Grafica 3D per i beni culturali: Tre esempi

20 Marzo 2014

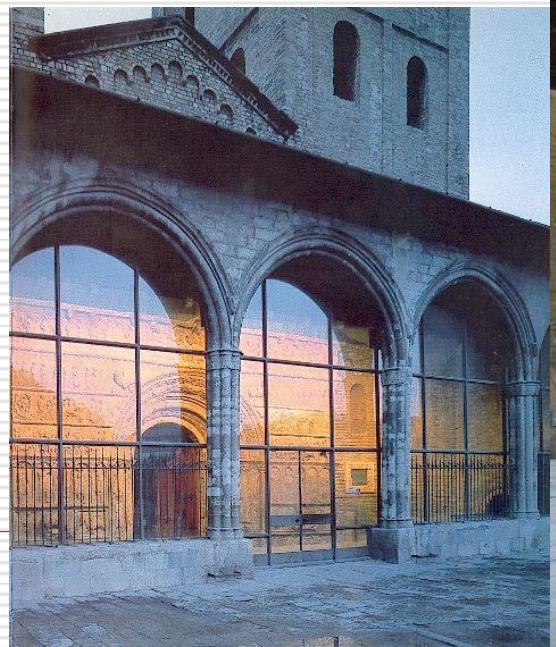
Example 1: Larger than life

Portalada, monastery of Santa Maria De Ripoll, Spain
7 x 11 meters… to be scanned at 1mm resolution

Portalada de Ripoll

Romanic sculptured entrance of the Benedictinian monastery of Ripoll (Spain)
Quite a large piece (7mx13m)
The museum needed a ***millimetric*** resolution for the entire surface

Joint project:
UPC
NMAC
CNR



A rigid substrate

Object is 70 square meters, scans are 30x30 cm
Object has no back-side → highly probable deformation

Solution: have a rigid reference of the entire object

2 scanning devices:
TOF scanning, lower resolution but intrinsically rigid
Triangulation scanning, higher resolution

Triangulation data aligned OVER the TOF model… no deformation and high resolution

MultiScale Acquisition

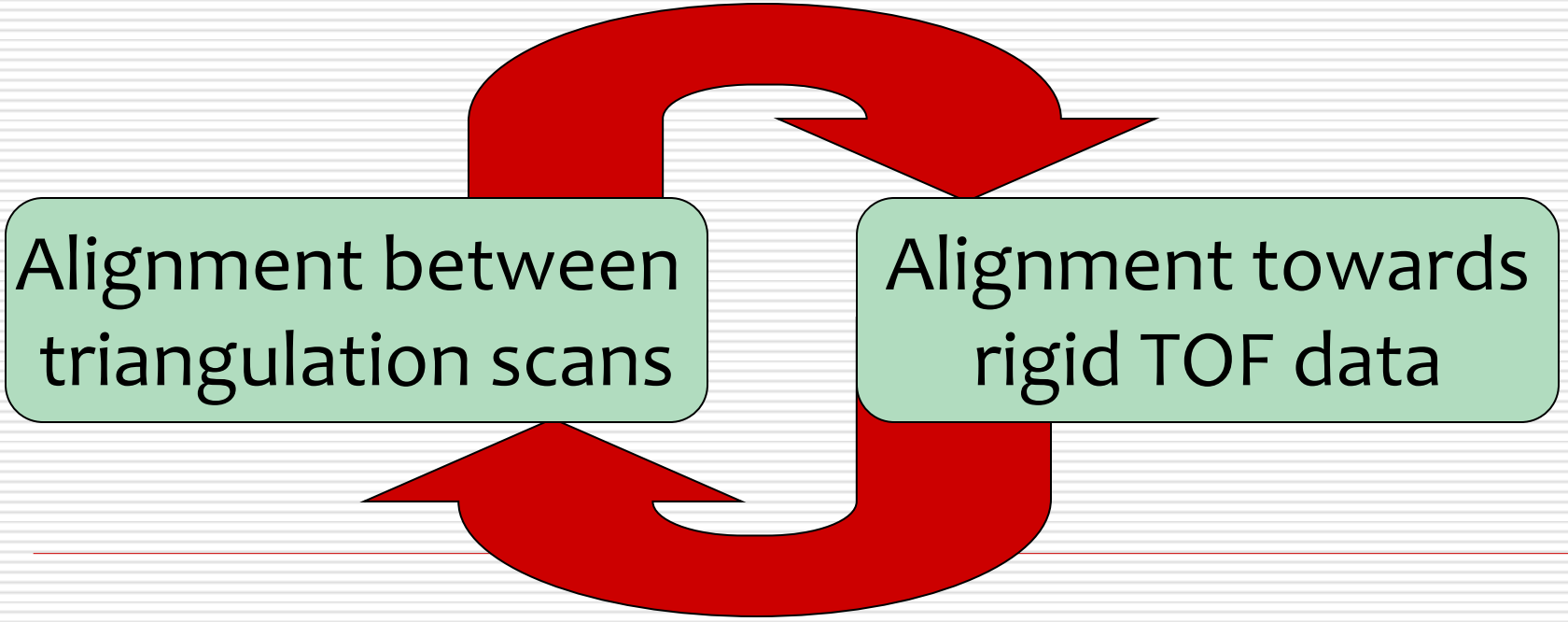
Triangulation
Minolta V910 (2x)
High resolution, small parcels

Time of Flight
Leica HDS3000
Low resolution, fullsize scans

MultiScale Processing

Range map alignment works well, but is impossible to guarantee a deformation-free result when the range maps are so small with respect to the object size (this is a scale-dependent problem)

Solution: use the precision of the triangulation range maps AND the rigidity of the TOF scan



Integration of different data sources

- All sections (colored frames) of Minolta data aligned locally
- Then, each section aligned with the Leica full model

==> medium quality alignment

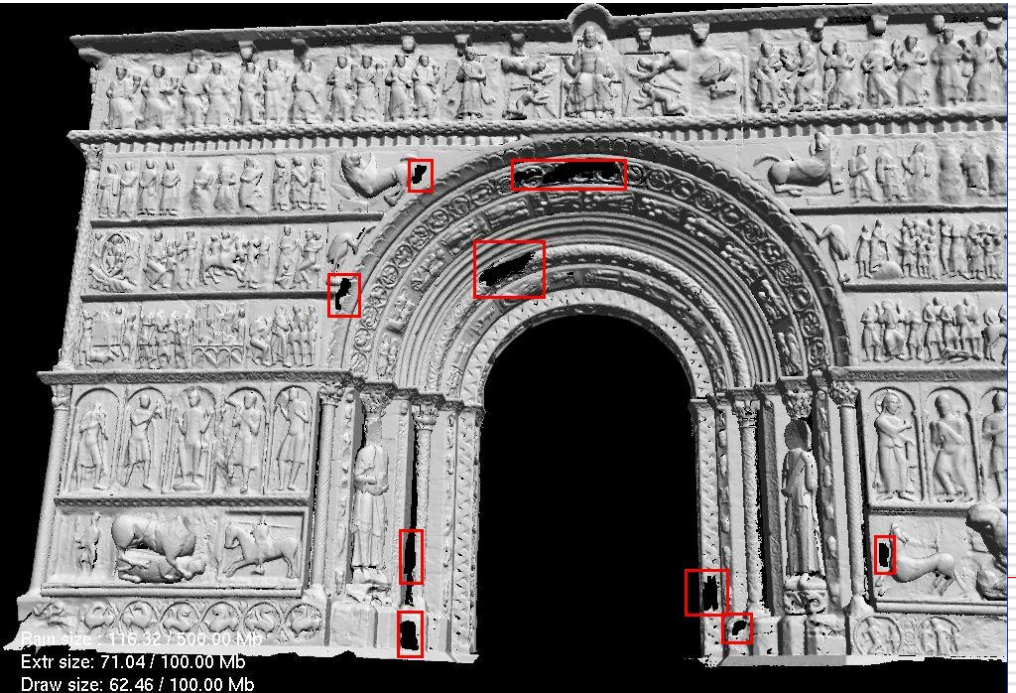
- Finally, refine global alignment between all Minolta range maps (from intermediate results)
- **Final reconstruction**: 170M tr, 26hours

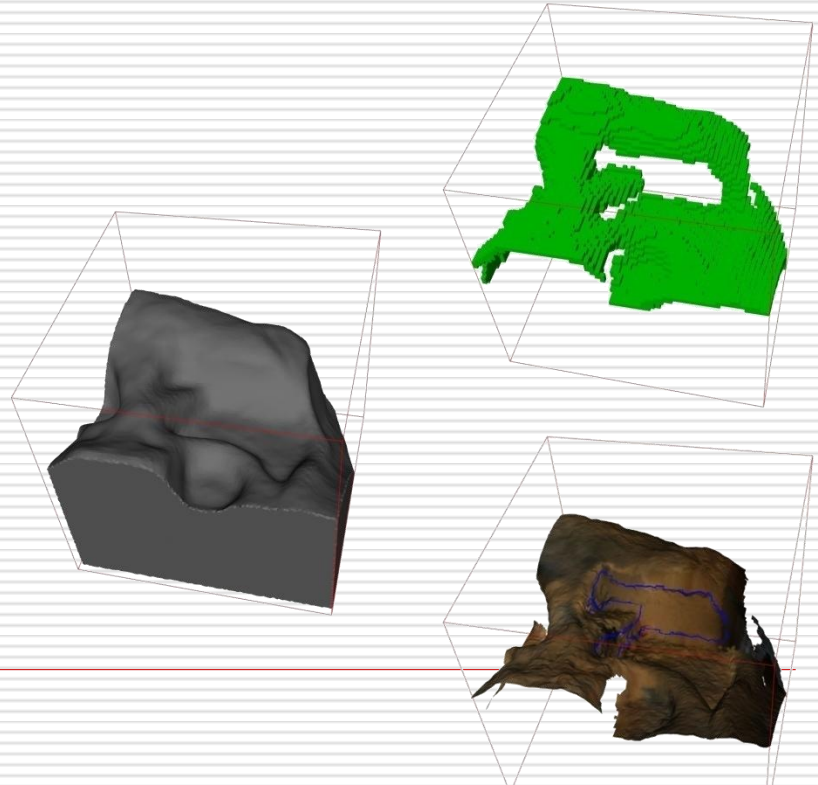
  + Color mapping (200 photos)

MultiScale Completion

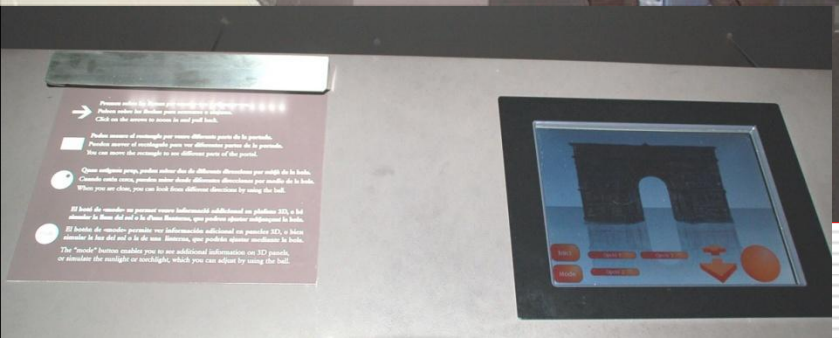
TOF data has been used to fill unsampled areas in the triangulation dataset…

Remaining holes have then been filled working at different level of resolution, from low to high…



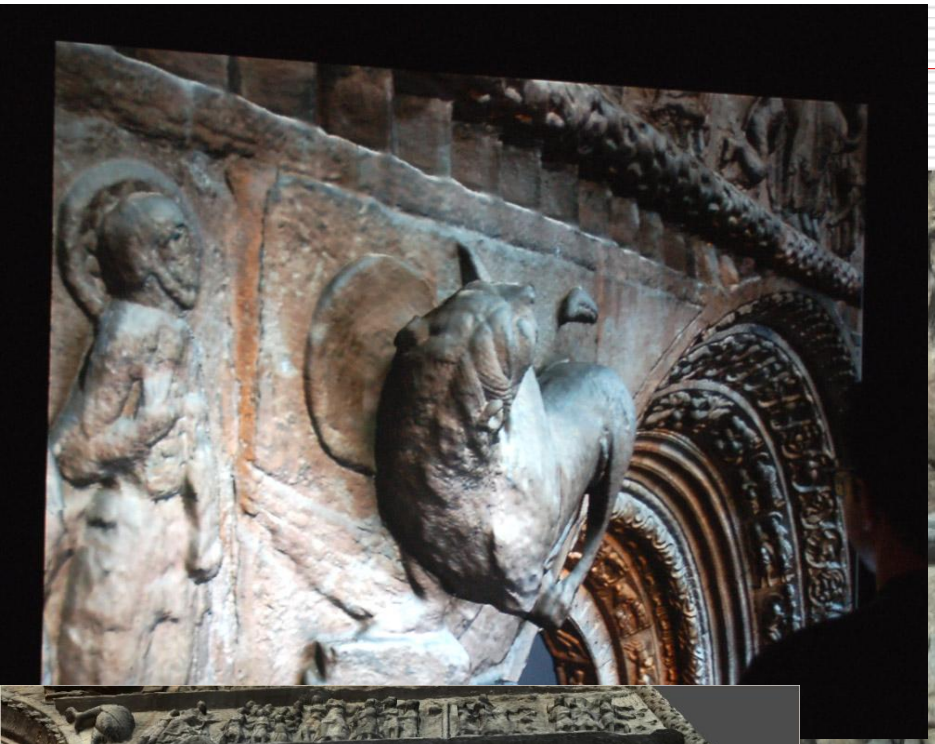


Results



The interactive kiosk

Results



The final 3D model

Portalada: lesson learned

- With a high quality planning, everything is possible.
- The integration of different technologies (with different accuracy) is possible, but you must be careful in handling data

Example 2: Support to restoration

Madonna of Pietranico, clay statue destroyed (again) by an earthquake.
19 fragments + several very small pieces

The Madonna project

The initial goal of the project was to:

- 3D Scan all the major fragments
- Obtain a virtual reconstruction of the original statue
- Study the original color

Scanning campaign:

- 19 fragments
- 15 to 70 range maps each
- Total N. of range maps: 580
- Voxel side merging: 0.3-0.5 mm
- Photographic campaign: nearly 500 images.

The Madonna project

The first goal was to “virtually reconstruct” the statue.

First idea: use images of the original statue and of the already found fragments combinations, find geometric alignment.

Result: FAILURE, due to difficult alignment and cracks surfaces.

Second idea: use 3D scans of already found fragments combinations, in order to obtain an initial position.

Result: OK, and two more combinations found!

The Madonna project

Final result: a virtual reconstruction of the statue.

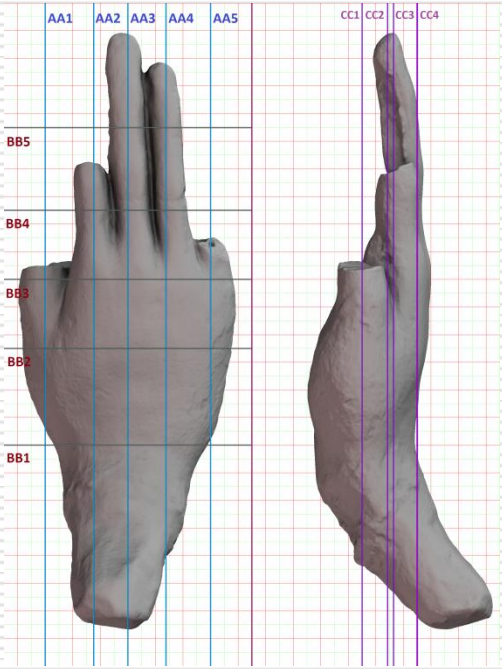
The Madonna project

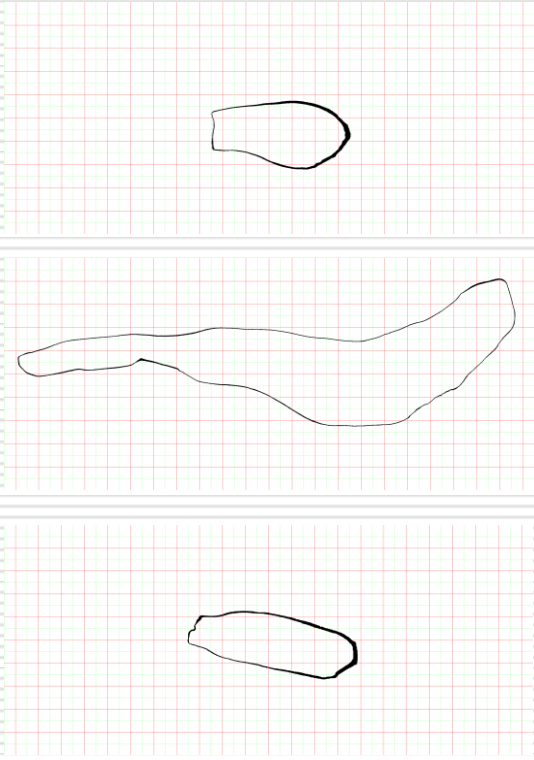
The second goal was to work on the original painting of the statue. A first coloring was obtained using MeshLab.

Result: people afraid of wrong hypotheses!

The Madonna project

But the most interesting stuff was obtained by supporting the work of restorers:

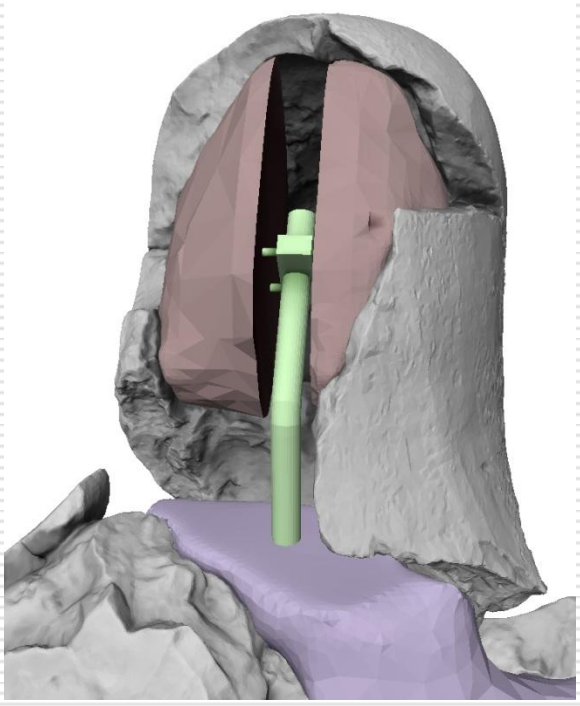




First: sections and ortho-views to reproduce symmetric stuff!

The Madonna project

But the most interesting stuff was obtained by supporting the work of restorers:



Second: designing the supports for physical reconstruction!

The Madonna project

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Second: designing the supports for physical reconstruction!

The Madonna project

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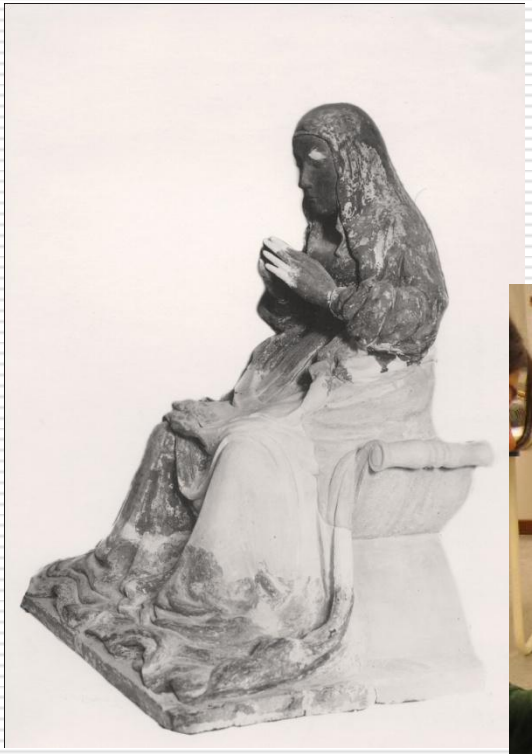
Second: designing the supports for physical reconstruction!

Madonna: lesson learned

- Also a typical, “boring” scanning campaign can become innovative
- Rapid prototyping must be part of restoration activity
- Finding a “common language” is the key



Example 3: Monitoring David

Michelangelo's David

(Galleria dell'Accademia, Florence, Italy)

- CH Ministry asked to monitor the status of lesions on the lower part of the statue (action originated by recent earthquake event)
- Existence of those lesions is known since end of XIX cent.
- Polo Museale Fiorentino defined a complex set of diagnostic investigation analysis, including:
  - Environmental vibrations
  - Conditions of the basement (via geo-radar)
  - Status of the marble fractures (images & 3D + CT?)
  - Finite element simulation
  - …

Monitoring Michelangelo's David

The lesions

- Very thin fractures
- Could be due to stresses created by the old pedestal in piazza Signoria (in very bad shape)
- Not clear if they are stable or potentially increasing
- Value of the artwork is so high, that situation should be under control

Monitoring Michelangelo's David

Sampling current conditions

- Polo Museale asked CNR to perform the best digital acquisition available with current technology
- Data sampling requirements:
  - Very **high resolution**
  - Include **colour** and **shape** data (some lesions are perceptible as surface discontinuities, other are mostly perceived as change of tone)
  - Possibly, **integrate** those two channels in a single model
  - Make the sampling process reproducible in time (**monitoring on time** the possible evolution of the lesions)

Monitoring Michelangelo's David

Shape sampling (1)

- CNR looked for **ideal 3D scanning technology**:
  - Sampling rate 0.1 mm, high accuracy
  - Sufficiently large view volume (the surface is poor of features, in the case of a device with a small working volume sampling many range maps geometric the further alignment could be an issue, reducing accuracy)
- Selected **Breuckmann's** technology:
  - System **smartSCAN-3D-HE** fulfilled our needs
  - Nice opportunity for *on-the-field* test of Breuckmann & CNR technologies

Monitoring Michelangelo's David

Shape sampling (2)

- On-site 3D scanning done in **1h 30m** (Breuckmann staff), including scanner setup time and calibration
- shots acquired: 23 (broncone), 18 (left leg)
- Each shot covered approximately 23 * 19 centimeters ➔ 0.1 mm inter-sampling density
- Due to inter-shot overlap, more than 1 sample every 0.1 mm

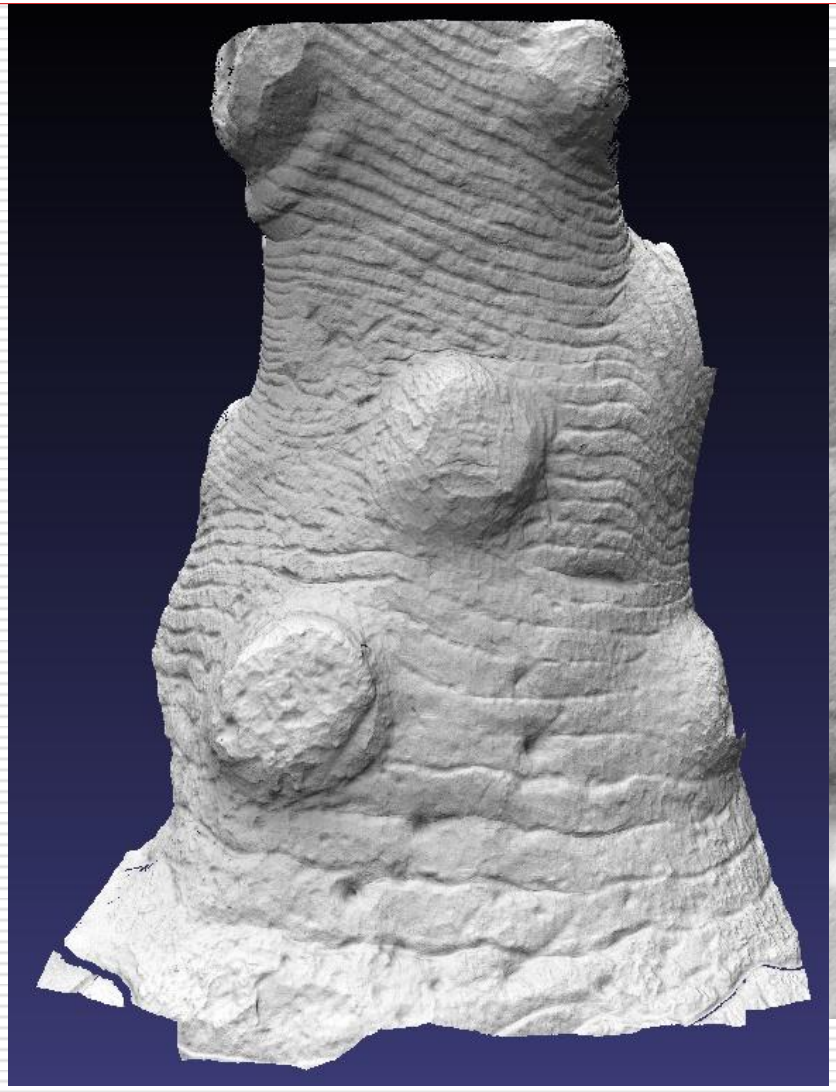
Monitoring Michelangelo's David

Shape data processing

- **Alignment** done with Breuckmann software
- **Reconstruction** performed with Breuckmann & CNR tools
- Master models:

  128 M triangles (broncone, i.e. right leg),
  57 M tr. (left leg)

Monitoring Michelangelo's David



Monitoring Michelangelo's David

Colour sampling (1)

- Performed by **Max Plank Kunsthistorisches Inst.** in Florence
  - Phototek group (Costanza Caraffa, Ute Dercks)
  - Commissioned to an MPI collaborator: R. Sigismondi, professional photographer
  - Used an **Hasselblad H3D 6x6**, with a digital back at **39 Mpixel**
  - Time required: around **4 hours**
  - Number of shots: 6 (broncone), 3 (leg)
  - Pixel sampling size: 0.1 mm (nearly identical to geometry sampling density)

Monitoring Michelangelo's David

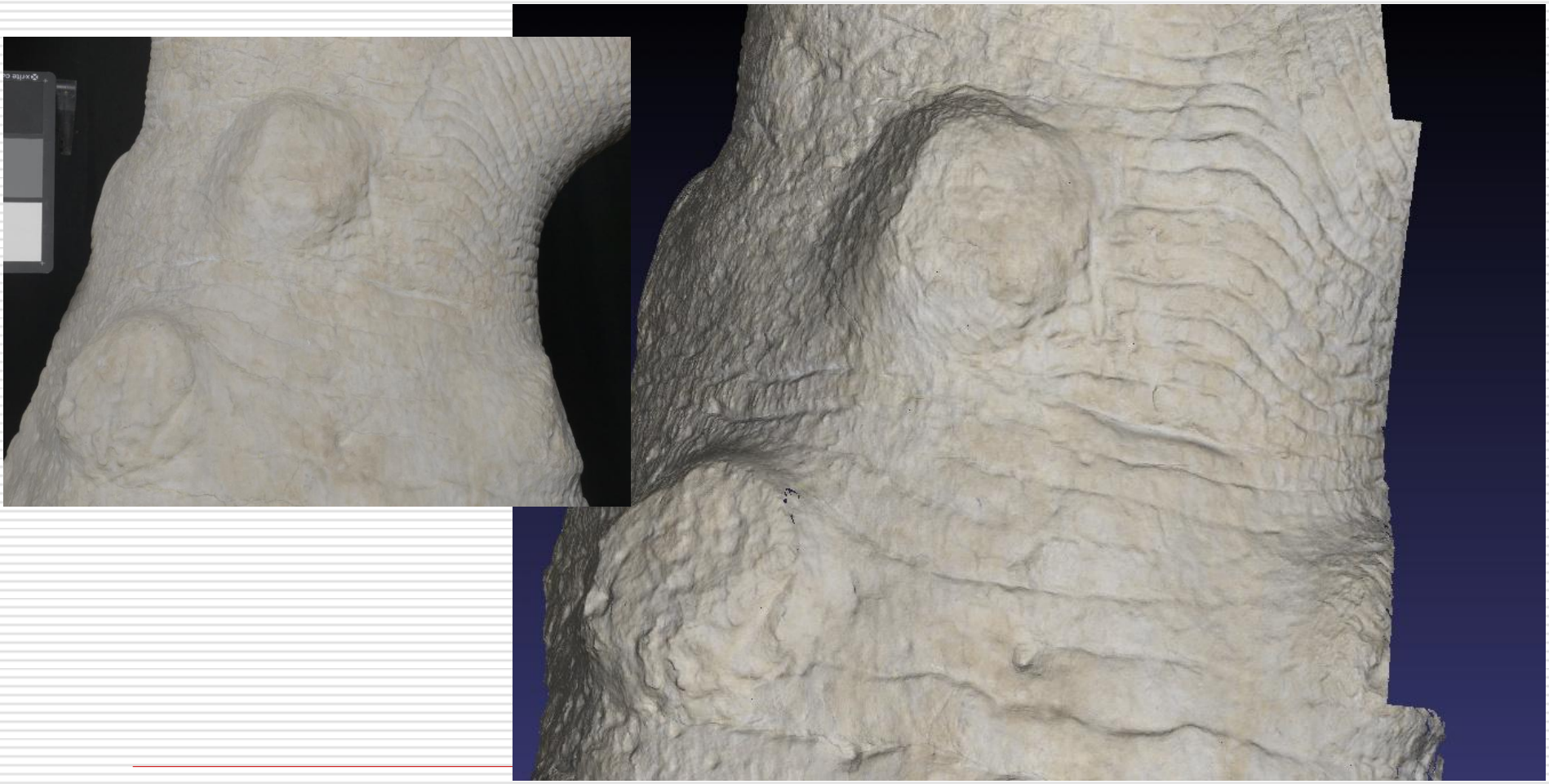
Monitoring Michelangelo's David

Colour mapping (1)

- Performed using CNR tools
- **Image-to-geometry** alignment is really **critical**: fractures in the images should be mapped on fractures on the geometry (accuracy should be at the 0.1 mm level!)
  - Initial selection of a few correspondences (2D->3D)
  - Refined with the new **automatic alignment** solution based on **mutual information** (see WP4, T4.5)
  - The coordinated use of correspondence-based and mutual information allowed us to get the required accuracy
- Colour mapping on the mesh via **colour-per-vertex** encoding

Monitoring Michelangelo's David

Colour mapping (2)



Monitoring Michelangelo's David

Preliminary evaluation

- The MIBAC Monitoring Commission was impressed by the quality of sampled data & models
- They are planning subsequent sampling on time (**3D monitoring**)

Lesson learned:

- Very good quality of the Breuckmann system, excellent SW front end (range map alignment)
- (Possibly) More flexible shape reconstruction with CNR tools
- Successful assessment of new CNR's colour back-projection algorithms

Next in line…

Next lesson:

- 3D scanning hands on!

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