"Multimodal Scanning of Cultural Heritage Assets for their multi-layered digitization and preventive conservation via spatiotemporal 4D Reconstruction and 3D Printing"

Full color and translucency 3D printing for cultural heritage

Presenter:

Philipp Urban

Competence Center 3D Printing Technology

Scan4Reco – GA: 665091

Applications in cultural heritage: Producing accurate replicas
Visualize hidden surfaces

Full Color 3D print (ICC) ← Full color + translucency → Full Transparent 3D print

We developed in Scan4Reco:
- Meaningful definition of translucency by defining A in RGBA
- A 3D printing pipeline for color and translucency reproduction

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Stratasys J750

Mimaki 3DUJ-553

Materials:
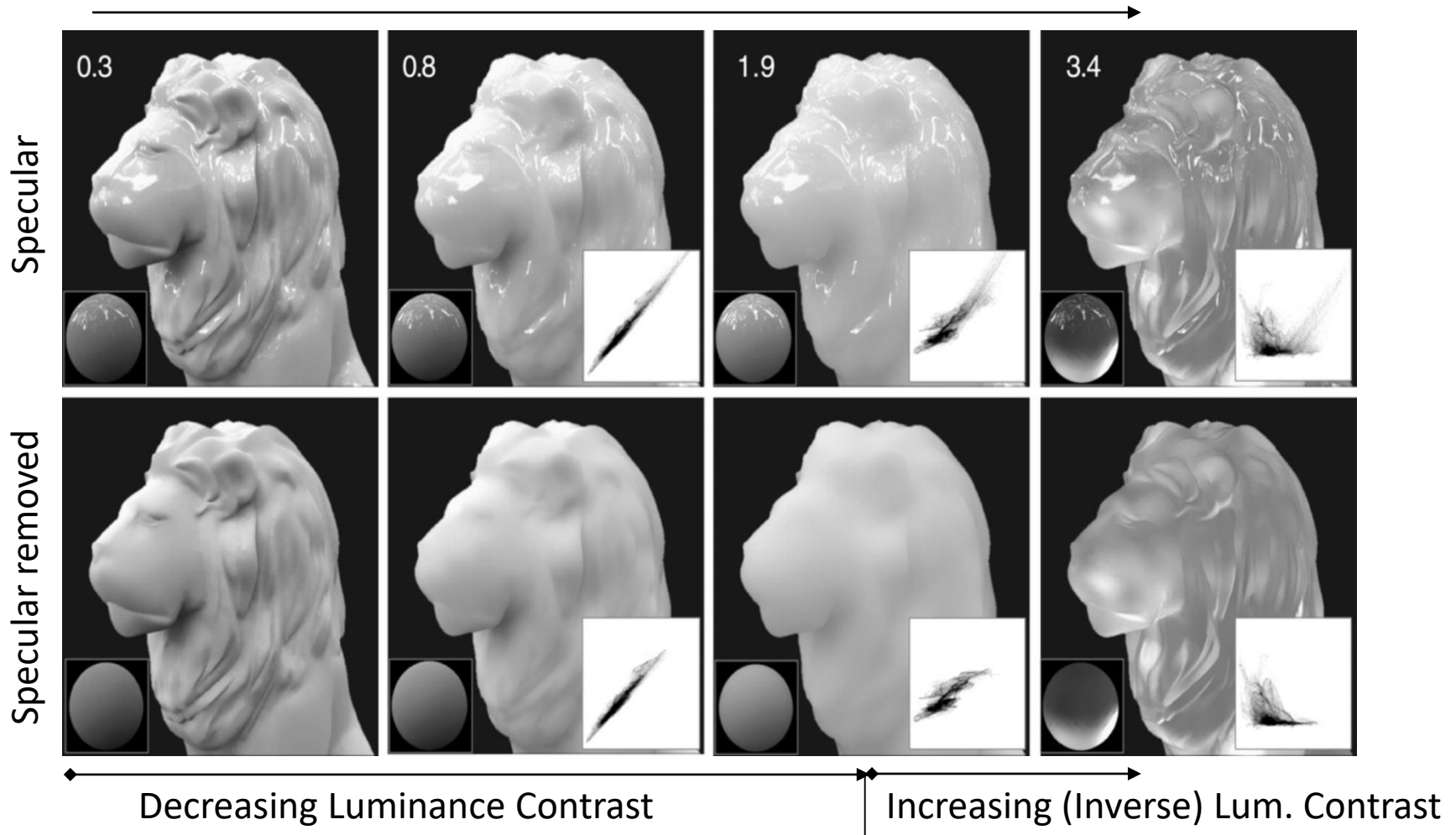
Cyan

Magenta

Yellow

Black

White

Transparent

Hi-Resolution Multimaterial 3D Printers (Polyjet)
Resolution (J750):   600 x 600 x 1600 dpi
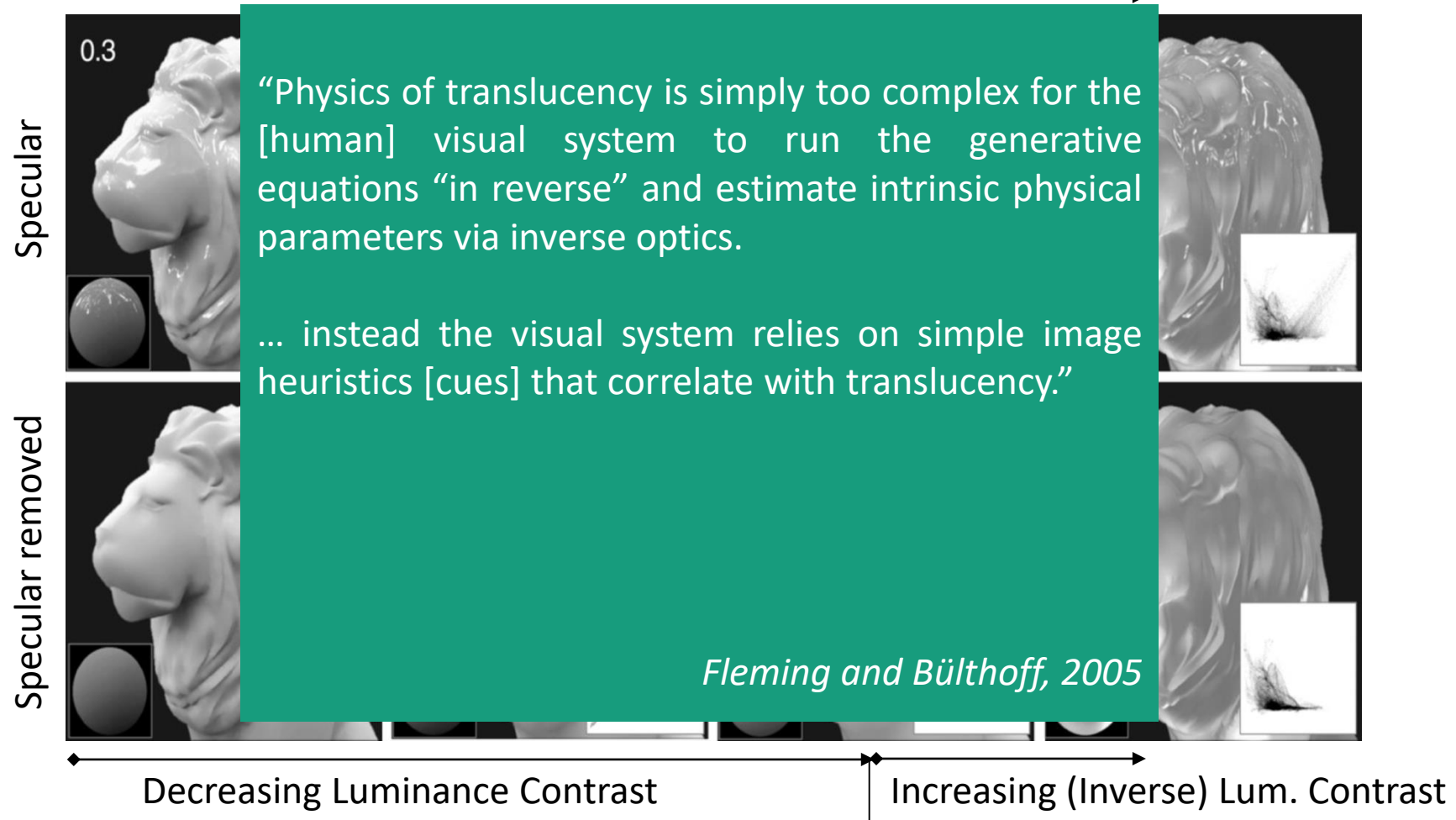   or approx. 36 Million Voxels / cm³

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Perceived Translucency

Specular

Specular removed

Decreasing Luminance Contrast

Increasing (Inverse) Lum. Contrast

Motoyoshi, 2010

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Perceived Translucency

Specular

Specular removed

"Physics of translucency is simply too complex for the [human] visual system to run the generative equations "in reverse" and estimate intrinsic physical parameters via inverse optics.

… instead the visual system relies on simple image heuristics [cues] that correlate with translucency."

Fleming and Bülthoff, 2005

Decreasing Luminance Contrast

Increasing (Inverse) Lum. Contrast

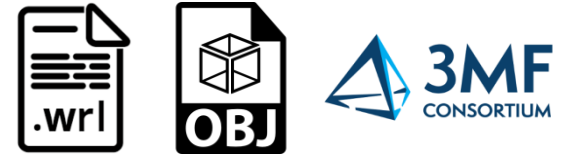*Motoyoshi, 2010*

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- α is device independent (based on reference materials)

- α is measurable (commercial spectrophotometers)

- α is nearly perceptual uniform (for reference materials)

- Add α to RGB
  $\rightarrow$ reproduce RGBA

Lateral

Material

Vertical

Urban et al., 2017

Lateral Light Transport

Vertical Light Transport

Opaque

$1 - \alpha$

Transparent

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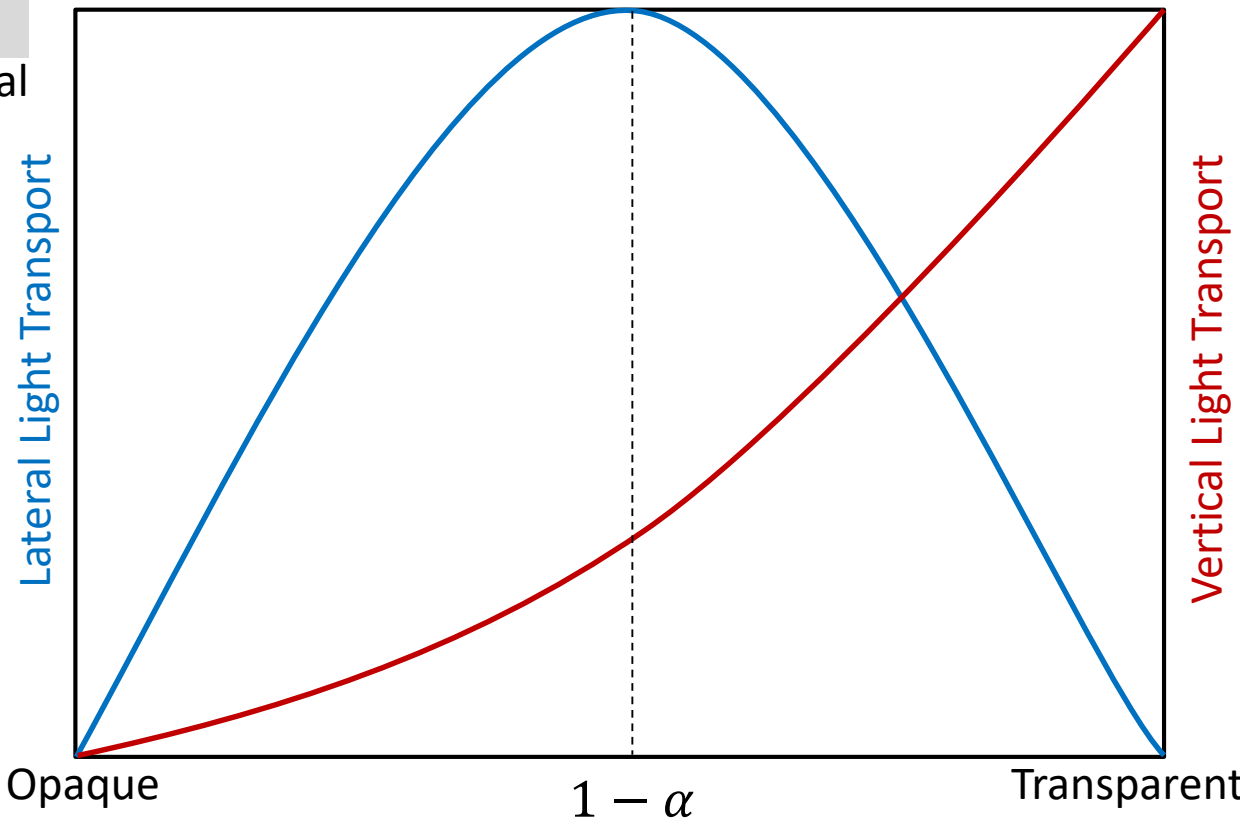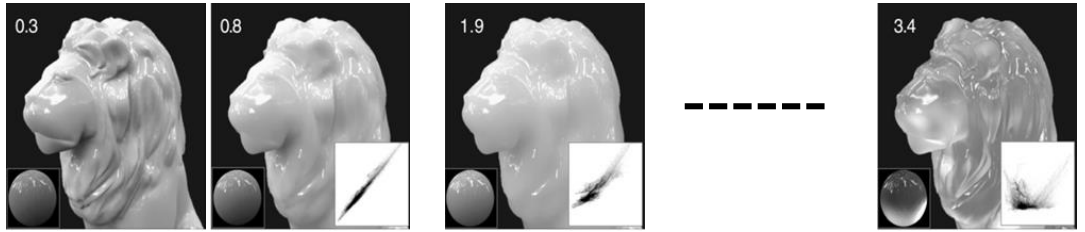
RGBA textured 3D models are

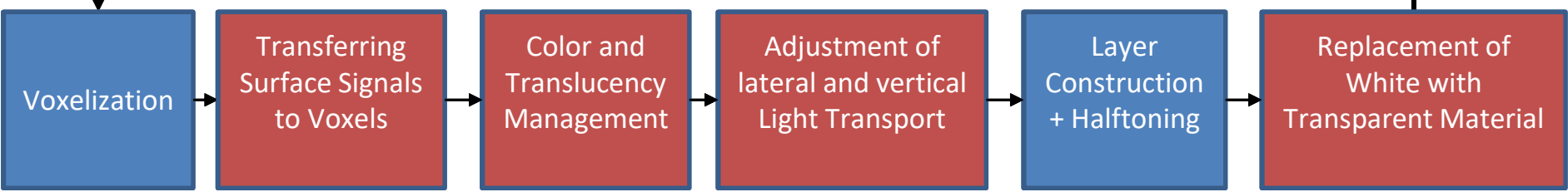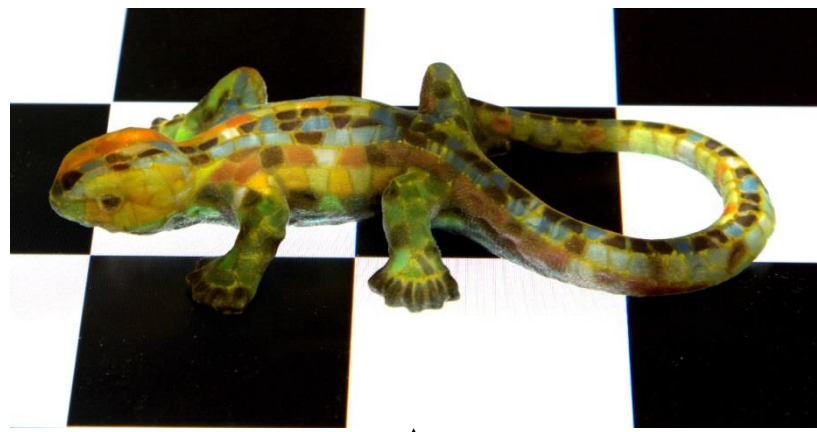- supported by various 3D file formats
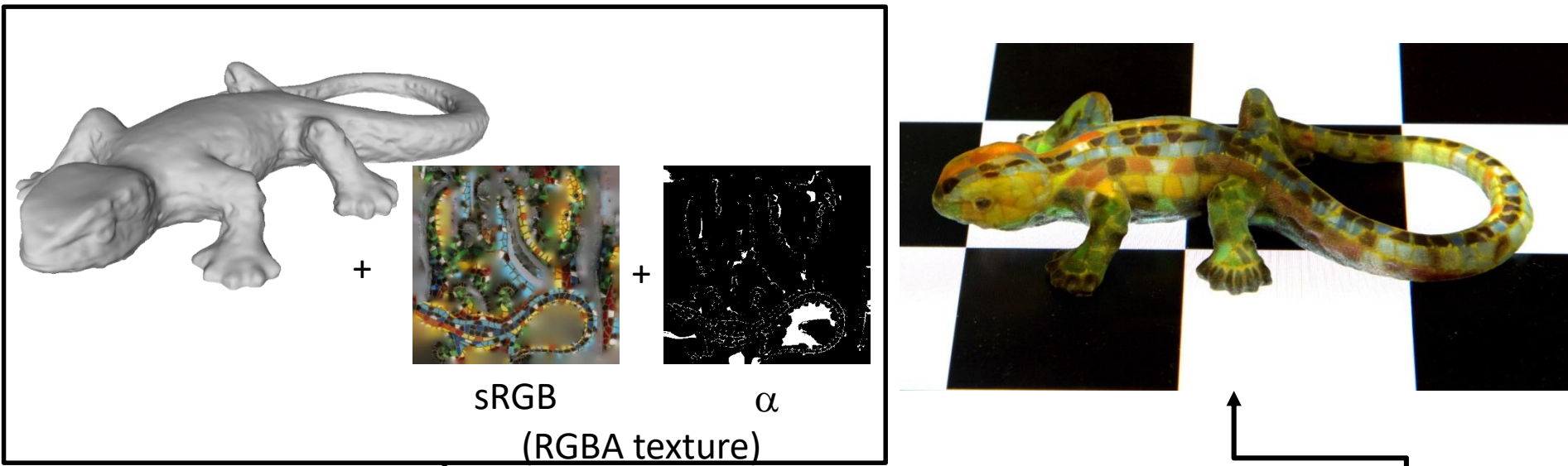
- can be created and modified by various 3D modeling tools

- RGBA textures can be modified by image processing tools

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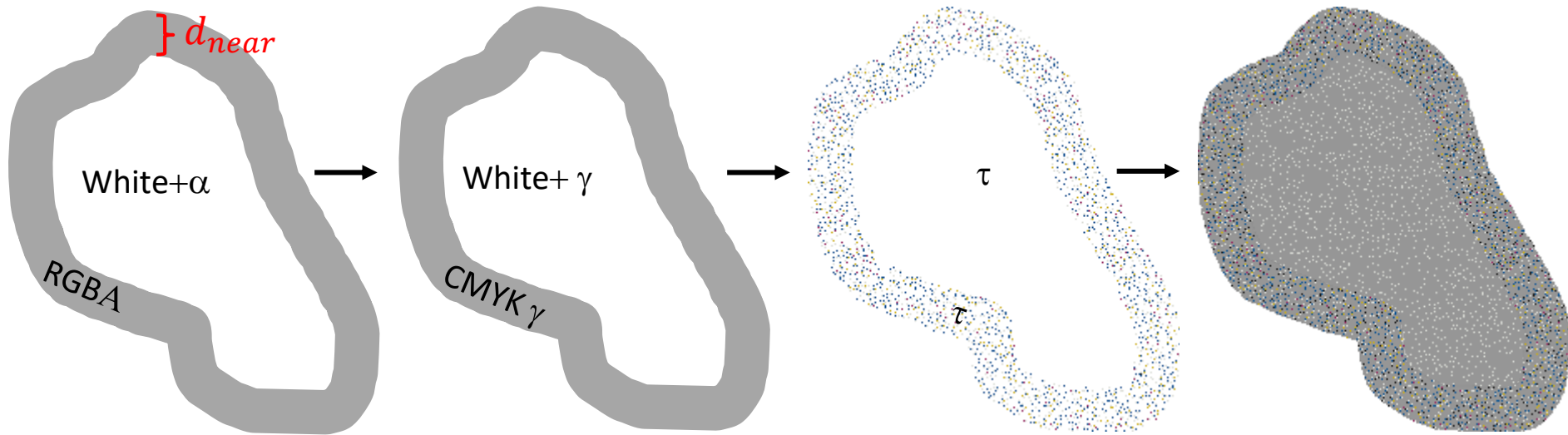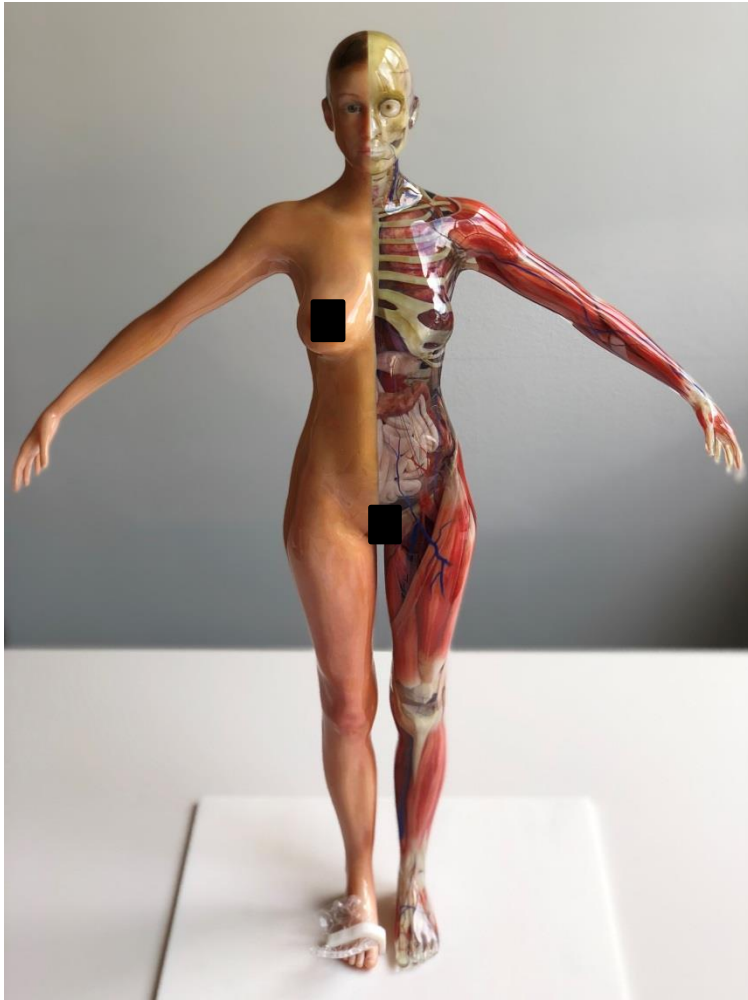sRGB + α
(RGBA texture)

| Voxelization | Transferring Surface Signals to Voxels | Color and Translucency Management | Adjustment of lateral and vertical Light Transport | Layer Construction + Halftoning | Replacement of White with Transparent Material |

Approach: Minimize translucency error while preserving relative color

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Transferring Surface Signals to Voxels

d_{near}

White+α

RGBA

White+ γ

CMYK γ

τ

τ

Revealing Internal Structures

47 cm (polished)

Revealing internal structures of complex models (28 sub-part). [skin: RGBA = (1,1,1,0)]
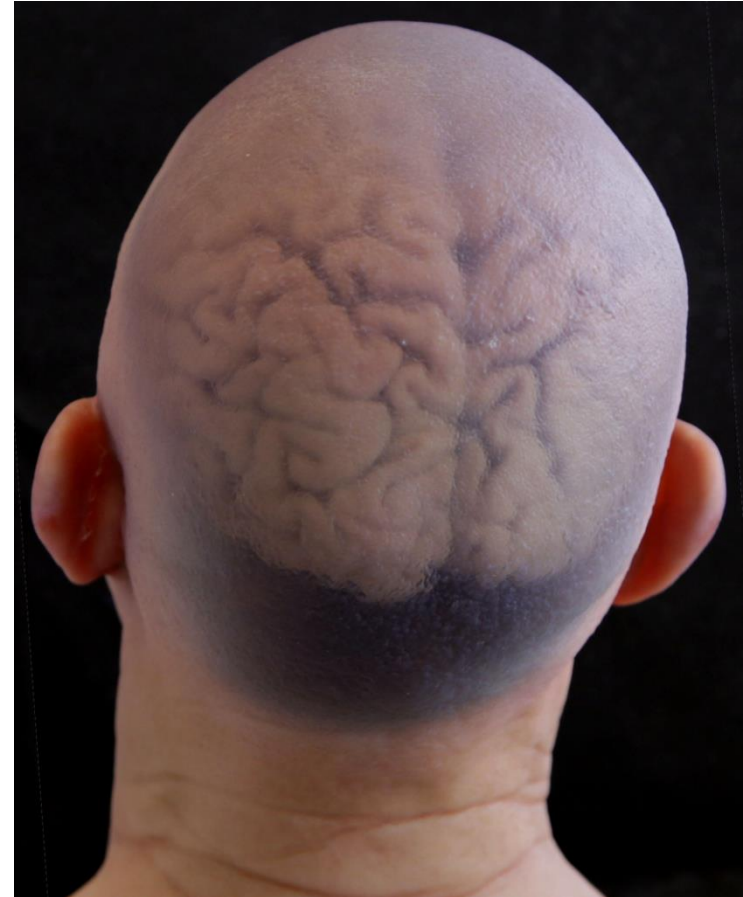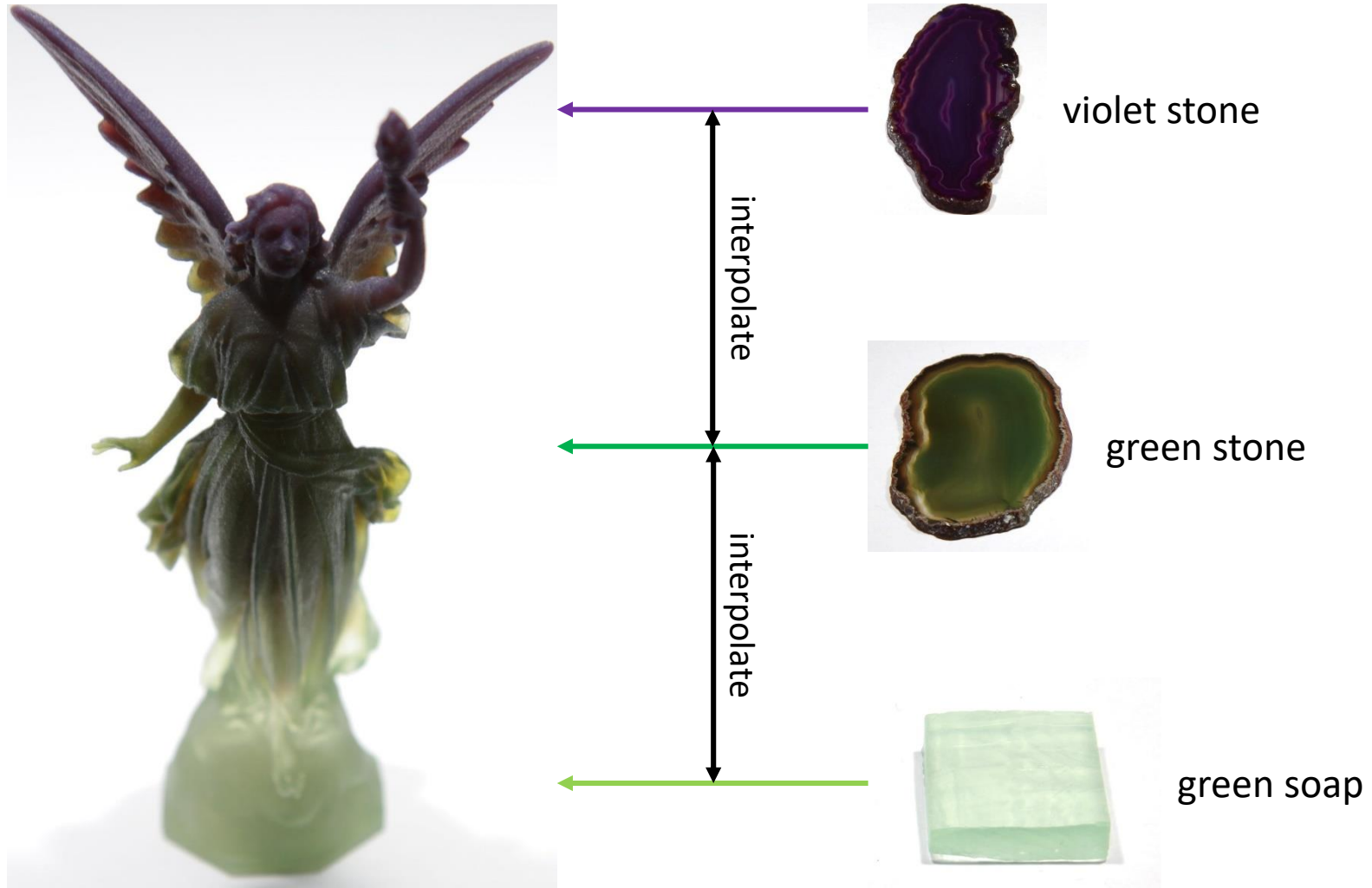
Accurate Subsurface Light Transport

25 cm

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violet stone

interpolate

green stone

interpolate

green soap

- **You can try the pipeline and upload your models to:** http://cappsit.s3cloud.de

End-to-End Cultural Heritage Replicas

Bavarian Palace Department, Artefacts „Rose Island (Lake Starnberg) "
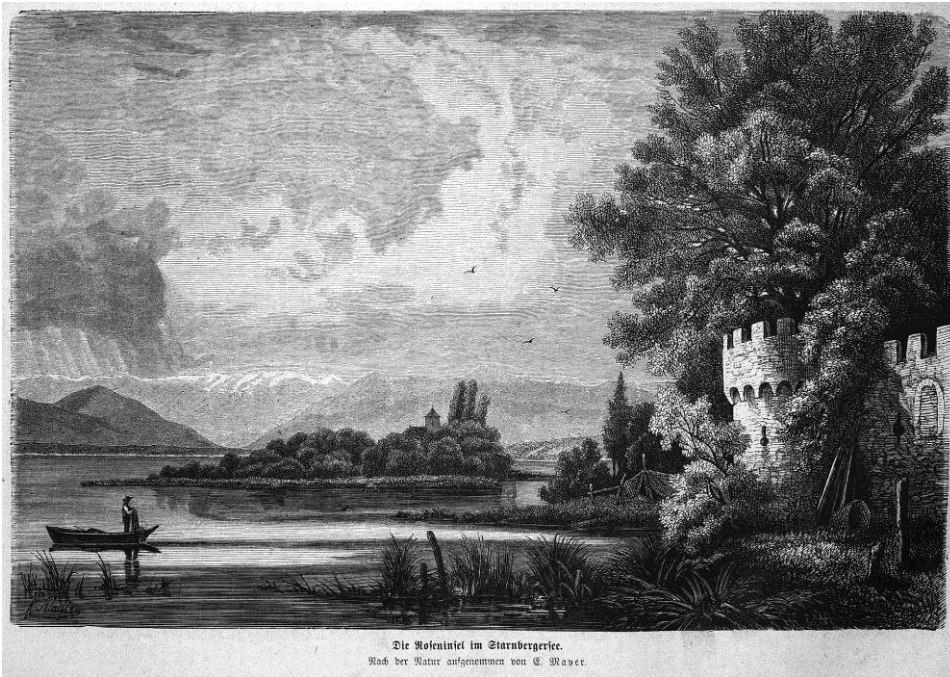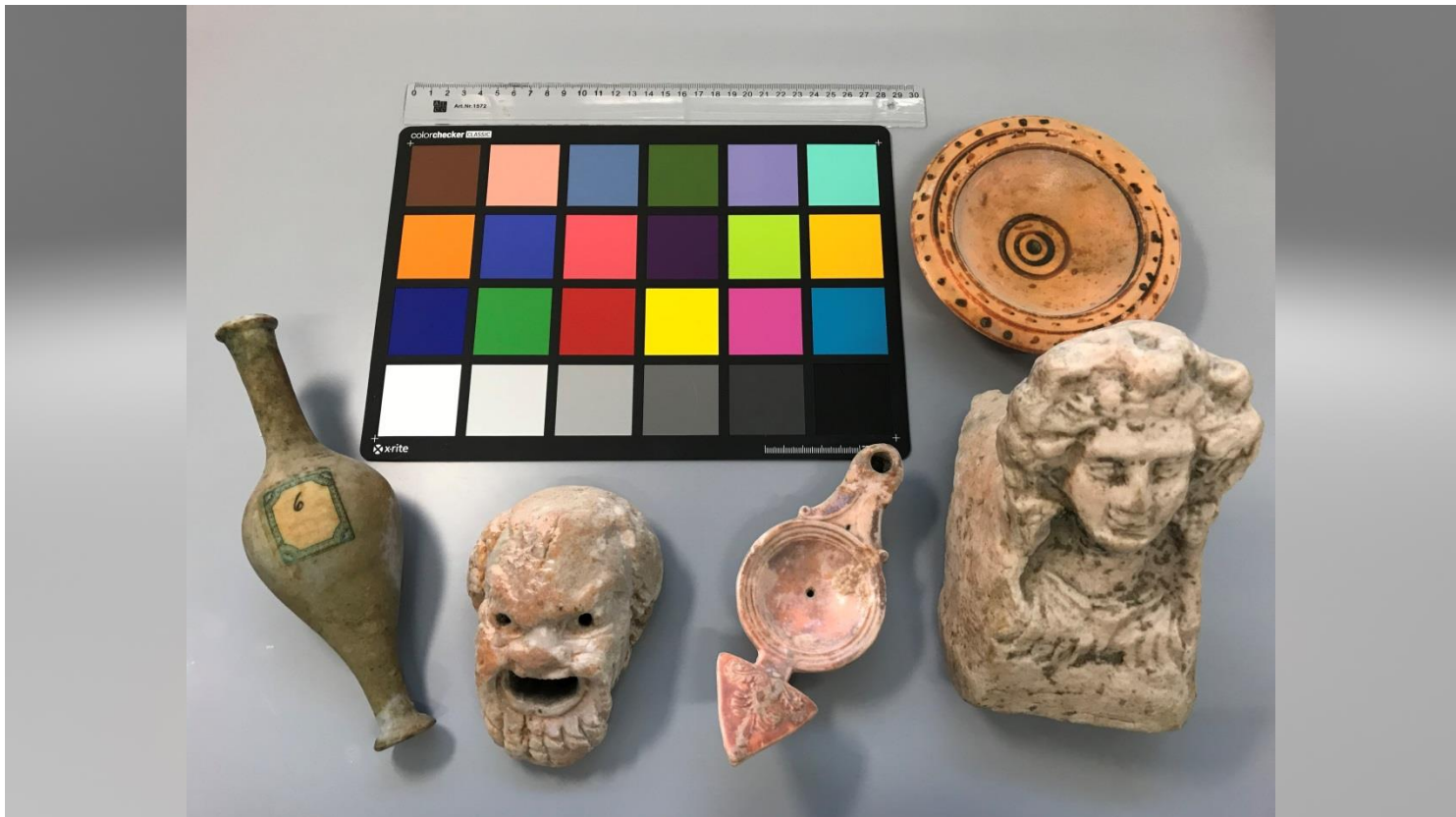

Site of royal villa of King Ludwig II of Bavaria

Darmstadt

Bavaria

Lake Starnberg

End-to-End Cultural Heritage Replicas

Bavarian Palace Department, Artefacts „Rose Island (Lake Starnberg) "

- **3D Scans by CultLab3D**
  http://www.cultlab3d.de/

- **Prints were made via Cuttlefish using:**
  http://cappsit.s3cloud.de

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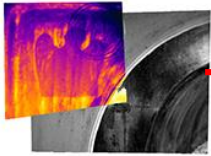
End-to-End Cultural Heritage Replicas

v. li.: Präsident Schlösserverwaltung Bernd Schreiber, Staatsminister Dr. Hans Reichart, Vorsitzende Förderkreis Marie v. Miller-Moll, MdL Dr. Ute Eiling-Hütig, Förderkreis-Vorstandsmitglied Dr. Hermann Köster, Dr. Thorsten Marr Schlösserverwaltung
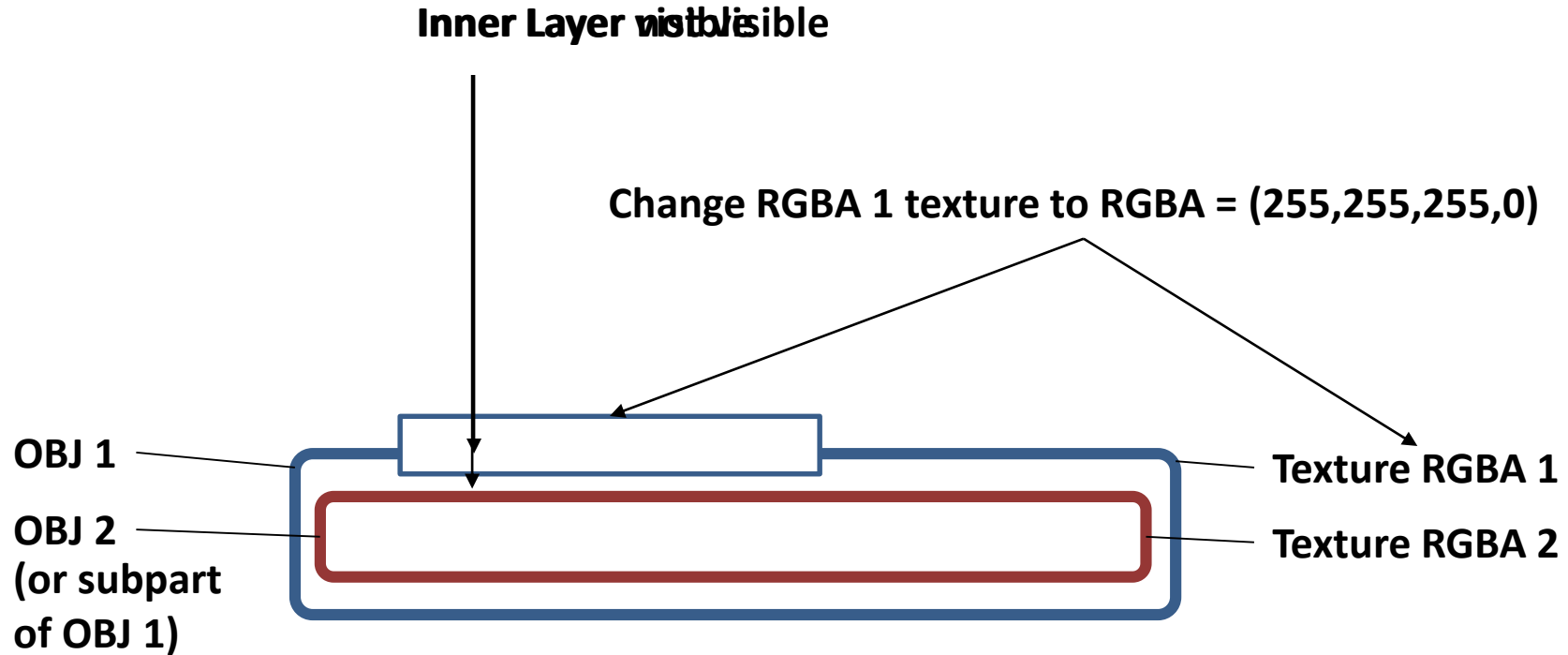
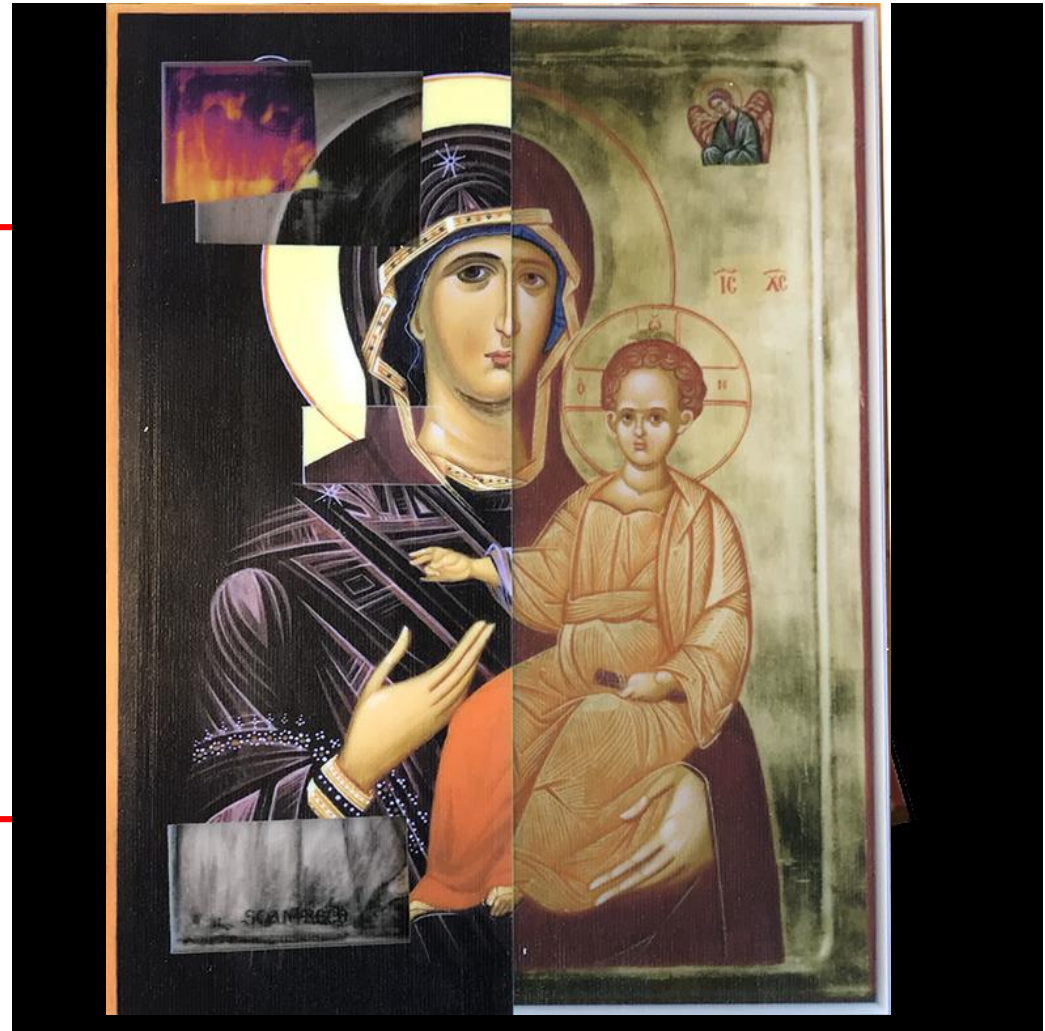# How to Design a Multilayer Object for 3D Printing

Visualization of Inner-Layers

RGBA = (255,255,255,0)

RGBA = (255,255,255,0)

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Inner Layer not visible

Change RGBA 1 texture to RGBA = (255,255,255,0)

OBJ 1

OBJ 2
(or subpart
of OBJ 1)

Texture RGBA 1

Texture RGBA 2

How to Design a Multilayer Object for 3D Printing

Visualization of Inner-Layers

3D Print

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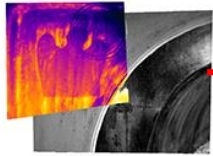
- **We defined A in RGBA:**
    - **Measureable**
    - **Perceptually meaningful**
    - **Supported by 3D file formats**

- **We developed a 3D printing pipeline for joint color and translucency 3D printing**
    - **Input: geometry + RGBA texture**
    - **Output : slices specifying for multi-material 3D printers**

- **Interesting applications for cultural heritage**
    - **Accurate replicas**
    - **Showing hidden surfaces**

- **You can try the pipeline and upload your models to:** http://cappsit.s3cloud.de

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Contact Details: *Philipp Urban*
philipp.urban@igd.fraunhofer.de

Fraunhofer IGD
• Competence Center 3D Printing Technology