Integrated High-Quality Acquisition of Geometry and Appearance for Cultural Heritage

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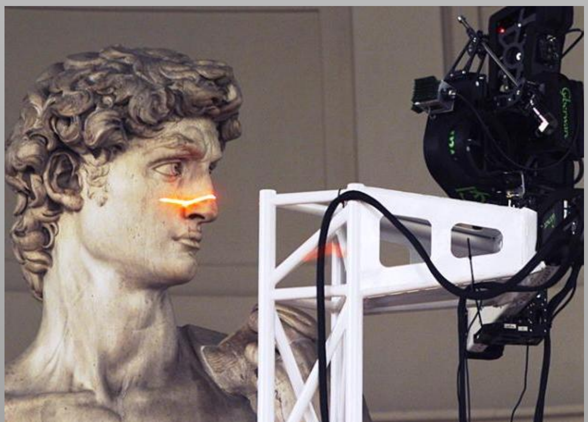
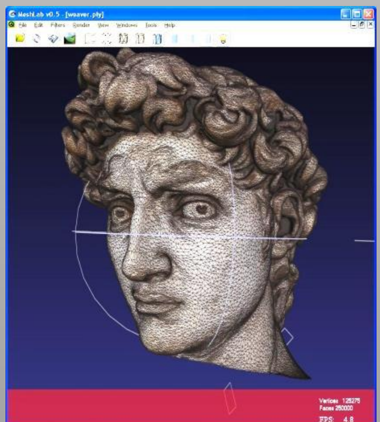
Outline

- Motivation
- Previous Work
- Overview
- Acquisition
- Postprocessing
- Results
- Conclusion

MOTIVATION

Motivation





- Digitization of CH artefacts
  - Public dissemination (see my talk tomorrow)
  - Exchange between experts and institutions
  - Novel tools for research

Motivation

- The “shapes” of objects are scanned in HQ
- … but what about “appearance”?

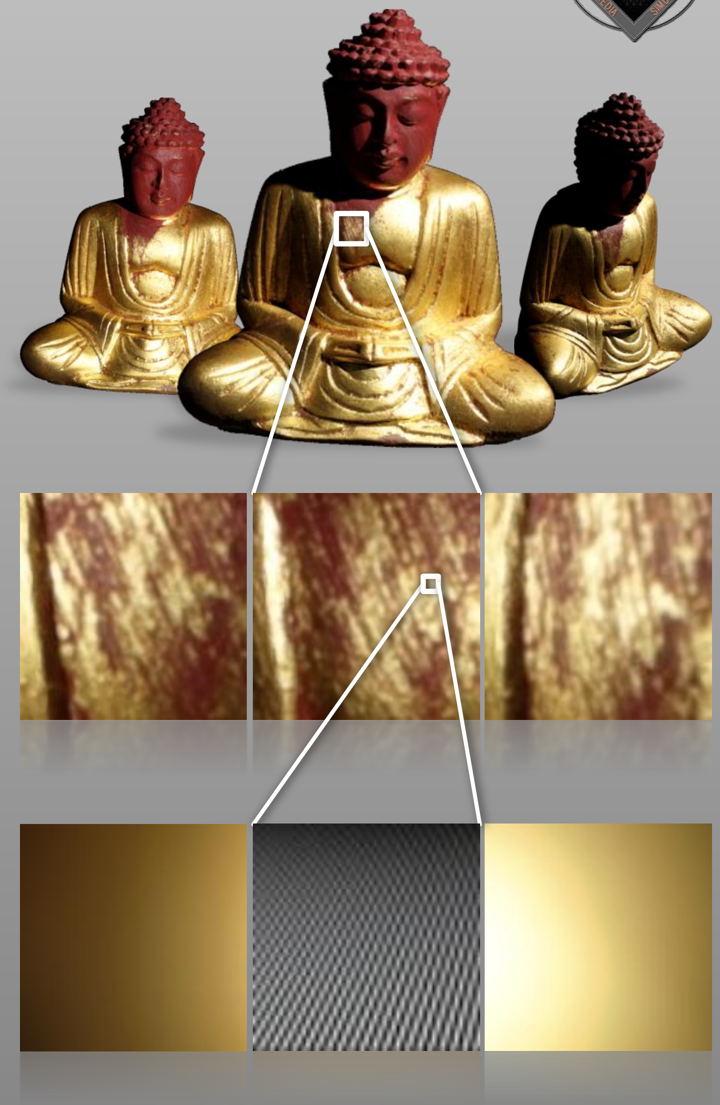
Geometry only

With texture

Correct appearance

Object Appearance

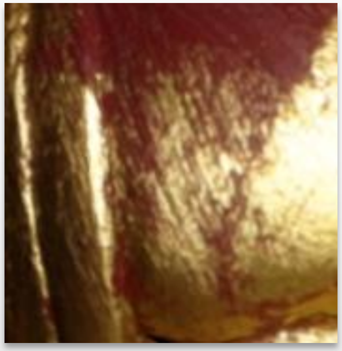
- Impression of reflection of incident light
- Influenced by features on different scales
  - Macroscopic
  - Mesoscopic
  - Microscopic
- Viewpoint and Illumination dependent



Form of Representation

Macroscopic scale

- 3D shape
- Explicit representation (e.g. polygon mesh)



Mesoscopic scale

- Individually resolved by human perception
- Statistical representation not accurate
- Explicit representation too costly

Microscopic scale

- Alignment of microscopic structures
- Statistical representation (e.g. BRDF)

Image based!

Form of Representation

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Image based!

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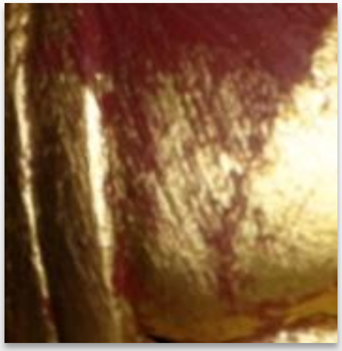

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- Statistical representation (e.g. BRDF)

Bidirectional Texture Function

Why BTF?

- Data-driven
  - No model assumption
  - No statistical approximation
- High compression ratios
- Good rendering properties
  - Full light transport simulation
  - Realtime
- Streamable over the Internet
  - see my talk tomorrow

PREVIOUS WORK

Previous Work

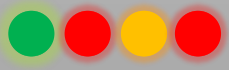
reference

rendering


Lensch et al. 2003: SVBRDF + external geometry

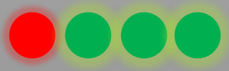
\+ Good geometry
\- Analytical BRDF model assumption
\- Mesoscale only indicated with normal-mapping
\- Separate acquisition □registration problem

macro meso micro acqu.




Müller et al. 2005: BTF + shape from silhouette

\+ Meso- <u>and</u> Microscale effects captured with BTF
\+ Integrated acquisition
\- Poor geometry

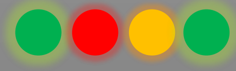


reference

rendering


Holroyd et al. 2010: SVBRDF + structured light

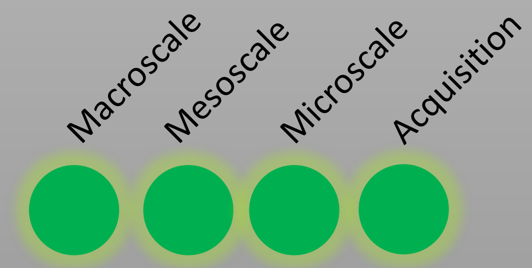
\+ High-quality geometry
\+ Integrated acquisition
\- Analytical BRDF model assumptions
\- Mesoscale only indicated with normal-mapping
\- Very sparse reflectance sampling



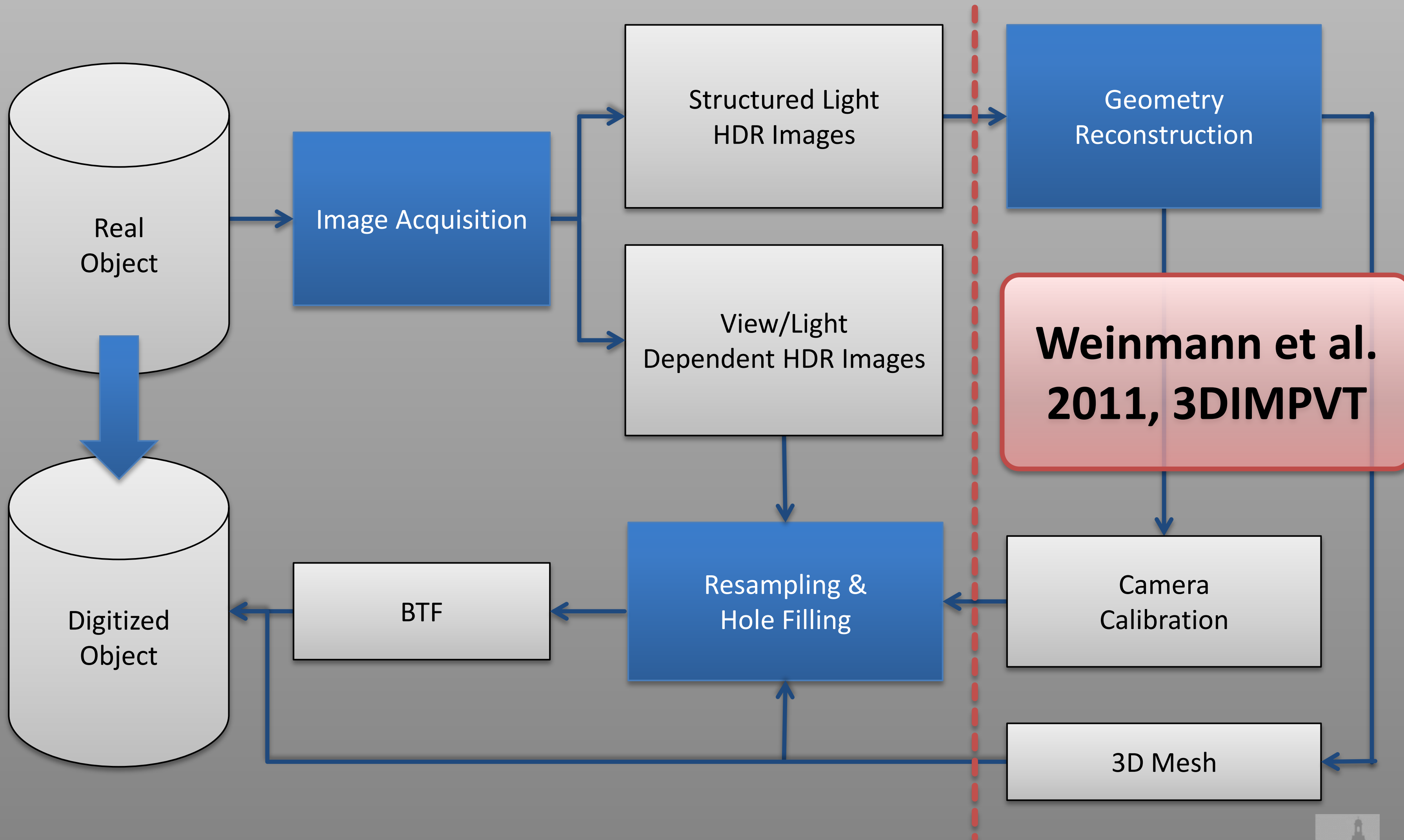
OVERVIEW

Goal: Digital Replica

- "Digital Replica"
  - Arbitrary viewpoint
  - Arbitrary illumination
  - Arbitrary arrangement (virtual scene)
- **High-quality geometry**
- **High-quality appearance** (BTF)
- **Acquisition integrated** in one setup
  - No error-prone registration
  - No movement during acquisition
    - Suitable for non-rigid objects
  - Automatable



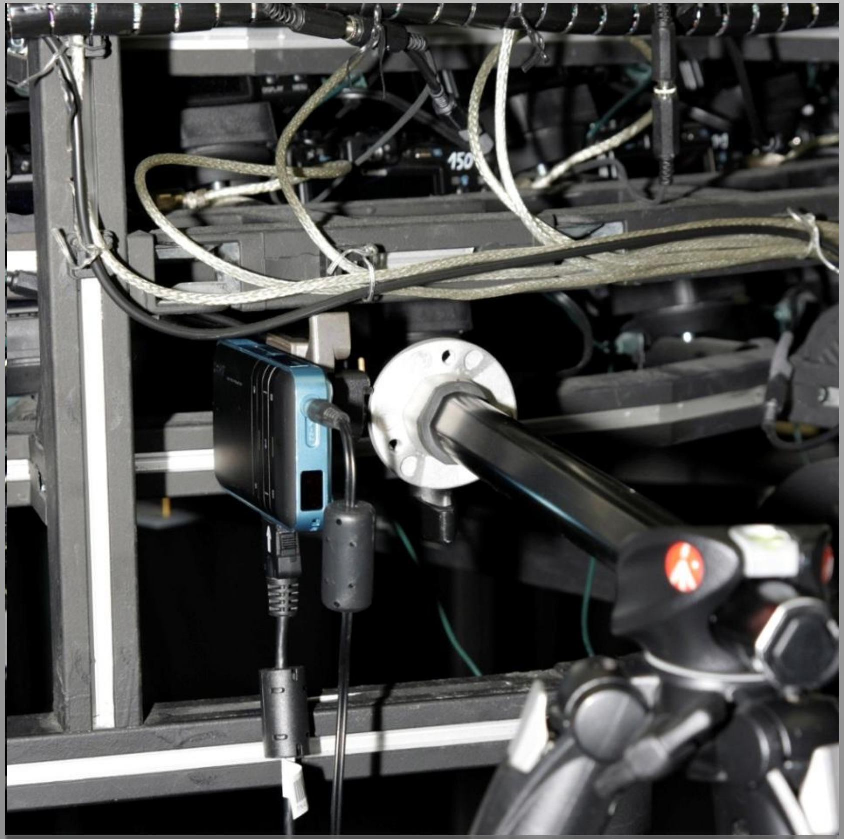
The proposed pipeline



ACQUISITION

The Capture Setup

- Multi-Camera Dome
  - 151 cameras:
    Canon PowerShot G9
    - 12 Megapixels
    - Integrated flash
    - Rapid acquisition
  - 8 projectors:
    Acer C20 Pico
    - At different positions
  - Completely computer controlled



Appearance Measurement

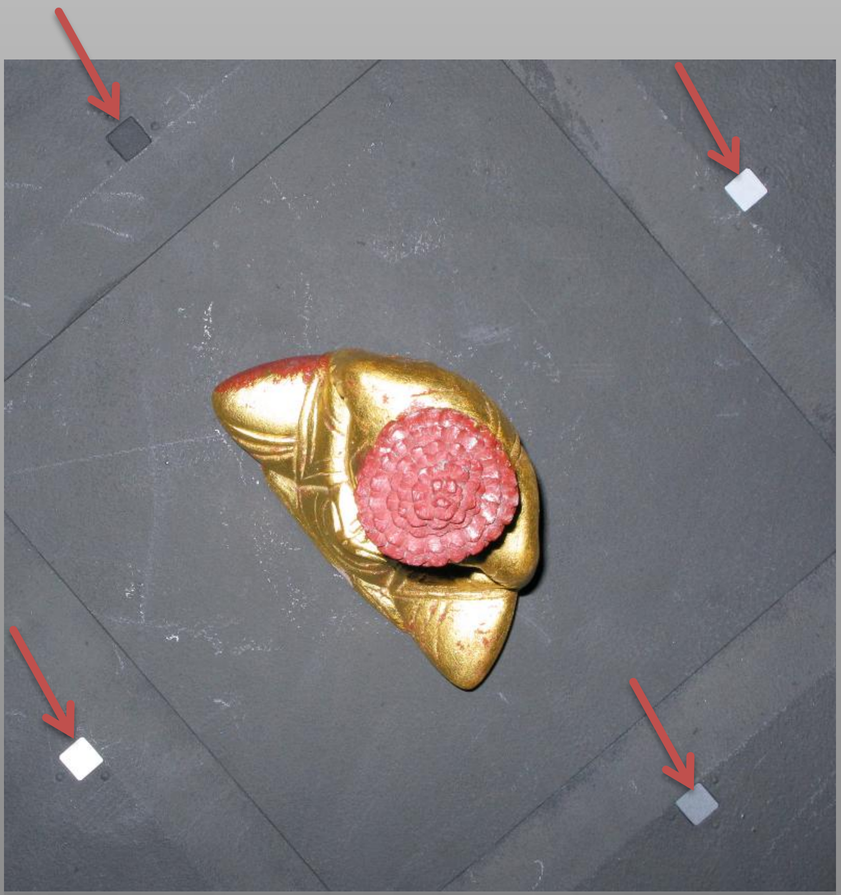
- Acquire light/view combinations:
- 151 flashes × 151 cams
- HDR: 3 exposures
- 68,403 images
- 2.5 hours
- 453 flash discharges
  ≈ a few seconds under 100W tungsten lamp

Geometry Measurement

- Acquire structured light sequences:
- 8 projectors × 38 patterns × 151 cams
- HDR: 3 exposures
- 137,712 images
- 1.2 hours

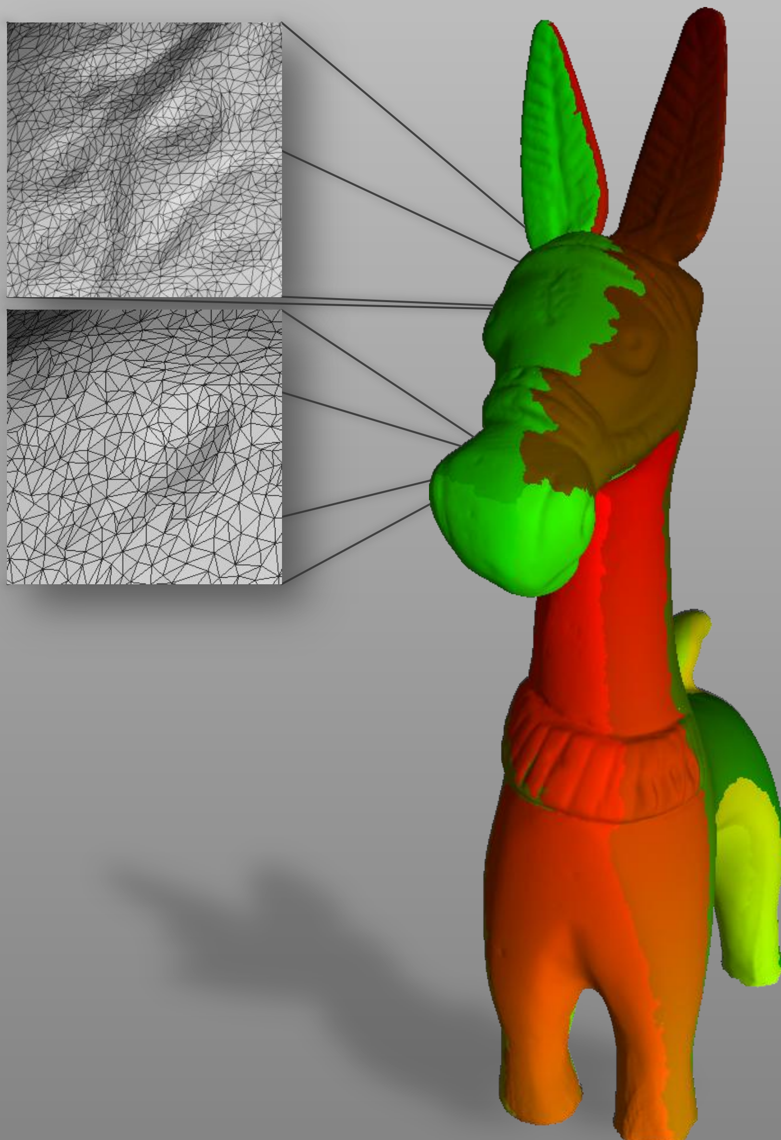
Calibration

- Geometric
  - From structured light: Weinmann et al. 2011
- Radiometric
  - Cameras: Known response curves
  - Flashes: Capture reflectance standards for every discharge

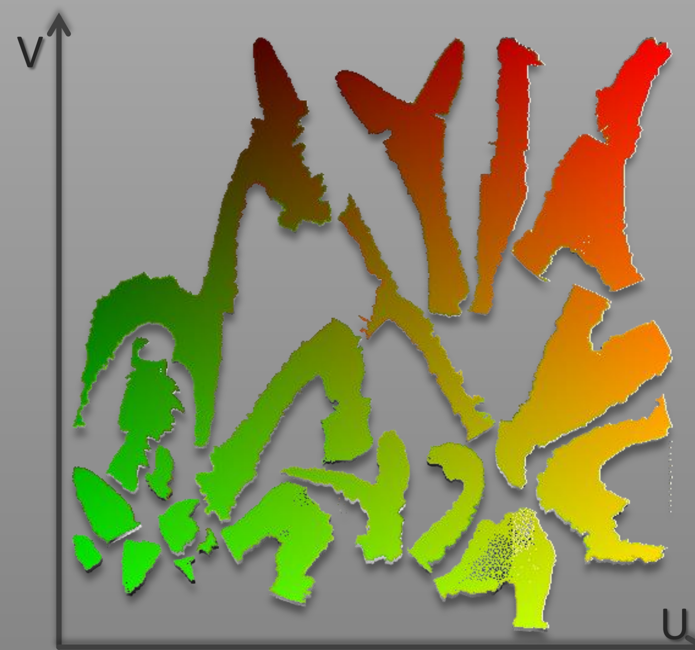


POSTPROCESSING

Geometry Reconstruction

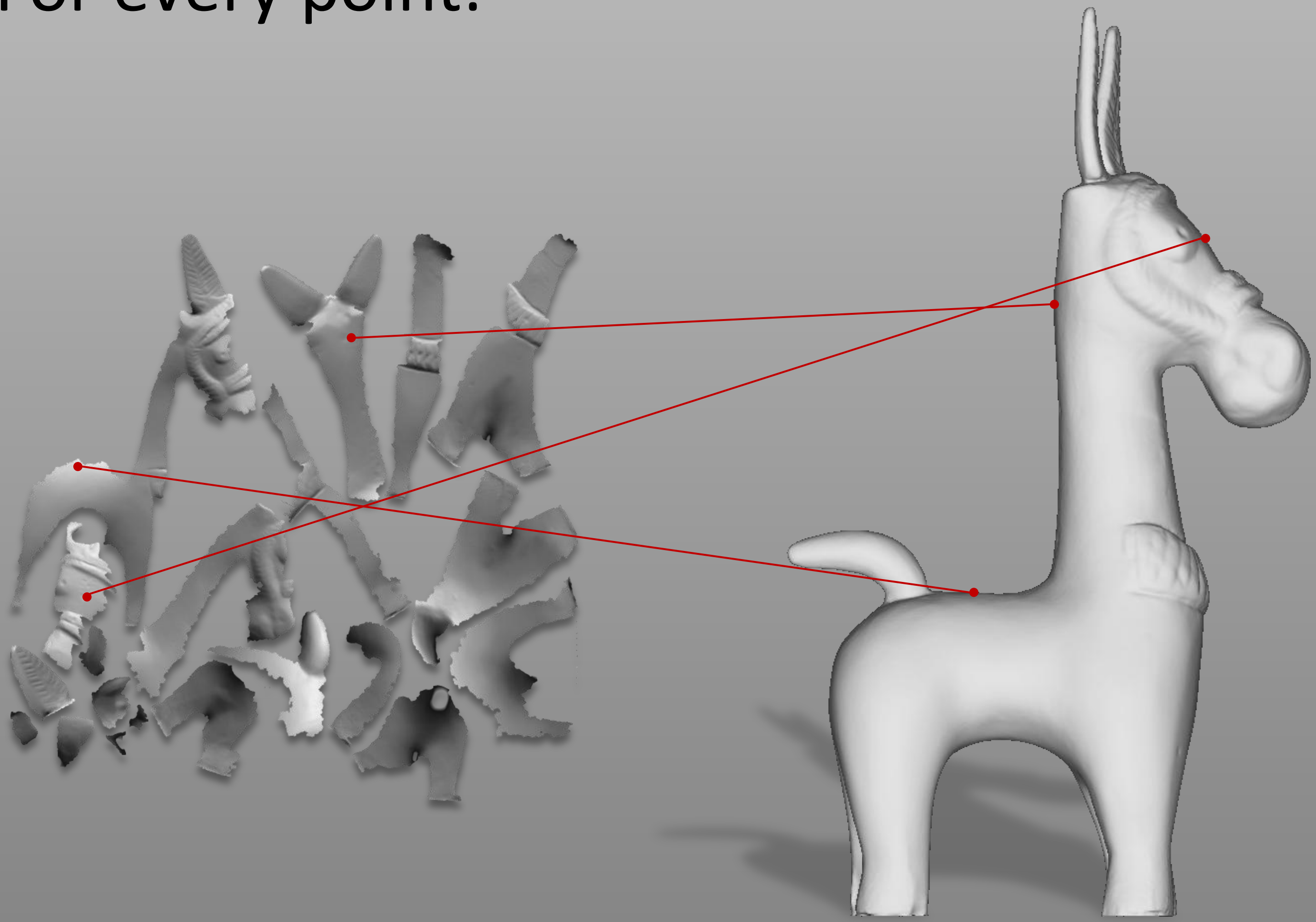


- Weinmann et al. 2011: HQ triangle meshes
- ABF++: Parameterization



Appearance Reconstruction

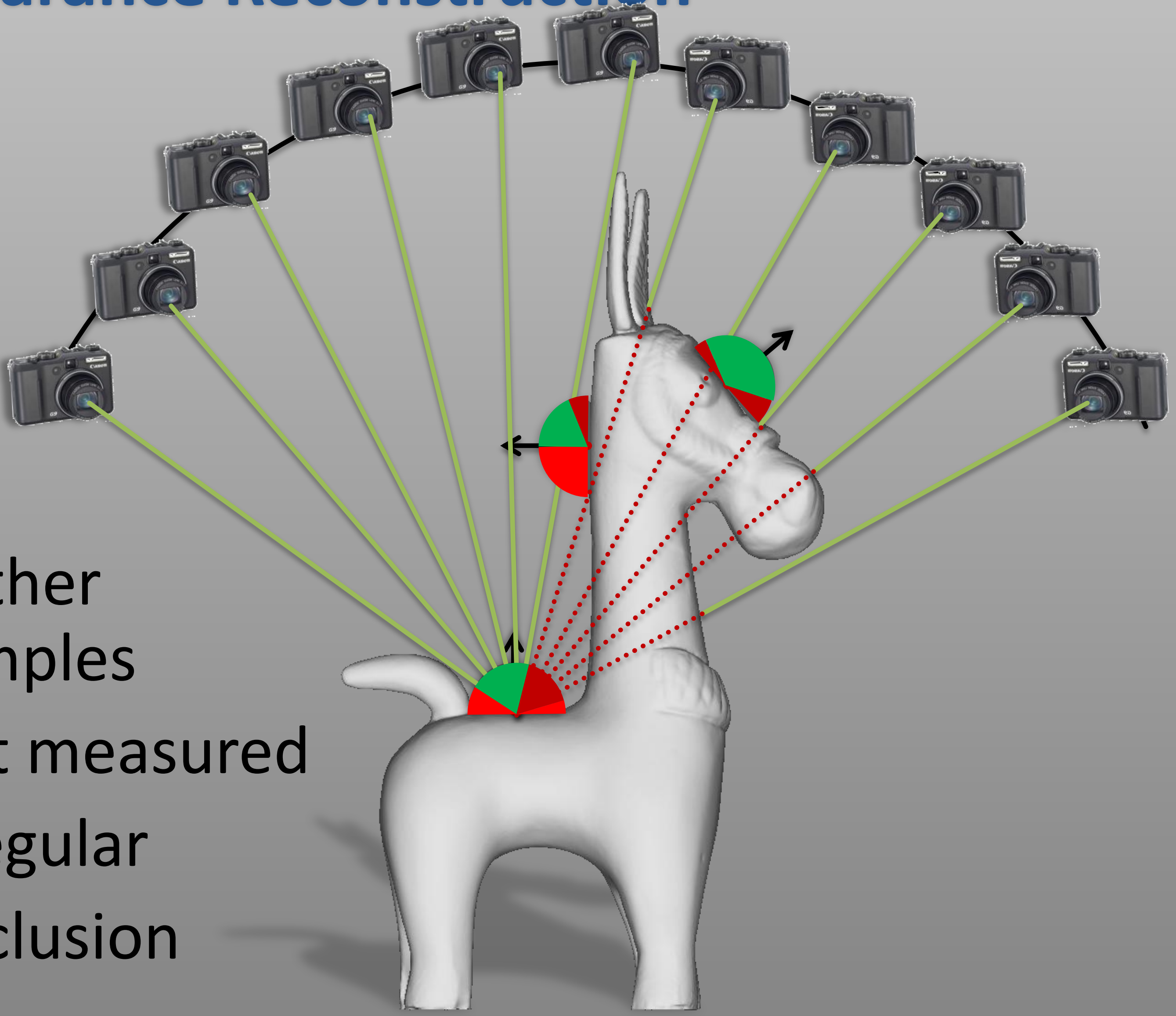
- For every point:



Appearance Reconstruction

- For every point:
- Measurement
  - Tabulated (151 × 151)
  - Camera hemispheres
- BTF
  - Tabulated (151 × 151)
  - In local orientation
  - Local hemispheres

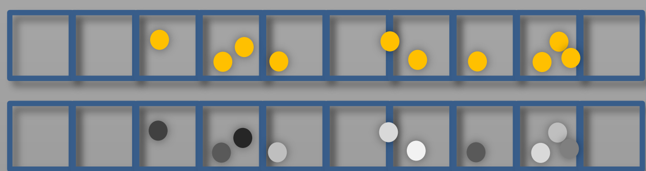
Appearance Reconstruction



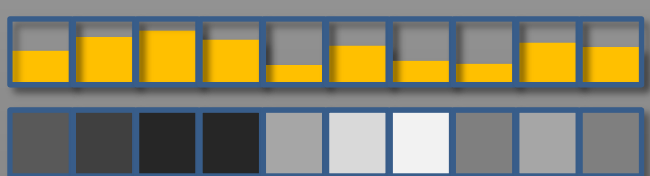
- Gather samples
- Not measured
- Irregular
- Occlusion

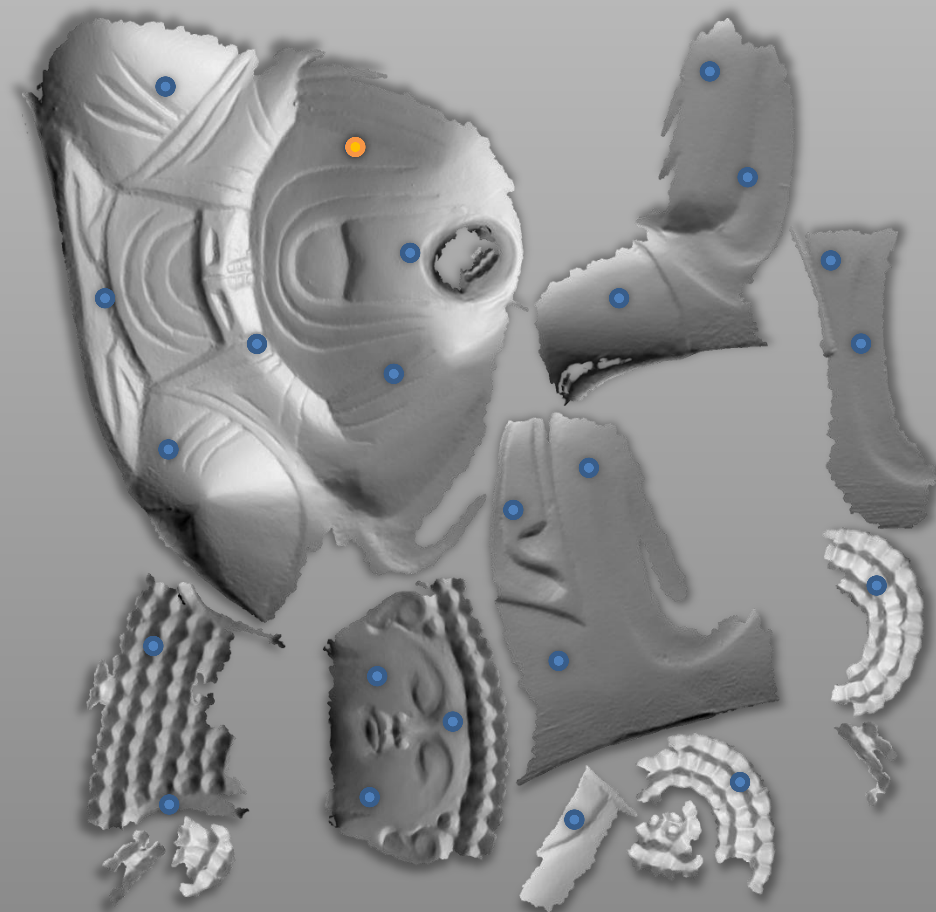
Resampling & Hole Filling

- Representative points (random sampling)
- Irregular samples & confidence



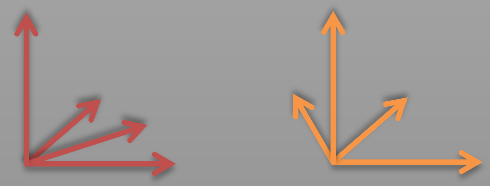
- Interpolate both
  - Radial Basis Functions

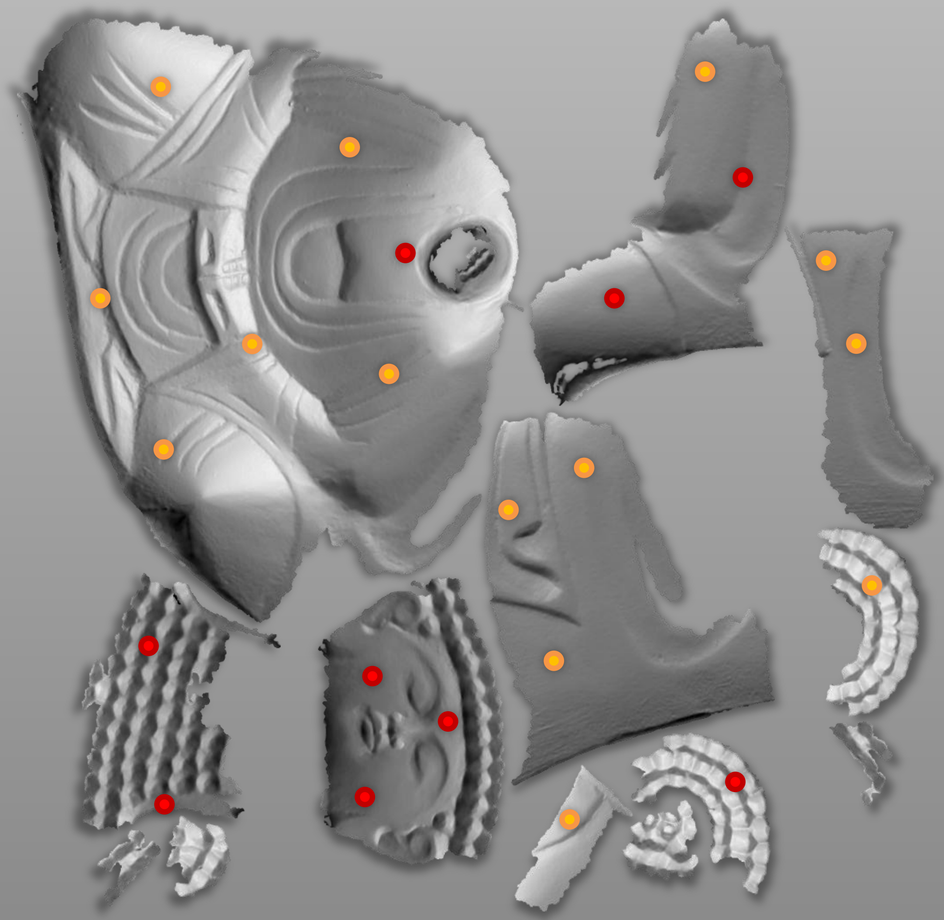




Resampling & Hole Filling

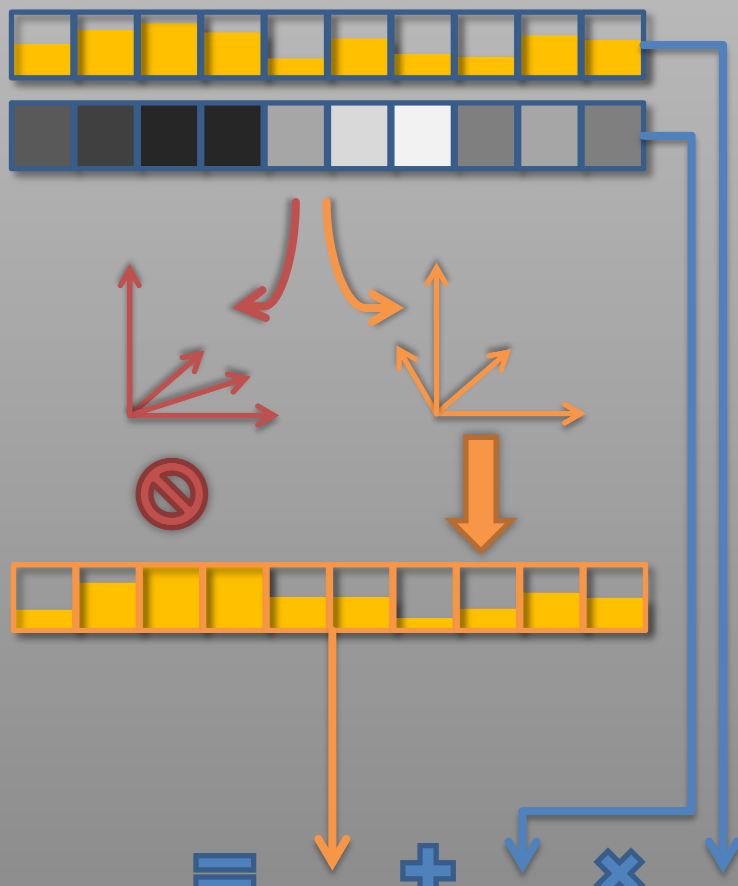
- Perform clustering
- Build low-rank basis per cluster
  - Non-negative Matrix Factorization





Resampling & Hole Filling

- All points
  - RBF interpolation
  - Project into bases
    - Data-driven regularization
      cluster-center
  - Choose representation with minimum error
  - Blend with interpolation w.r.t. confidence



RESULTS

Datasets

- Geometry: ≈ 250k – 560k vertices (500k – 1M Δ)
    - Edge length ≈ 317 µm
- Appearance: BTF
  - Spatial resolution 2048 × 2048 (4.2 Megapixel)
    - Texel ≈ 117 µm surface resolution
  - Angular resolution 151 × 151
  - Uncompressed: 534.4 GB
    Compressed: 1.59 GB (780 MB,125MB)
  - Resampling: 25 hours
    Compression: 8 hours

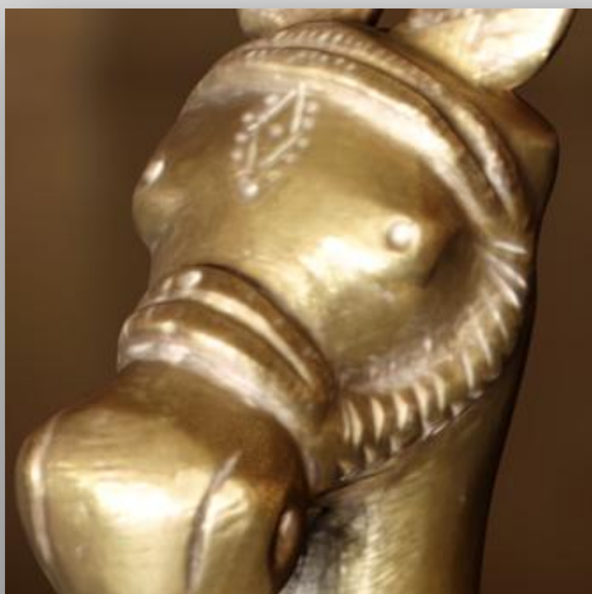
Quality

Faithfulness

Photographic
picture

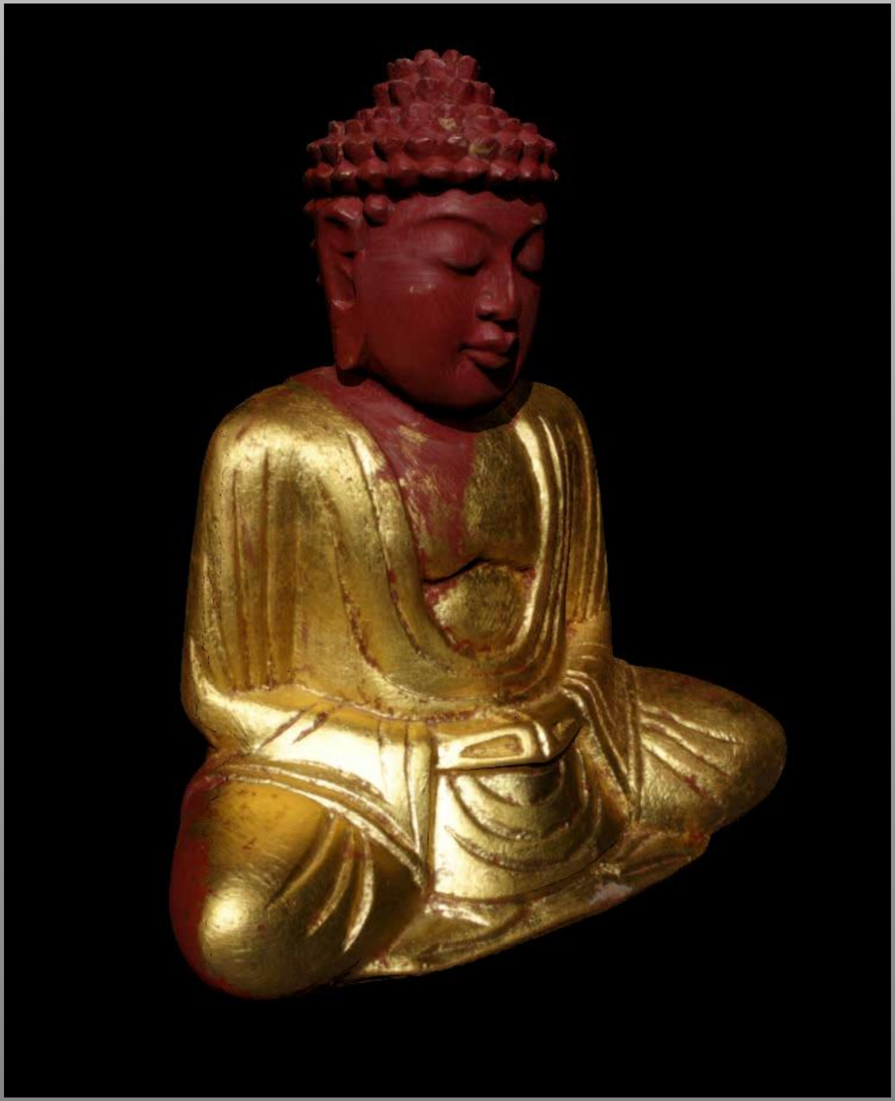
Our Result
(tonemapped HDR)

Polynomial Texture Map
Malzbender et al. 2001
(Single view and LDR!)




Photorealistic Rendering

Interactive Inspection



CONCLUSION

Conclusion

- High-quality „Digital Replicas“
  - Free viewpoint
  - Arbitrary illumination
  - Photorealistic
  - Realtime
- Integrated acquisition setup
  - Geometry + appearance
  - Rapid automated acquisition
- Processing pipeline
  - Triangle Mesh + BTF

Technical Contribution

Questions

Thank you for your attention!

Datasets are available for download at
http://btf.cs.uni-bonn.de
ftp://btf.cs.uni-bonn.de

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