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FRAUNHOFER INSTITUTE
FOR COMPUTER GRAPHICS RESEARCH IGD

3D SCANNING TECHNOLOGIES

Beyond state-of-the-art

Advanced 3D scanning technologies for digitizing cultural heritage objects

Digital transformation opens new opportunities for studying, preserving, and working with cultural assets. From digital archiving, to web-based visualization, to 3D printing, the scope of application is diverse. A precise 3D digitization of the geometry and optical material properties is decisive for a realistic representation.

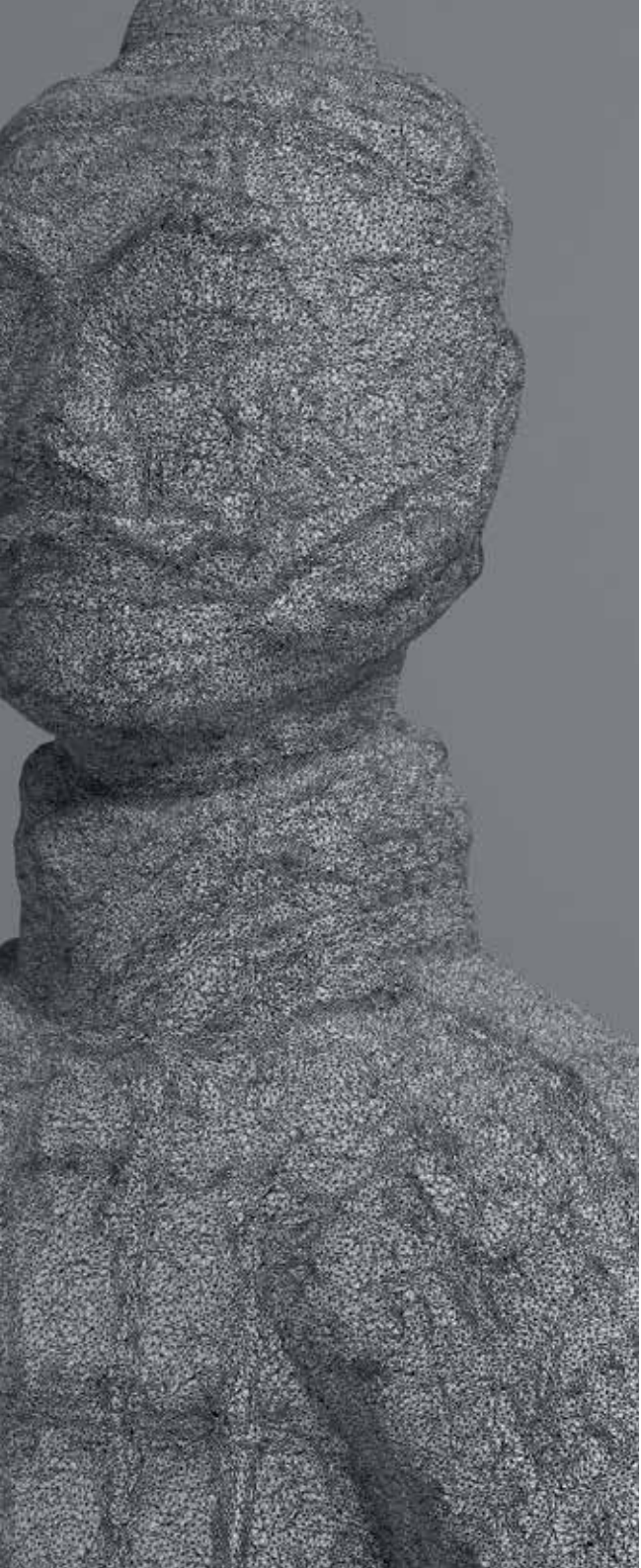
The Competence Center Cultural Heritage Digitization at Fraunhofer IGD develops technologies for documenting, annotating, and virtually reproducing cultural objects. We focus on 3D scanning technologies that enable us to capture objects efficiently. Our automated and high-speed procedures are easy to use and significantly reduce scanning costs. The objects are reproduced true to the original and with micrometer precision. In doing so, we continuously expand the state-of-the-art.

CultLab3D

CultLab3D is an extendable, modular scanning facility using the next generation of autonomous and compliant robots, as well as optical scanning technologies. The system consists of two scanning units (CultArc3D, CultArm3D) connected by a tray conveyor system. The entire acquisition process for geometry and texture of an object takes less than ten minutes, on average, at a resolution in the sub-millimeter range.

Applications

CultLab3D is currently designed for high-precision 3D acquisition of objects up to 50 kg in weight providing high throughput. In the industrial domain, CultLab3D can be used to digitize the product portfolios of online retailers.



Specialty

- High throughput (10 min / object)
- Fully automatic 3D acquisition process
- Photogrammetry
- Acquisition of an object from all sides (incl. bottom side)
- Color calibrated
- Extendable with additional scanning modules

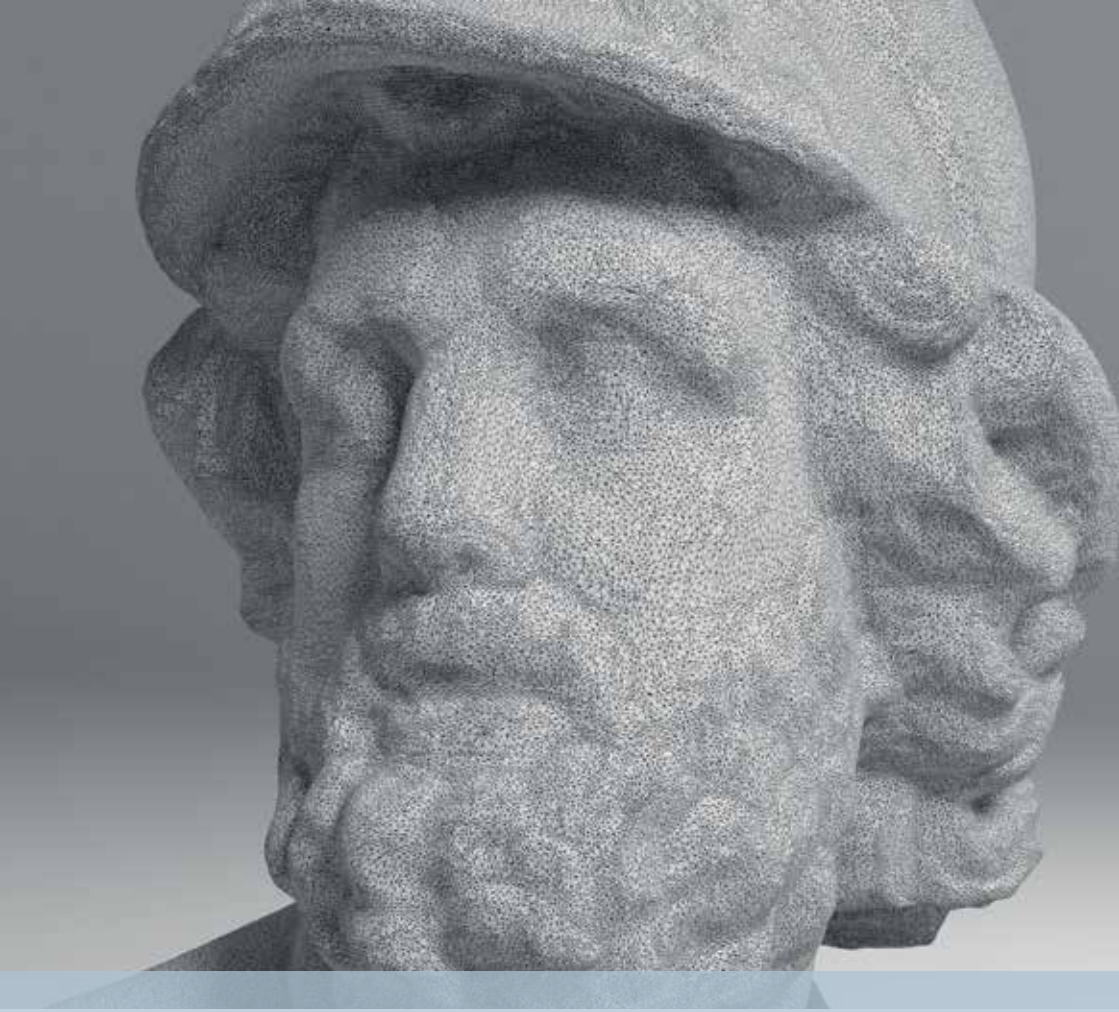
Technical Properties

Acquisition
Geometry, texture, and optical material properties

Set-Up
2 scan stations: CultArc3D and CultArm3D, 1 conveyor belt

Measurement Volume
Cylindrical, 60 cm diameter x 60 cm height

Resolution
Up to 200 µm



Specialty

- Short scan duration of three minutes
- Fully automated scanning process
- 3D acquisition from all sides of the object (incl. bottom side)
- Color calibrated
- Combination with fully automated digitization pipeline CultLab3D (Fraunhofer IGD) possible

Technical Properties

Acquisition
Geometry, texture, and optical material properties

Set-Up
18 color cameras,10 MP (9 movable, 9 static from below), 9 ring daylight sources and illumination from below

Measurement Volume
Cylindrical, 60 cm diameter x 60 cm height

Resolution
Up to 200 µm



CultArc3D

The image-based 3D scanner CultArc3D captures geometry, texture, and material properties in high resolution. It consists of two aluminum arcs equipped with cameras and ring lights, allowing for the digitization of the object from all sides, and for all possible combinations of camera perspectives and light directions. The bottom side of an object is acquired as well, through a transparent carrier disk. Capture time for the acquisition of geometry and texture is approximately three minutes per object.

Applications

CultArc3D digitizes objects with a maximum weight of 50 kg.
Long objects can be captured step-by-step up to a height and width of 60 cm.

CultArm3D

The 3D scanner CultArm3D consists of a camera or, optionally, a structured light scanner, mounted on a lightweight, compliant robotic arm. The geometry and texture of the objects placed on a turntable are digitized automatically. CultArm3D can be used both independently and in combination with the CultArc3D scanner (Fraunhofer IGD). In combination, CultArm3D captures remaining holes, occlusions, or geometrically complex surface areas in higher detail.

Applications

CultArm3D digitizes objects with a maximum weight of 50 kg.

Specialty

- Lightweight, compliant robotic arm
- Autonomous "next-best-view" scan planning
- Photogrammetry or structured light
- Color calibrated
- Combination with fully automated digitization pipeline CultLab3D (Fraunhofer IGD) possible

Technical Properties

Acquisition
Geometry and texture

Set-Up
1 color camera,18 MP
(optionally 1 structured light scanner),
1 ring daylight source,
2 soft boxes for diffuse lighting

Measurement Volume
Cylindrical, 60 cm diameter x 60 cm height

Resolution
Up to 200 µm (photogrammetry) or up to 50 µm (structured light)

Specialty

- Fast geometry acquisition combinable with automatic view-planning
- Instant visual feedback and 3D model finishing
- Iterative and automatic registration and refinement
- Color calibrated
- No post-processing or additional computation time

Technical Properties

Acquisition
Geometry and texture in real-time

Set-Up
1 mono camera for geometry,
1 color camera for texture,
2 high-power LED mini pattern projectors

Measurement Volume
25 cm x 25 cm x 20 cm (at 60 Hz)

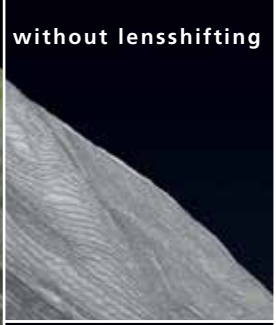
Resolution
30 µm lateral (flexible)
300 µm depth (upgradable, dependent on camera and projector resolution)

Real-Time Structured-Light Scanner

The Real-Time Structured-Light Scanner captures geometry and texture in 3D within a short time. It consists of two high-power LED projectors and two cameras, monochrome and color. It allows for fast assembly, set-up, and calibration. Due to its minimalistic design, the scanner can be hand-held or mounted on a light-weight robot arm. While scanning, the user receives instant feedback about the quality and completeness of the resulting model. For autonomous scanning on a robot arm, this continuous flow of 3D data can be fed into a novel reactive view-planning algorithm that guides the robot with the attached scanner to explore and to scan areas with no coverage or poor quality to complete the scan to a certain quality requirement.

Applications

The Real-Time Structured-Light Scanner captures objects of arbitrary size.

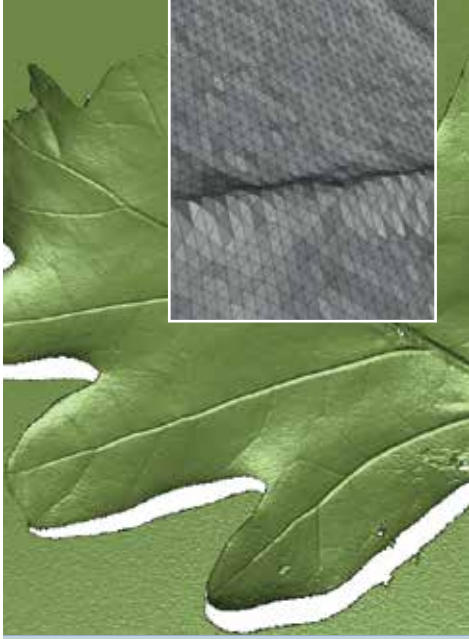


Meso-Scanner V1

The Meso-Scanner V1 captures three-dimensional objects in high resolution. It projects a structured light pattern on their surface. Using a patented mechanical lens-shifting method, the pattern is shifted over the object surface in discrete sub-pixel steps. Depth resolution is two to three times higher than without lens-shifting.

Applications

The Meso-Scanner V1 captures flat objects with up to 3 cm in height (e.g. coins, seals) and a maximum scan area of 12 cm x 8 cm.



Specialty

- Lens-Shifted structured light (linear actuator) for high resolution (up to 2,048 steps)
- Captures very fine surface details
- Color calibrated
- Resolves even very smooth surface gradients

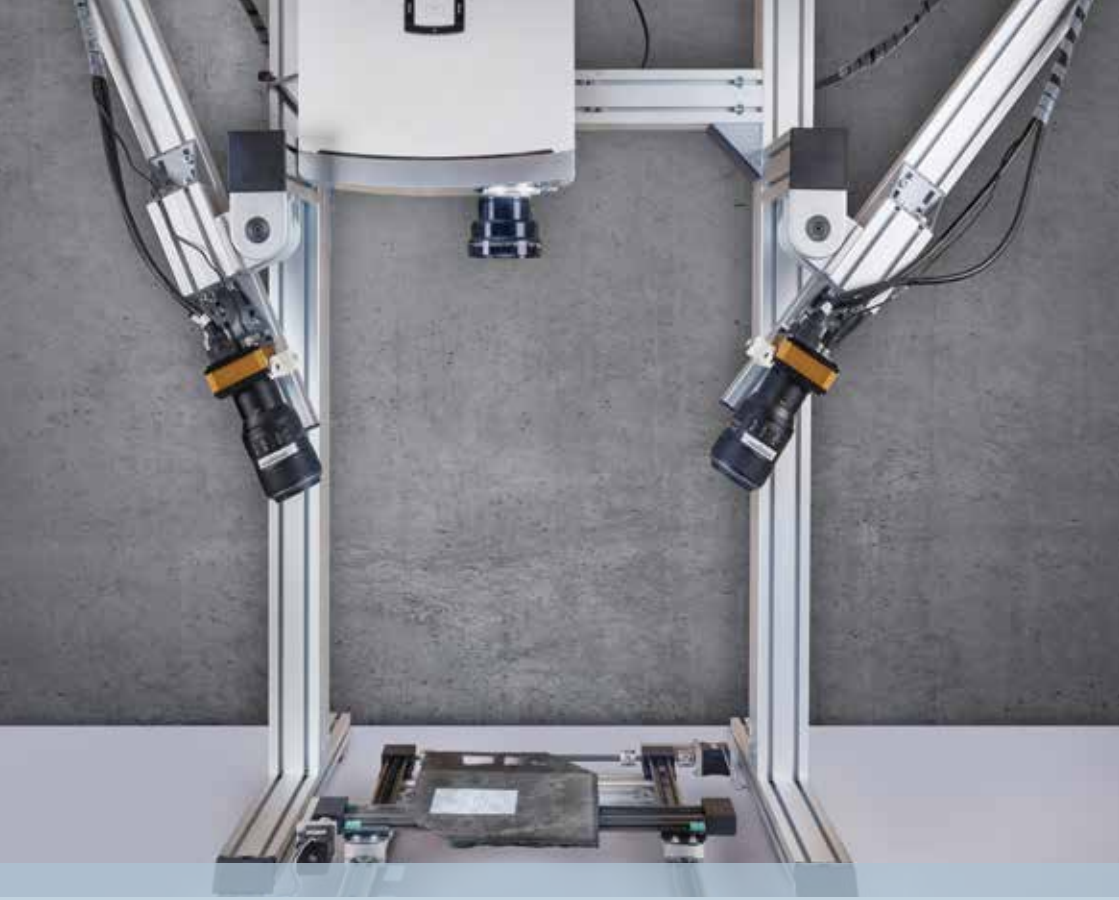
Technical Properties

Acquisition
Geometry and texture
(meso = between micro and macro)

Set-Up
1 color 12MP camera,
1 projector (SVGA)

Measurement Volume
120 mm x 80 mm x 50 mm

Resolution
55 µm lateral
20 µm depth



Specialty

- Lens-shifted structured light (linear actuator), higher resolution than Meso-Scanner V1 (10,000 discrete steps)
- 2 cameras for robustness against difficult materials (shiny, reflective)
- Resolves fine surface details and even very smooth surface gradients
- Color calibrated
- Combination with fully automated digitization pipeline CultLab3D (Fraunhofer IGD) possible

Technical Properties

Acquisition
Geometry and texture
(meso = between micro and macro)

Set-Up
2 color cameras, 25 MP,
1 full HD projector,
Optional: cross table for automatic acquisition of larger measurement areas

Measurement
160 mm x 140 mm x 50 mm
[length x width x height]

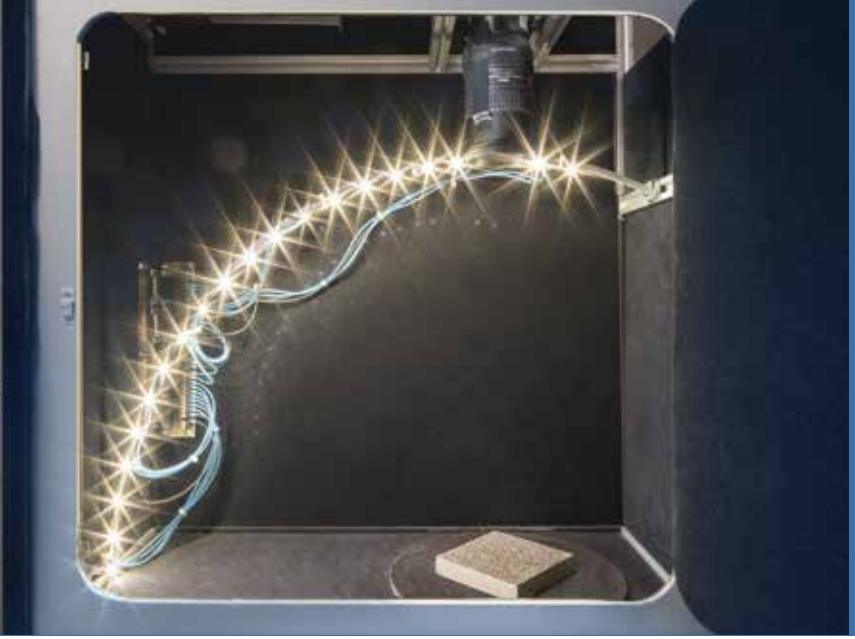
Resolution
32 µm lateral
15 µm depth

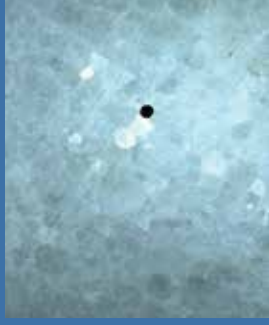
Meso-Scanner V2

The Meso-Scanner V2 digitizes objects in 3D with considerably higher lateral and depth resolution. To this end, a very fine structured light pattern is projected on the object surface. Due to a patented, mechanical lens-shifting method, depth precision is two to three times higher than without. The refined version uses two fast industrial color cameras to provide a higher robustness against reflections and is therefore particularly suited to scan shiny and reflective surfaces. Acquisition time was reduced to about 5 minutes for this second version. Furthermore, Meso-Scanner V2 offers the possibility to capture surfaces exceeding the measurement volume by using a displaceable cross table.

Applications

The Meso-Scanner V2 captures flat objects with up to 5 cm in height and a maximum area of 16 cm x 14 cm.





HDR-ABTF-Scanner

The HDR-ABTF-Scanner digitizes the optical material behavior of objects (e.g. textiles and leather) faster, easier, and more precisely than conventional scanners. The surfaces are illuminated from different directions. The scanner captures texture and light-surface interaction of materials in different lighting situations using an Approximate Bidirectional Texturing Function (ABTF). Moreover, exposure bracketing per direction of incidence represents the object surface in High Dynamic Range (HDR). Users may apply the scanned material when working with programs for true-to-life 3D visualizations, e.g. as part of the design process.

Applications

The HDR-ABTF-Scanner captures the optical material properties and lighting behavior of flat objects (e.g. isotropic material samples) with sizes up to 15 cm x 15 cm. The 3D scanner can be adjusted to objects with a maximum height of 10 cm.

Specialty

- Material behavior of flat materials
- Shiny and mirroring materials
- Output for fast real-time rendering
- Reproduction of spatially-varying light dependent material effects
- Color calibrated
- Support of "Unity3D game engine"

Technical Properties

Acquisition
Optical material properties

Set-Up
1 color camera, 25 MP,
20 light sources,
1 turn table

Measurement Volume
15 cm x 15 cm (adjustable for objects of heights up to 10 cm)

Resolution
30 µm lateral resolution

Fraunhofer Institute for Computer Graphics Research IGD
Fraunhoferstrasse 5
64283 Darmstadt
Germany

CONTACT:
Pedro Santos
Head of Competence Center Cultural Heritage Digitization
Phone +49 6151 155-472
pedro.santos@igd.fraunhofer.de

https://fh-igd.de/CHD_en

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