3D Models from Range Sensors

Gianpaolo Palma

Who

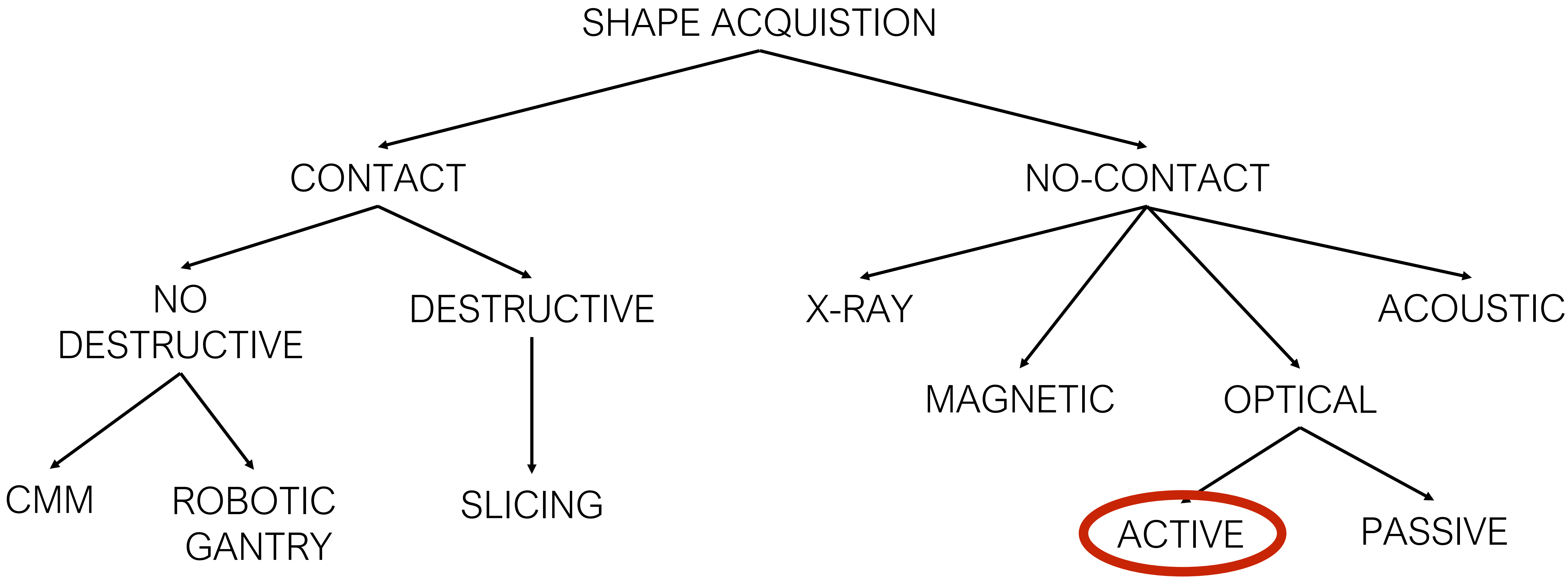
- Gianpaolo Palma
  - Researcher at Visual Computing Laboratory (ISTI-CNR)
  - Expertise: 3D Scanning, Mesh Processing, Computer Graphics
  - E-mail: gianpaolo.palma@isti.cnr.it

Office hours

- Where
  - Room I-54, Gate 7 or 8, ISTI-CNR, via G. Moruzzi n. 1
- When
  - By appointment
  - Please, send an e-mail to confirm an appointment

3D Models from Range Sensors

- How to create a complete 3D model of your object of interest using 3D active optical scanning devices



3D Models from Range Sensors

- Why active optical scanning devices?
  - High accuracy
  - Several technologies that scale with the object size
  - Cheaper than a CT scanner, more accurate output than passive technologies

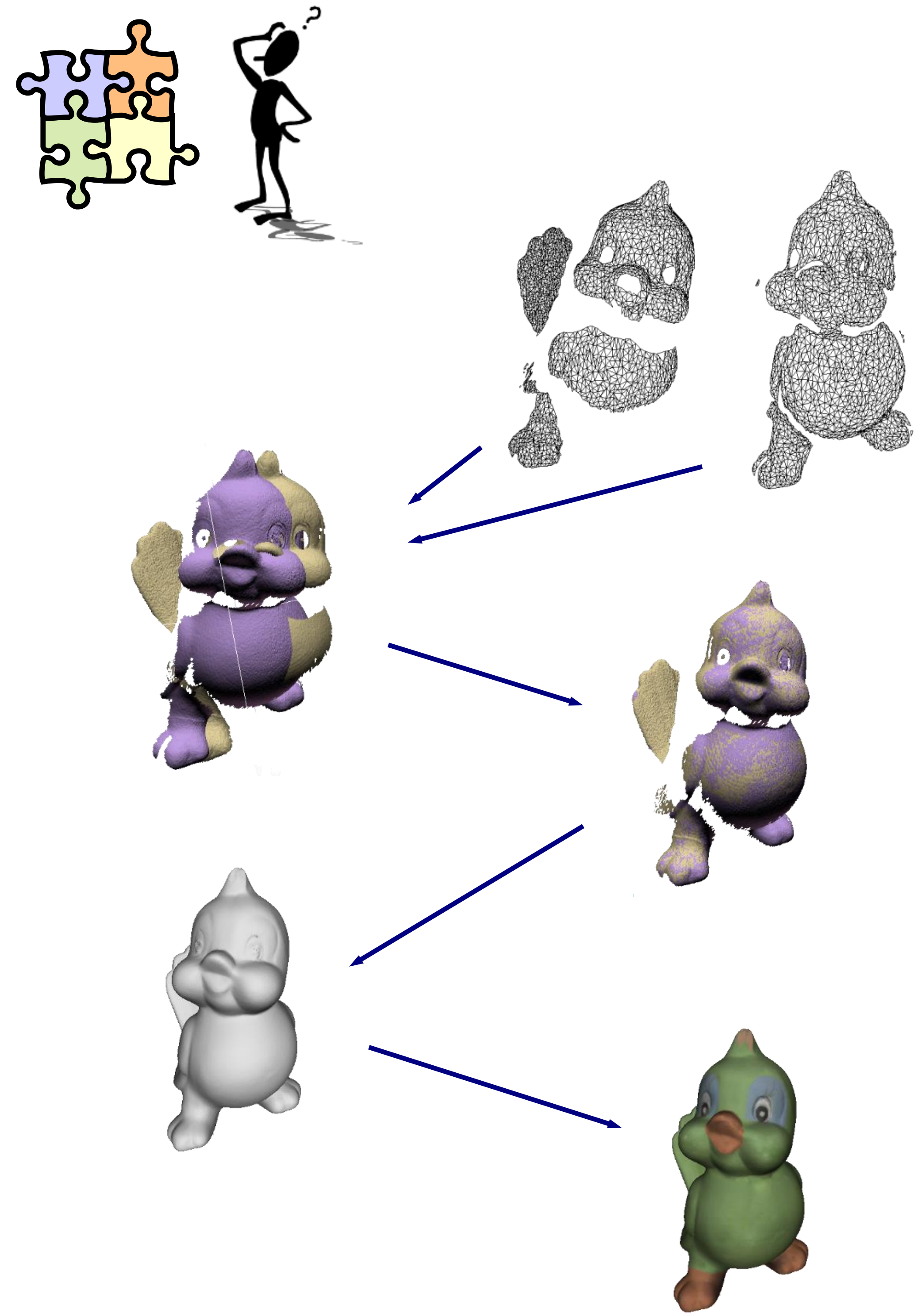
Outline

1. 3D scanning pipeline (1h)
2. 3D optical active scanning devices (2h)
3. Surface cleaning and smoothing (1h)
4. Surface registration (2h)
5. Surface reconstruction (2h)
6. Mesh repairing and simplification (2h)
7. Color integration and appearance modeling (2h)

Laboratory with **MeshLab** (8h)

3D scanning pipeline

- Planning
- Acquisition
- Editing
- Registration
- Merging
- Simplification and Repairing
- Color acquisition & Mapping



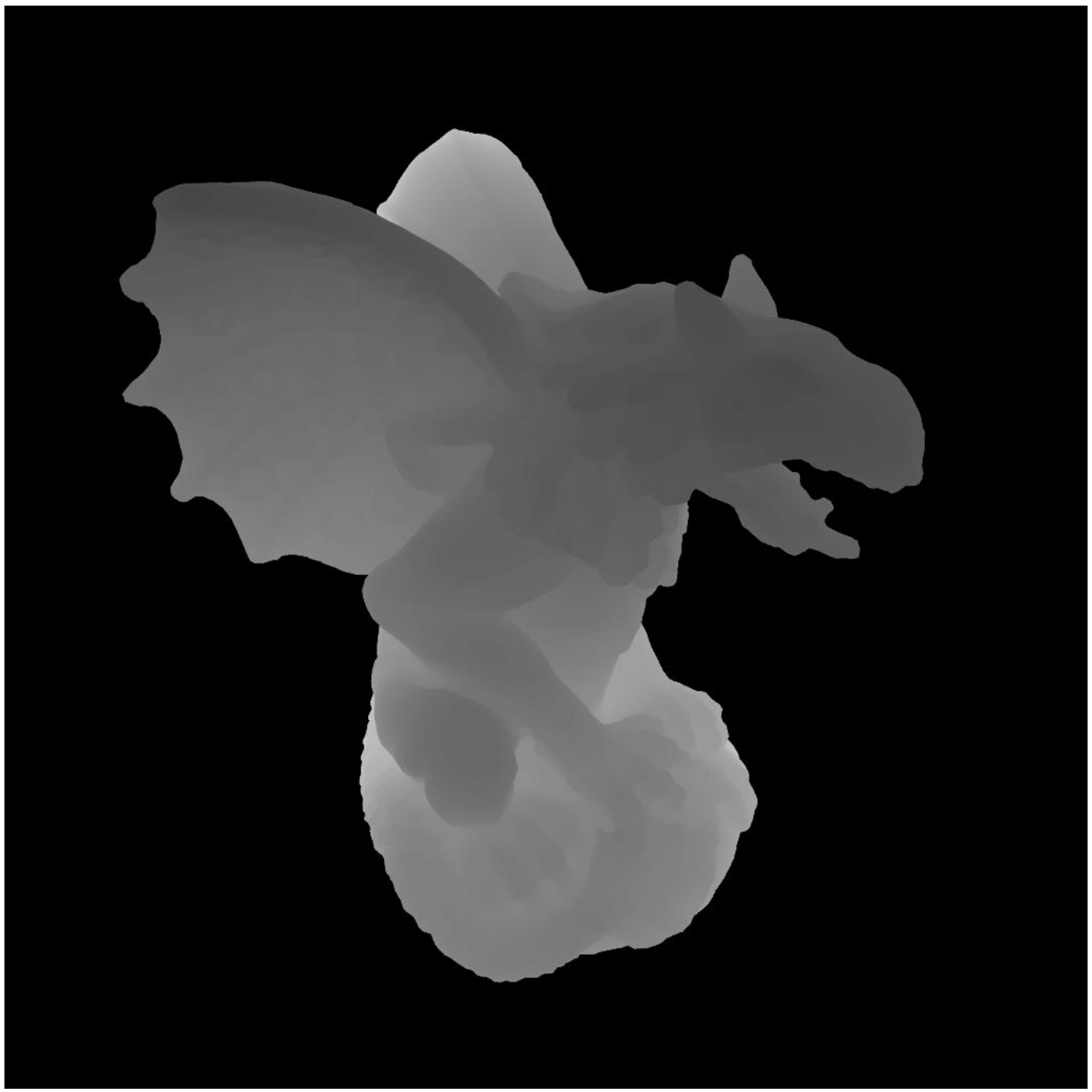
3D scanning pipeline: Planning

- Select the scanning technology
  - Accuracy of the final model
  - Size of the object
  - Optical properties of the objects
- Planning the acquisition
  - Scanning support
    - E.g. Do you need scaffolding?

3D scanning pipeline: Acquisition

- Setting of the support structures from the acquisition
    - E.g. scaffolding, support for markers, lighting condition
- Acquisition of multiple range scans from different point of views
    - Complete coverage of the object
    - High redundancy of data

3D Scanning Outputs: Range Maps

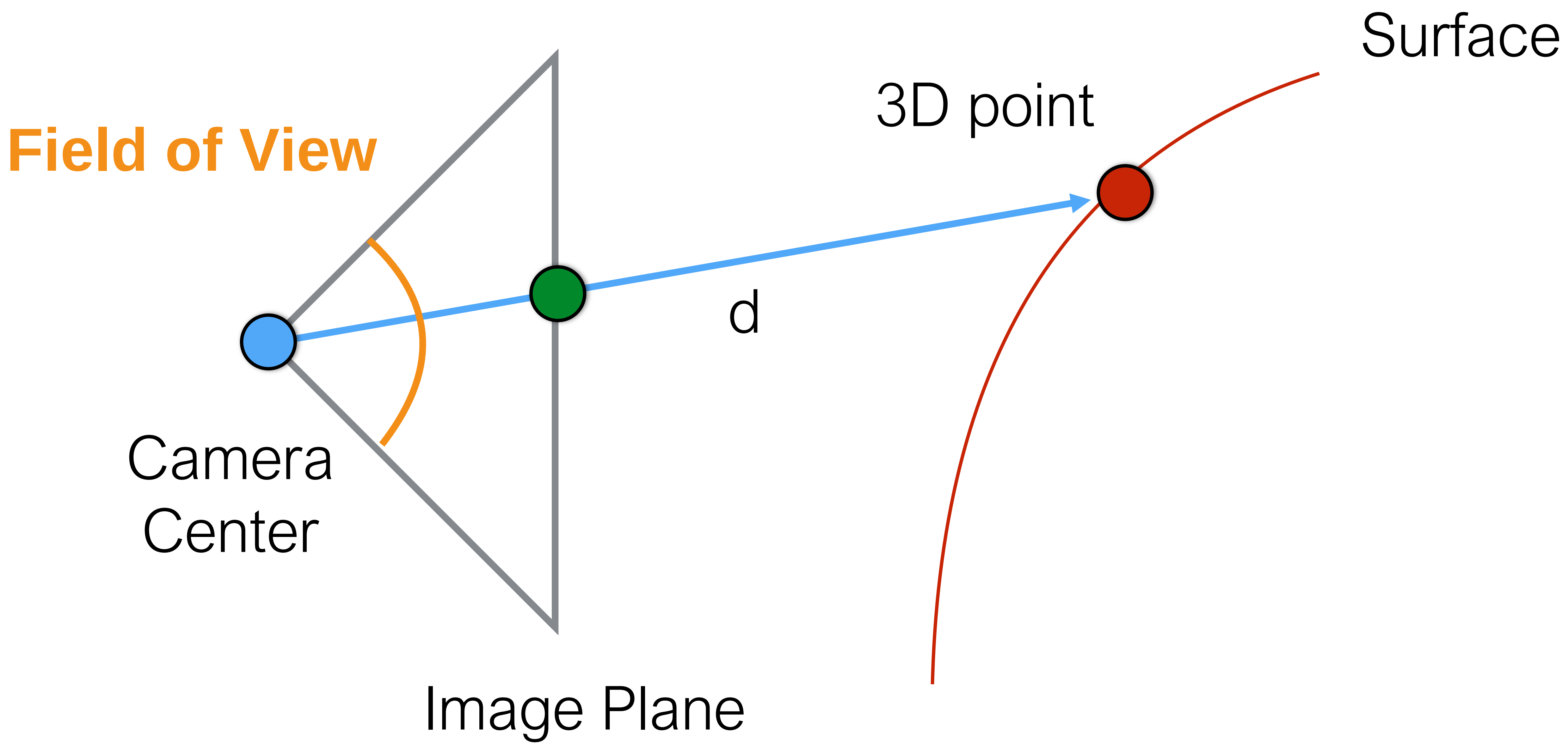


Each pixel in the image encodes the distance of the surface from the camera

3D Scanning Outputs: Range Maps

- Metadata:
  - Camera extrinsics: position and rotation
  - Camera intrinsics: field of view, size of pixels in mm
- From Metadata:
  - we can obtain 3D points!

3D Scanning Outputs: Range Maps



Camera Model: Pinhole Camera

- The perspective projection is defined as

$$\mathbf{m} = P \cdot \mathbf{M} \quad \Rightarrow \quad \mathbf{m}' = \mathbf{m}/\mathbf{m}_z$$

$$P = K[I|\mathbf{0}]G = K[R|\mathbf{t}]$$

$$K = \begin{bmatrix} -fk_u & 0 & u_0 \\ 0 & -fk_v & v_0 \\ 0 & 0 & 1 \end{bmatrix}$$

Intrinsic Matrix

$$\mathbf{t} = \begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix} \qquad R = \begin{bmatrix} \mathbf{r}_1^\top \\ \mathbf{r}_2^\top \\ \mathbf{r}_3^\top \end{bmatrix}$$

Extrinsic Matrix

Camera Model:
Pinhole Camera – Inverse projection

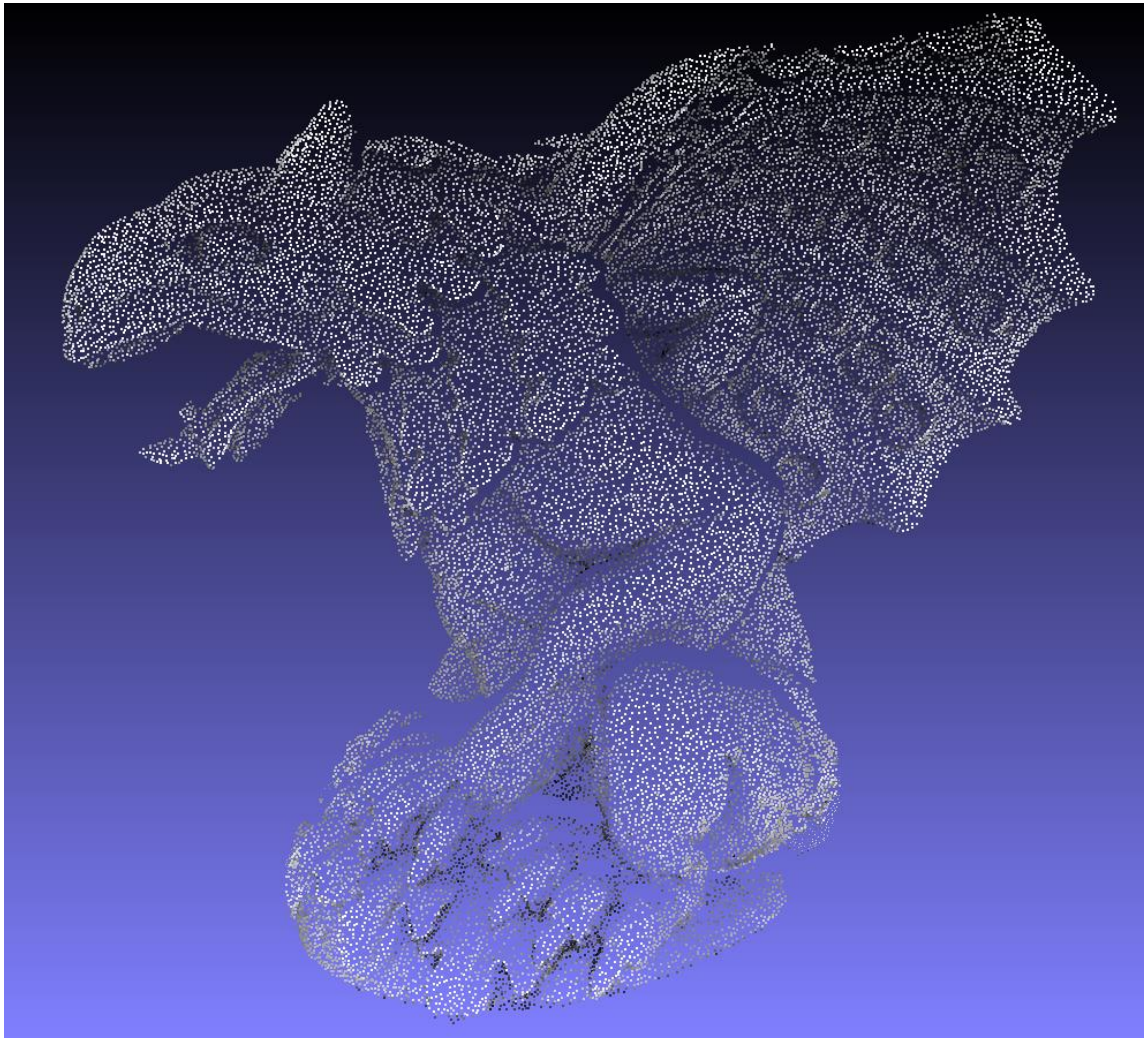
- Using the depth *d* of the point and its image coordinates *m'*, the inverse perspective projection is defined as

$$\mathbf{m} = [\mathbf{m'_x}\ \mathbf{m'_y}\ 1] \quad \Rightarrow \quad \mathbf{M} = P^{-1}\mathbf{m}$$

$$\mathbf{P}^{-1} = R^{-1}[I| - \mathbf{t}]DK^{-1}$$

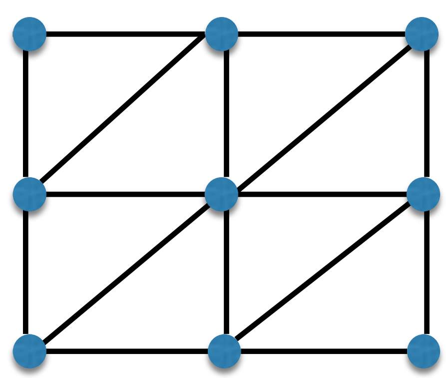
$$D = \begin{bmatrix} -d & 0 & 0 \\ 0 & -d & 0 \\ 0 & 0 & -d \end{bmatrix} \quad K^{-1} = \begin{bmatrix} \frac{1}{-fk_u} & 0 & 0 \\ 0 & \frac{1}{-fk_v} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -u_0 \\ 0 & 1 & -v_0 \\ 0 & 0 & 1 \end{bmatrix}$$

3D Scanning Outputs: Range Maps as Point Cloud



3D Scanning Outputs: Range Maps as Triangle Mesh

- Topology from adjacent pixels in the range maps

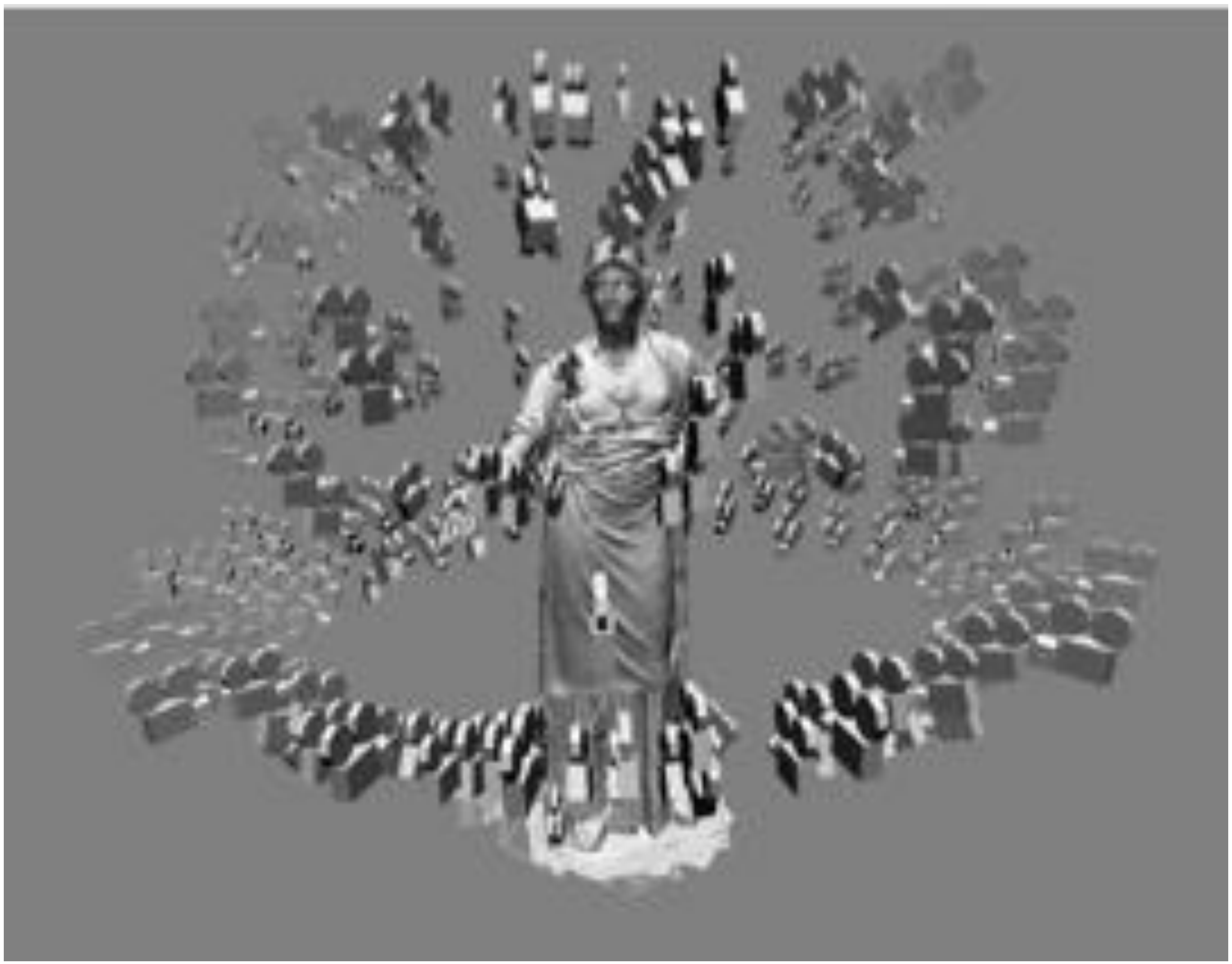


- Discard bad triangles (viewed from very grazing direction)

3D Scanning Outputs: Range Maps

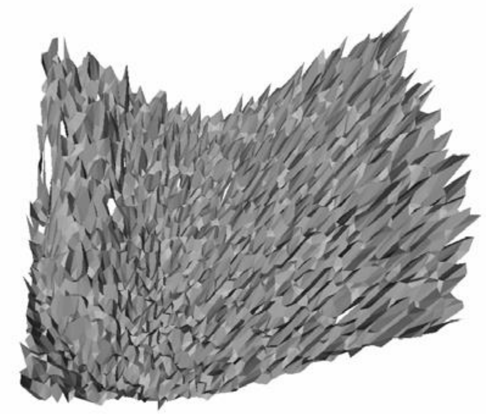
- A range map is already a 3D model… but it will be surely incomplete
- A single acquisition ***IS NOT enough*** to reconstruct an entire object
- Multiple shots are needed to obtain a complete sampling of the surface with the requested accuracy
  - How many?
  - Which ones to choose?

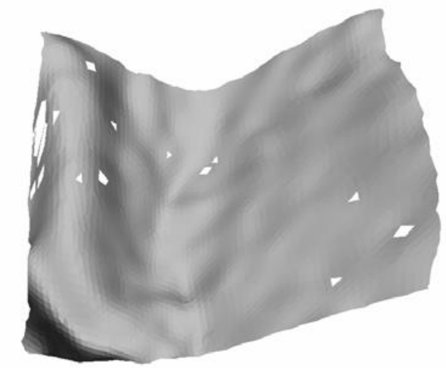
3D Scanning Outputs: Range Maps

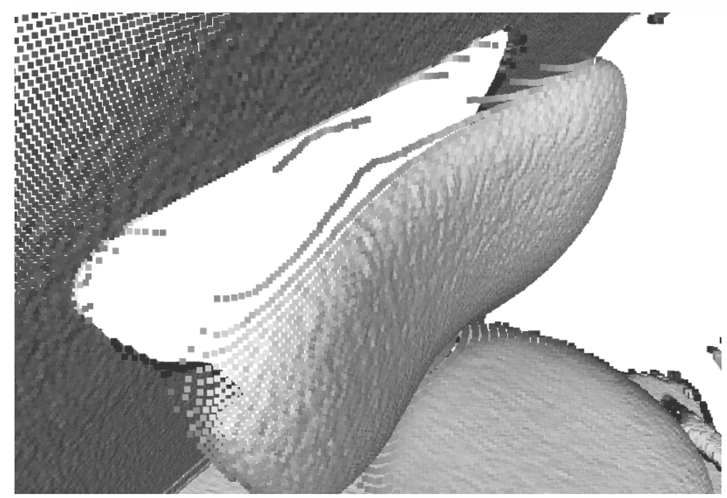


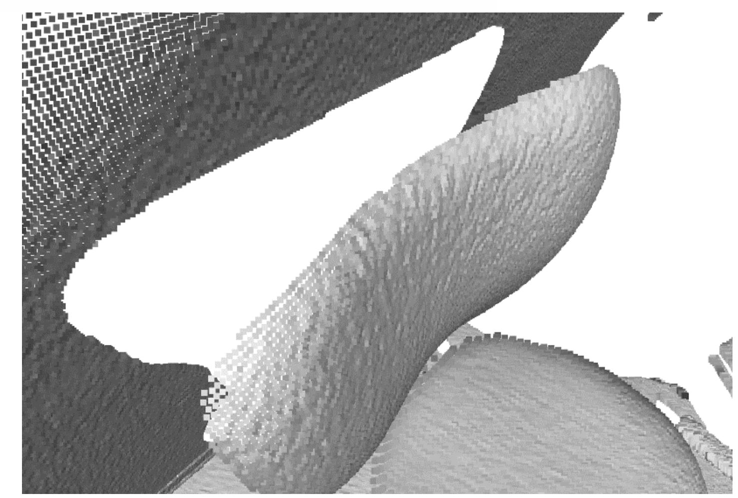
3D scanning pipeline: Editing

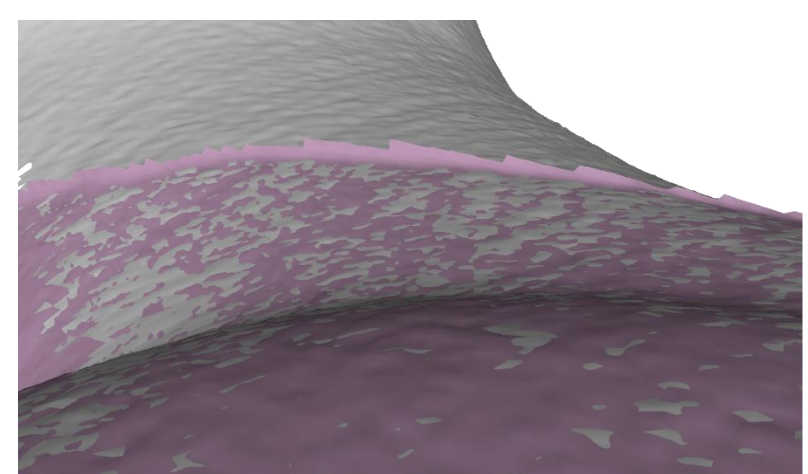
- Remove noise
- Remove scanning artefact
  - Outliers
  - Wrong geometry





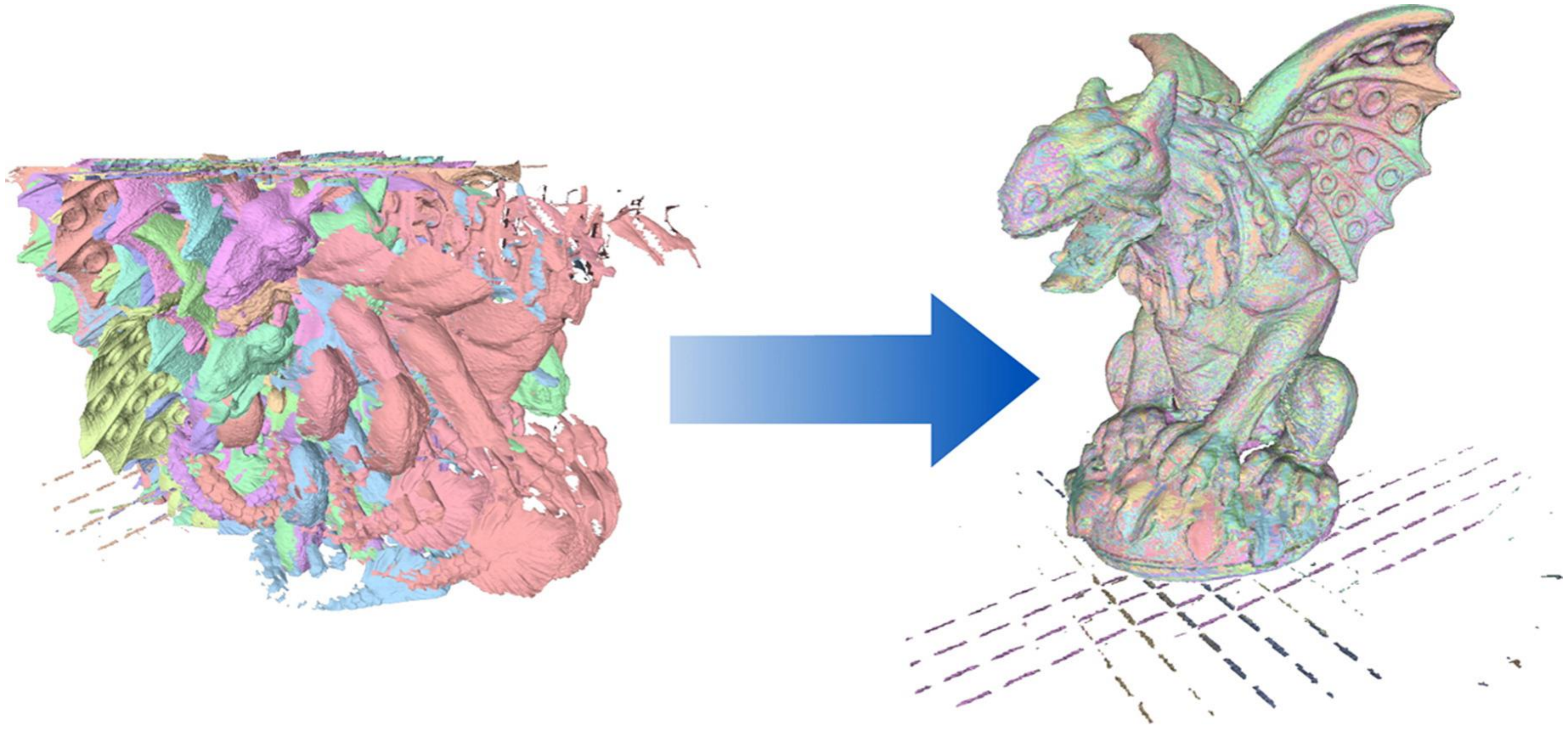






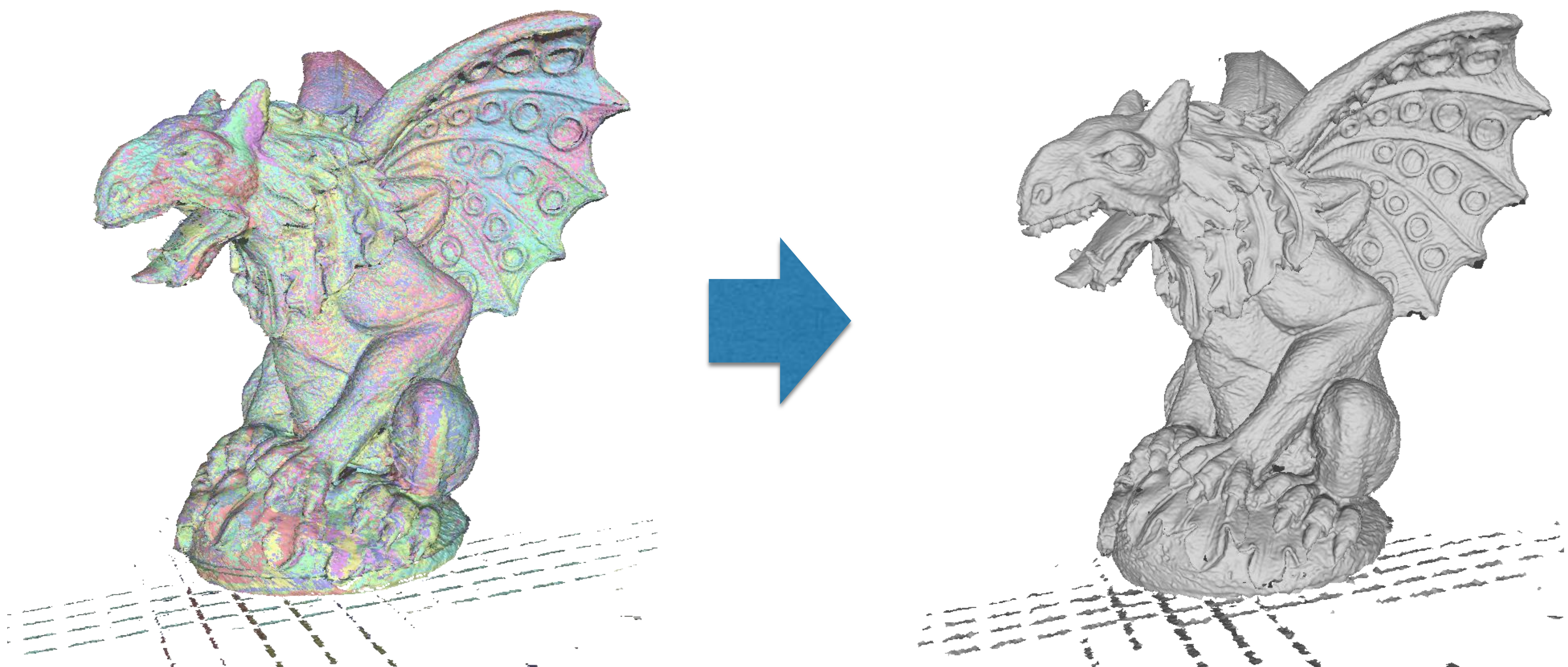
3D scanning pipeline: Registration

- Alignment of the range maps in the same reference system
  1. Rough alignment (manual or automatic)
  2. Pair-wise refinement by ICP (Iterative Closest Point)
  3. Global registration



3D scanning pipeline: Merging

- To compute a continuous surface by integration of the redundant data in the overlap regions of the input range maps



3D scanning pipeline: Simplification and Repairing

- Correct small artifact of the 3D models (e.g. no-manifolds vertices and edges, holes)
- Create smaller versions of the 3D models by removing the triangles in a controlled way

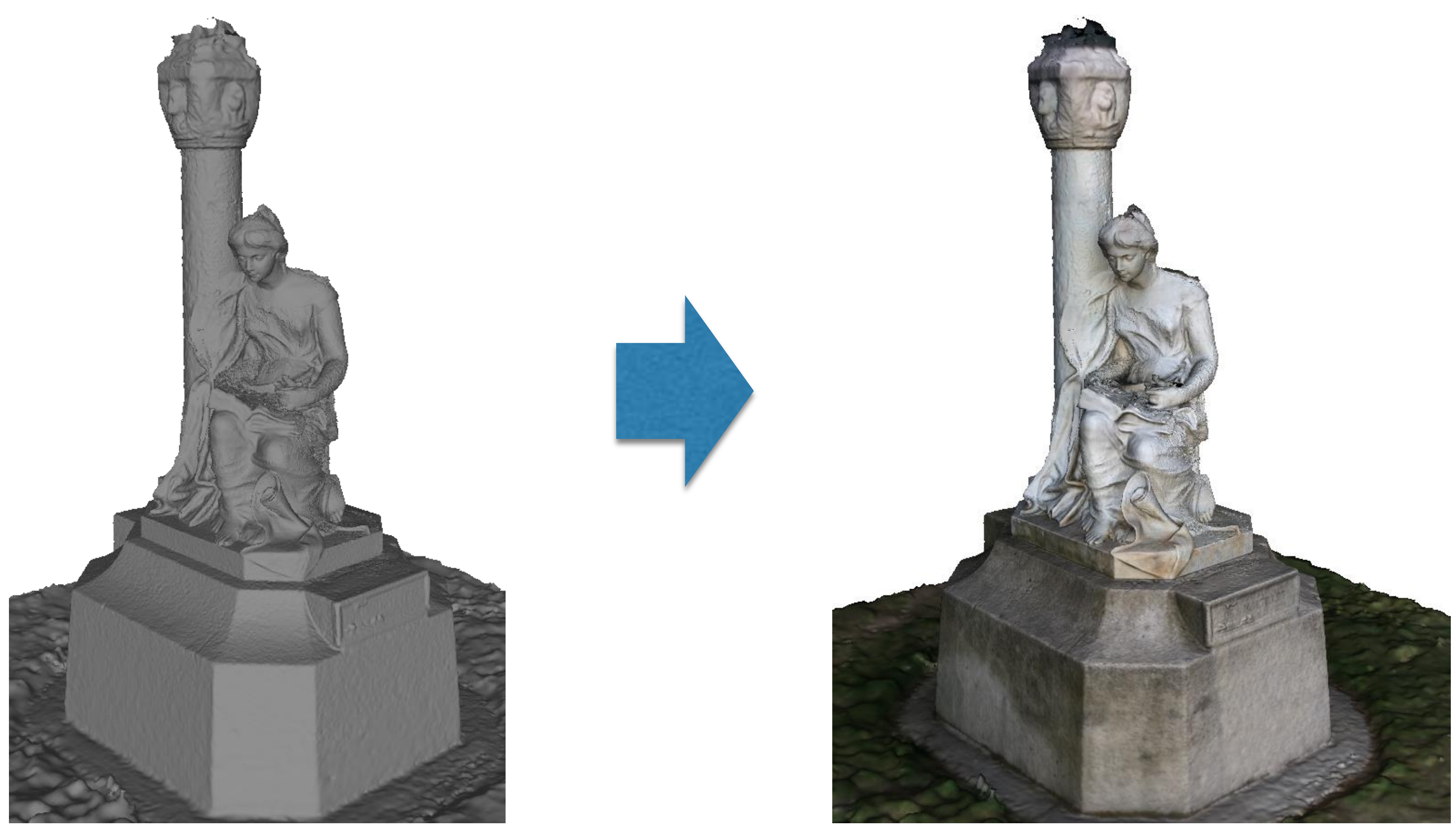
4M TRIANGLES

1M TRIANGLES

250K TRIANGLES

3D scanning pipeline: Color and Appearance

- How to add color and appearance information on the surface
- Ad-hoc photographic campaign
  - Registration of the images, projection and integration of the color data



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