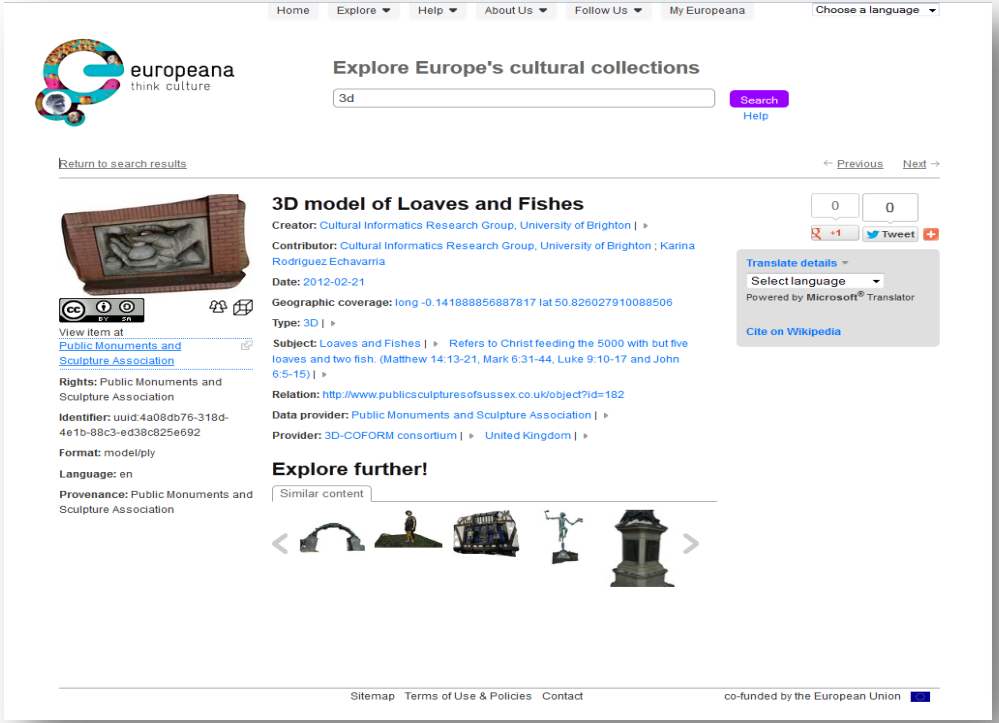
3D Internet: X3DOM – Declarative (X)3D in HTML5



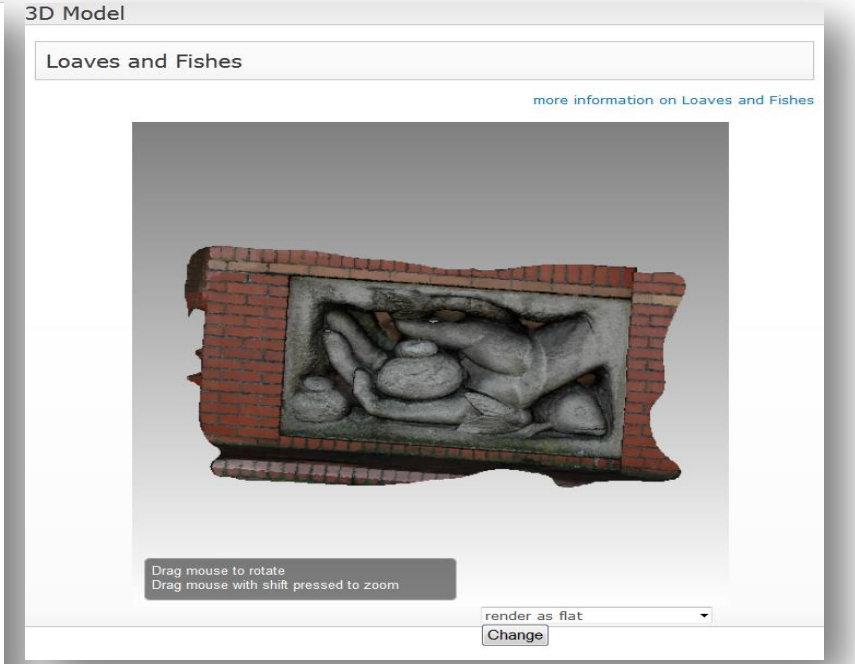
- X3DOM := X3D + DOM
- DOM-based integration framework for declarative 3D graphics in HTML5
- Seamless integration of 3D content into the web browser

TECHNISCHE UNIVERSITÄT DARMSTADT
TU Graz
Fraunhofer IGD

Example: 3D artifacts in Europeana



Europeana



3D web presentation

TECHNISCHE UNIVERSITÄT DARMSTADT
TU Graz
Fraunhofer IGD

Thank you for your attention.

CultLab 3D

Fast, Economic and Precise 3D Digitization of Cultural Heritage

Competence Center Cultural Heritage Digitization

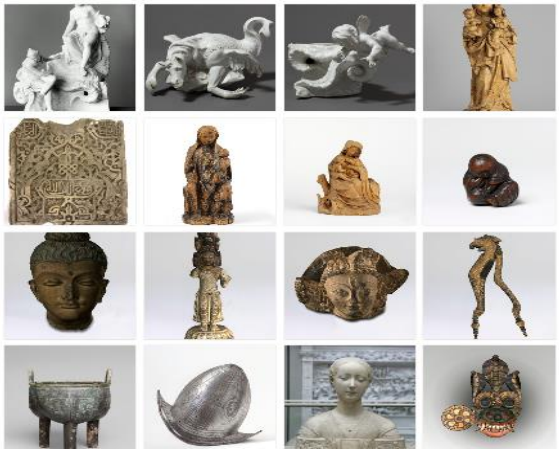
Visit us on…

TECHNISCHE UNIVERSITÄT DARMSTADT TU Graz Fraunhofer IGD

Thank you for your attention.

CultLab 3D

Fast, Economic and Precise 3D Digitization of Cultural Heritage



Martin Ritz

Competence Center Cultural Heritage Digitization
Fraunhofer Institute for Computer Graphics Research

Fraunhoferstraße 5 - 64283 Darmstadt - Germany

eMail: Martin.Ritz@igd.fraunhofer.de
Web: http://www.igd.fraunhofer.de

TECHNISCHE UNIVERSITÄT DARMSTADT TU Graz Fraunhofer IGD

Thank you for your attention.

Competence Center
Cultural Heritage Digitization

TECHNISCHE UNIVERSITÄT DARMSTADT

TU Graz

Fraunhofer IGD