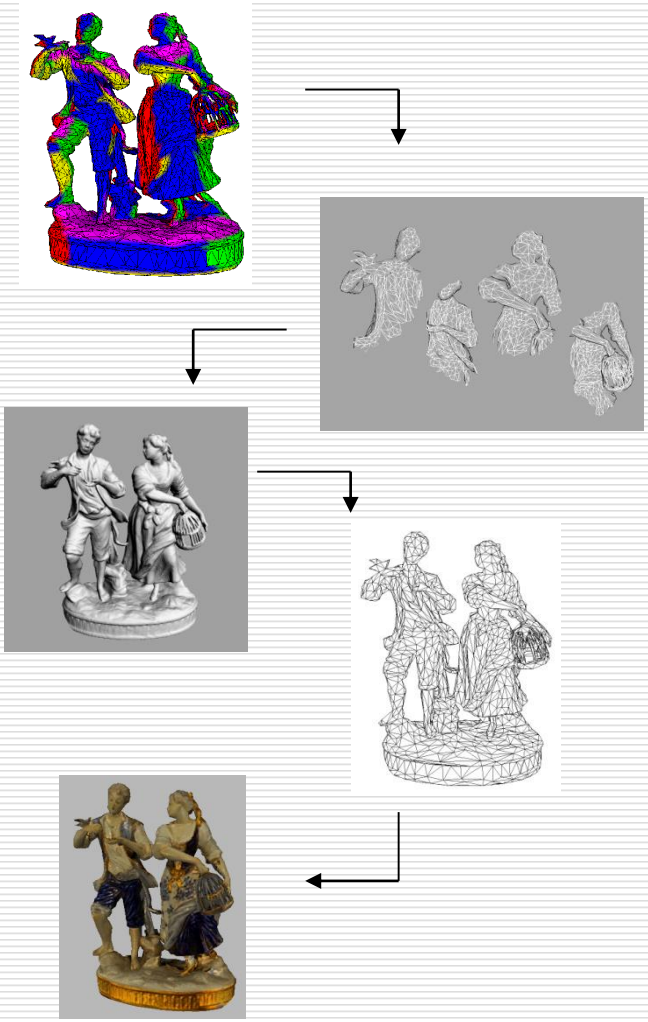
Grafica 3D per i beni culturali: 3D scanning in MeshLab

12-17 Aprile 2018

3D Scanning Pipeline

- *[**Acquisition planning**]*
- **Acquisition** of multiple range maps
- Range map **filtering**
- **Registration** of range maps
- **Merging** of range maps
- Mesh **Editing**
- Interactive **visualization**
- **Capturing/Integration** of **appearance** (color acquisition, registration, mapping on surface, color visualization)
- Archival and data conversion



Alignment

Each part of the model is in its own coordinate system. There is no spatial relationship between the different parts, as they have been generated in a different processing run

Goal: bring all the parts in a common reference system (like a 3D jigsaw puzzle)

Beware: lot of manual intervention is needed!

Two steps:

1. **Rough** alignment: user manually positions the various chunks in more or less the correct position
2. **Fine** alignment: the computer automatically perfecs the alignment using the shared area between the range maps

Redundancy is MANDATORY

Manual Alignment

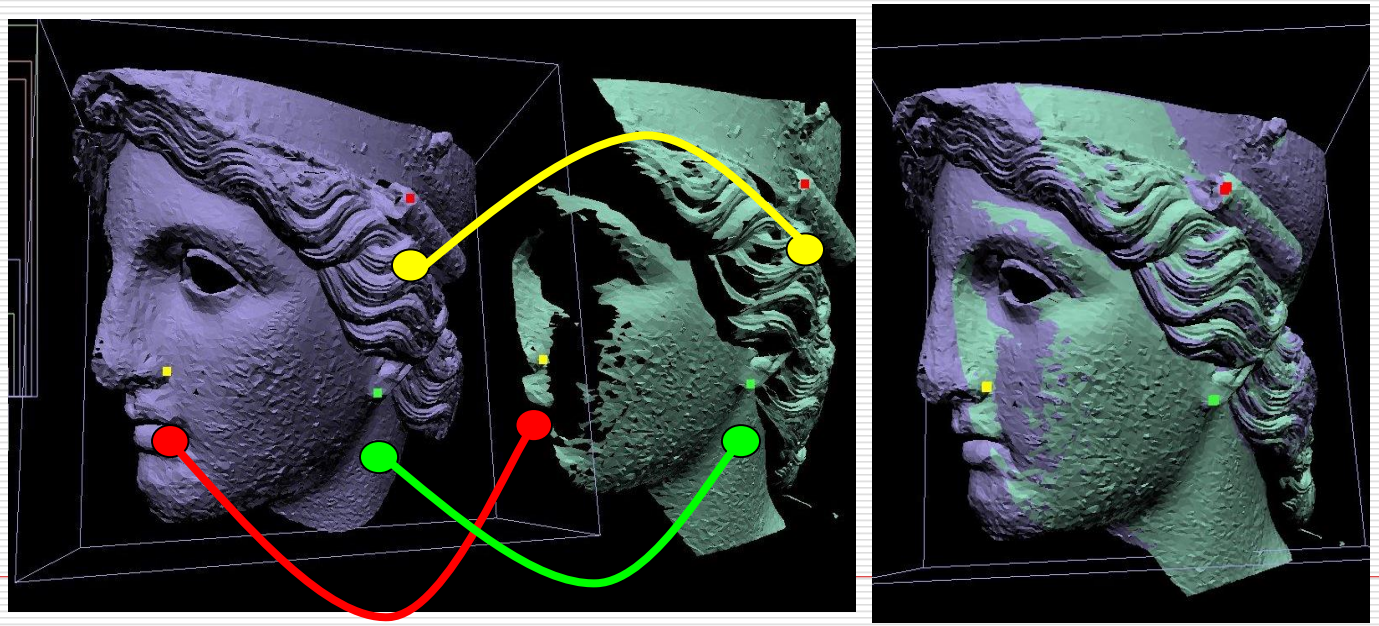
First step.

It is necessary to have an overlap region with some common feature

Common method: picking shared reference points.

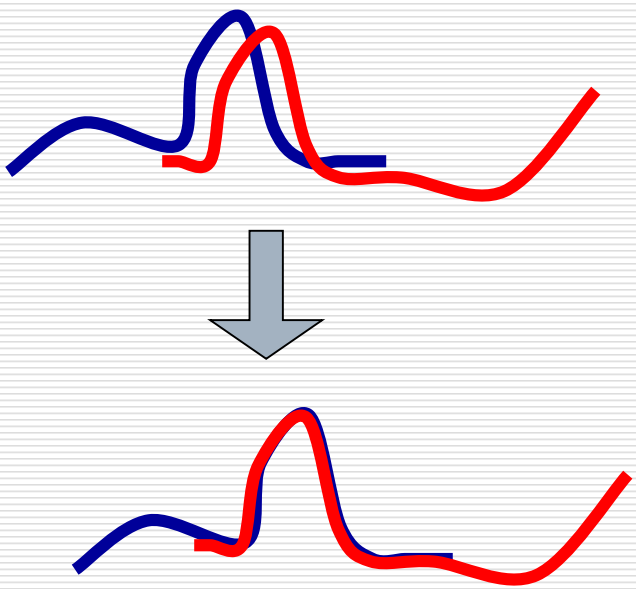
Models are roughly positioned according to the point couples

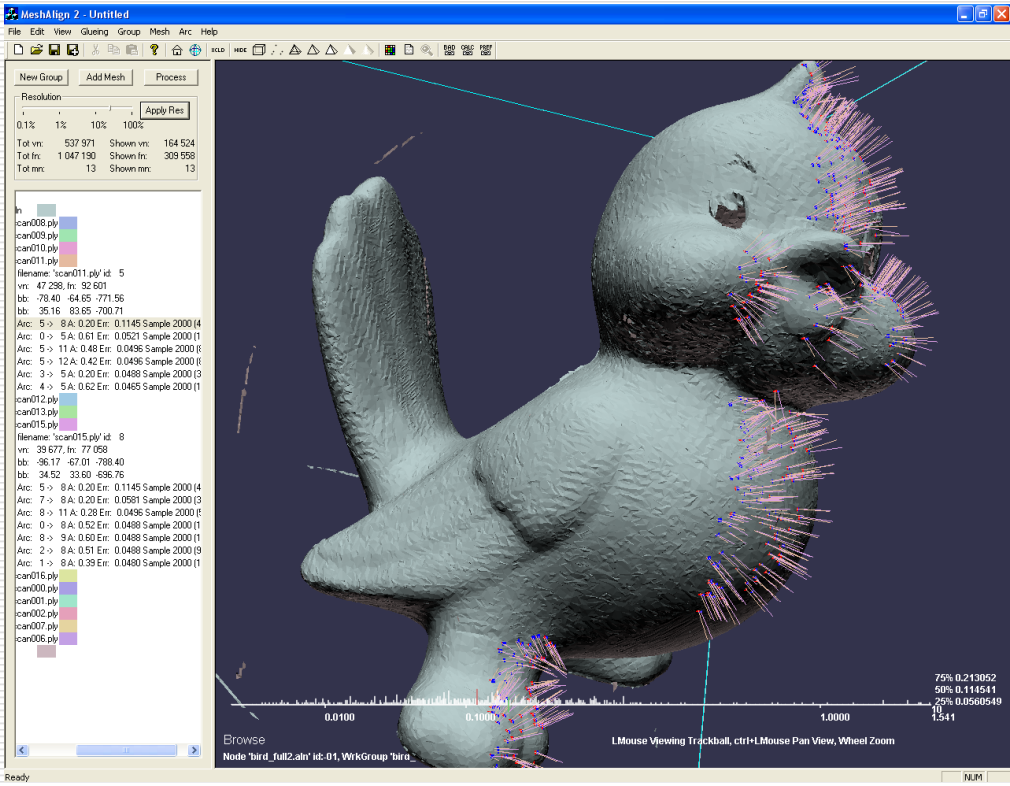
selected. Not a perfect alignment, but enough to start the next phase



Fine alignment

All the range maps are finely registered using redundant areas that are present in adjacent range maps.
Range maps are moved until the common parts are sticked together





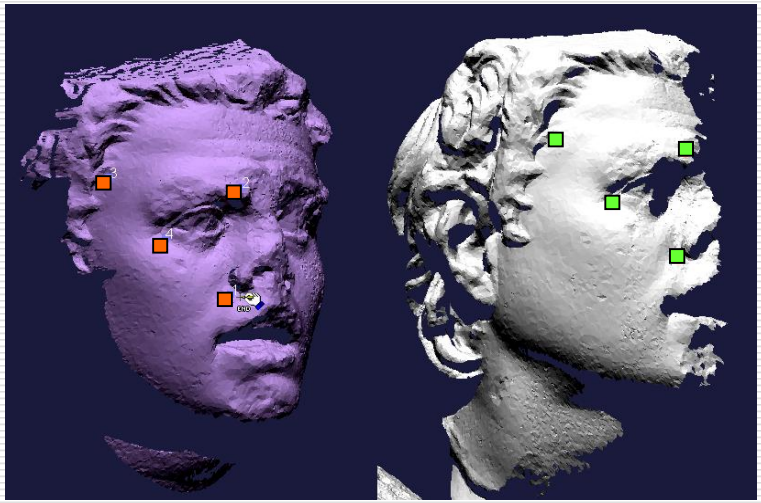
Example: MeshLab

Our internal alignment tool (MeshAlign)

With a multiresolution data representation can work with hundreds

of range maps at the same time

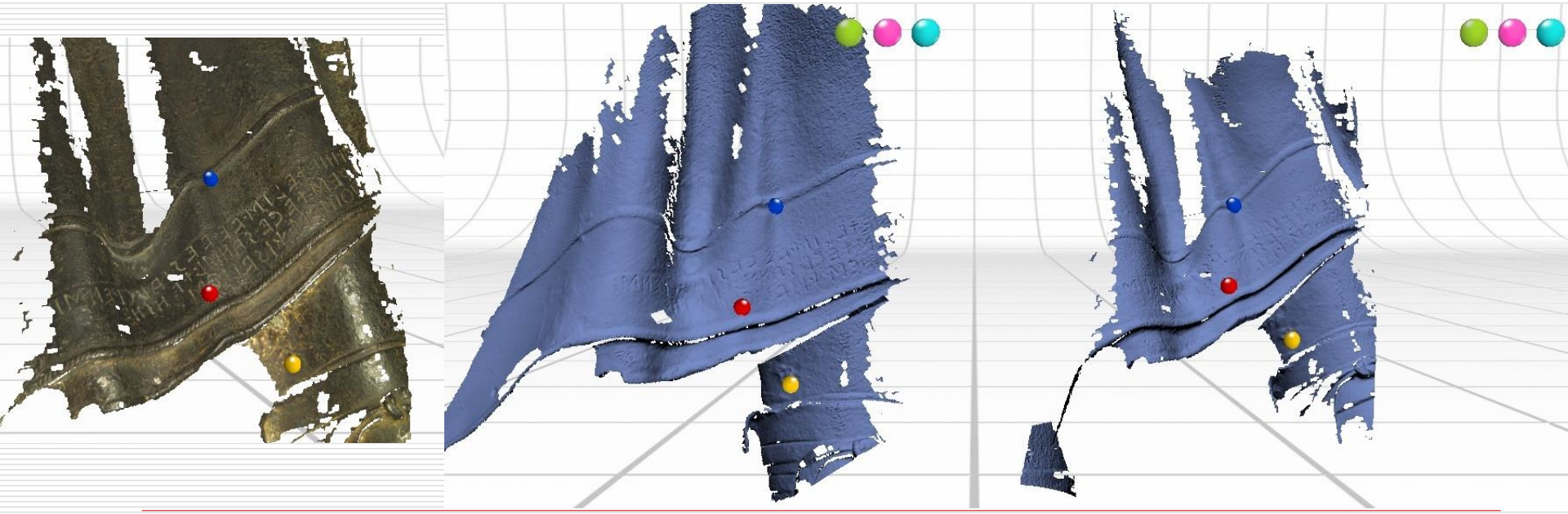
- 4 point matching
- group management
- tweakable alignment parameters
- really powerful, but not so easy to use without training



Example: NextEngine ScanStudio

Bundled with NextEngine Desktop Scanner

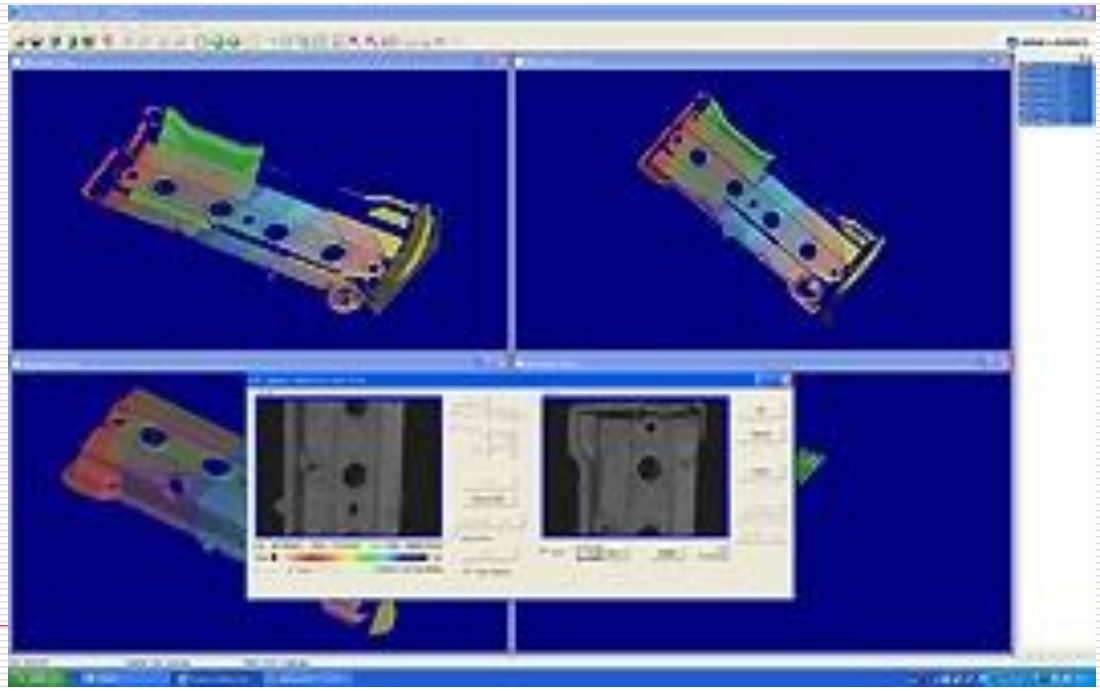
- 3 or more points rough alignment (on geometry or geometry +color)
- semi-automatic alignment for rotary stage scans
- Fully automatic fine alignment (just with target error)



Example: Minolta PET, GOM …

Current tools for mesh acquisition and processing

- alignment during acquisition, selecting points on the viewfinder
- 1 point alignment (if possible)
- Automatic alignment for rotary stage scans
- Fully automatic fine alignment (some parameters)



Not always necessary

Not all scans need the alignment step or, at least, an explicit

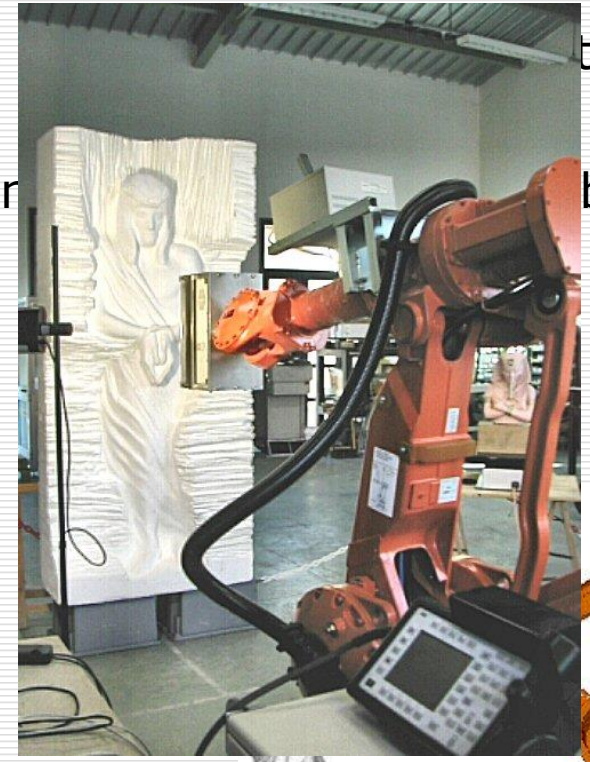
alignment step.

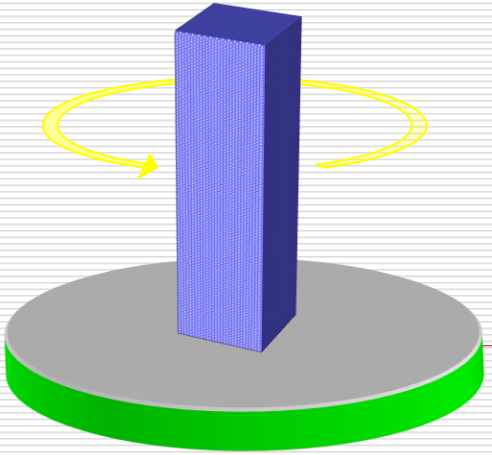
- Aerial/satellite is aligned while produced
- Automatic matching and alignment is possible in some cases
- Scans can be aligned using reference markers…

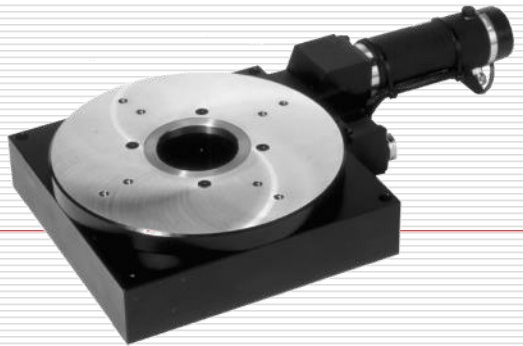
Scanner tracking

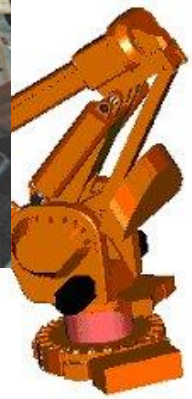
If scanner position is known in each shot, alignment phase can be reduced (rough alignment) or completely eliminated

- **Rotary stage**: PC-controlled, 1 DOF angle rotation. Simple and effective
- **Arm positioning system**: 2 to 6 axis, t very high precision ans speed-up
- **Tracking system**: generally wireless, r but flexible









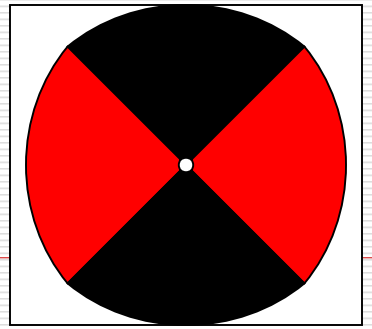
Markers

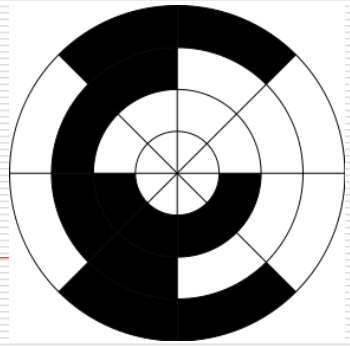
Markers are physical objects placed near/onto the surface to be acquired that are recognized by the scanner (known patterns/geometries, color-codes, materials)

Their position is used as a reference for rough **and** fine registration

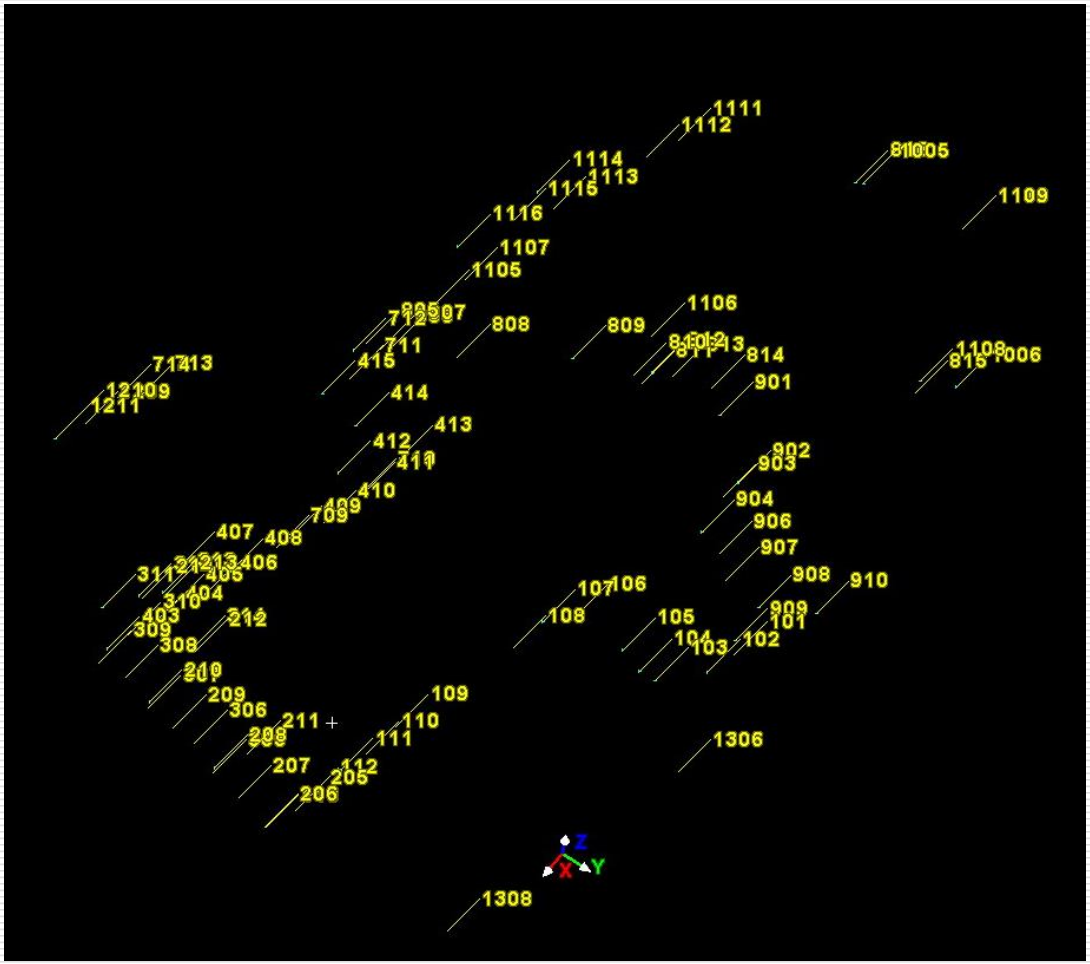
"Total Station" is used in surveying and laser 3d scanning of building a theodolite is used to determine the position of reference points.

This technique is quite slow but really precise and reliable (we have used it in the last 7000 years)





Markers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Alignment: comments

The alignment step is a key one in the scanning pipeline. In order to go on with the merging phase, an indication about the error is needed. Final error is the sum (at least) of these two values:

- Acquisition error: the error for the single acquisition. Dependent on object, hardware, acquisition environment.

- Alignment error: the error in alignment of the range maps. Dependent on object, scans quality and number, overlapping.

Both the values are “statistically” known, the alignment error cannot be less than the acquisition error.

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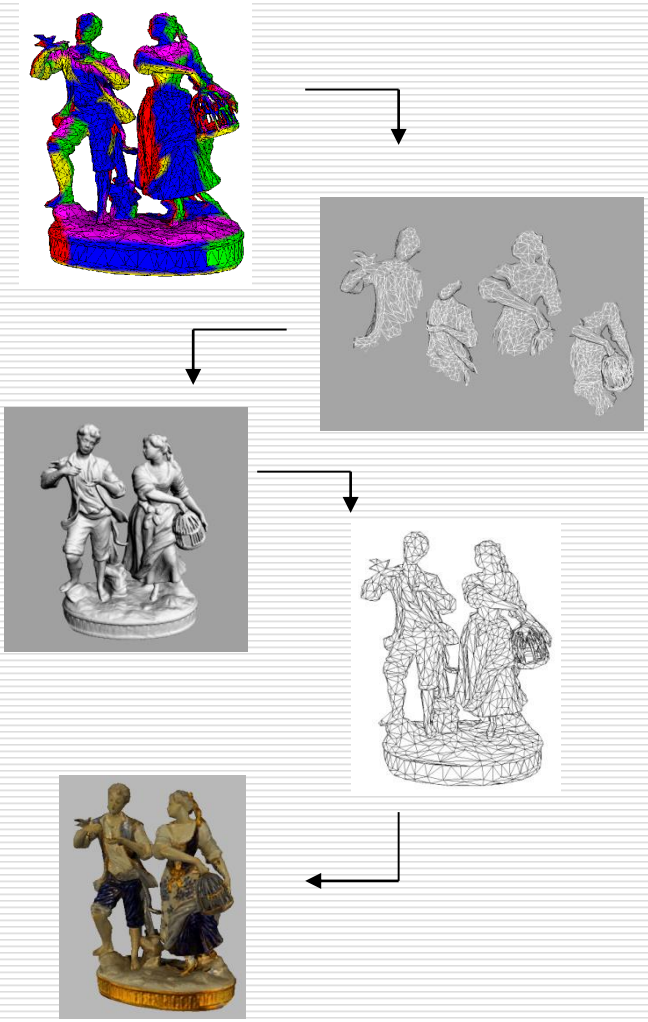


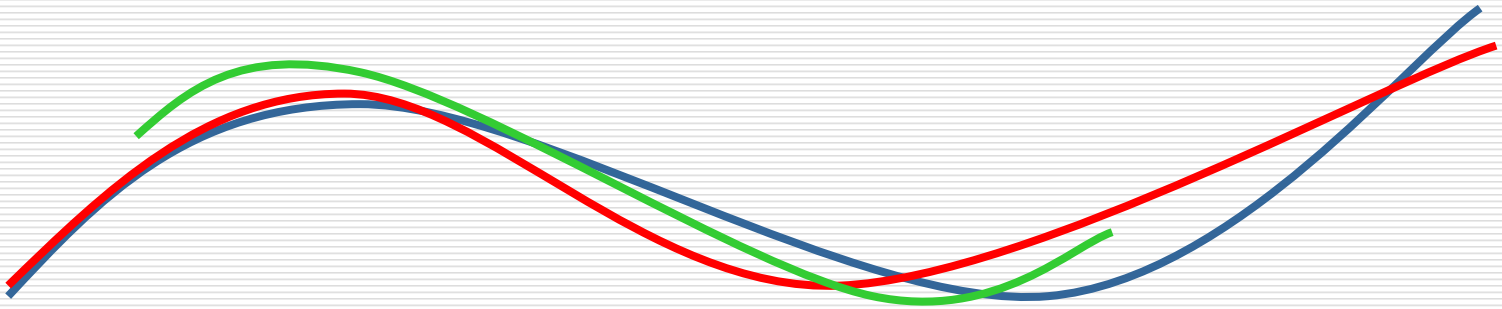
Range maps Merging

When all maps have been generated, cleaned and aligned, it is time to generate a single surface

Why ? to cover the entire surface we need all maps, but more maps covers the same area, with intersecting and overlapped triangles…
Moreover, the sum of all map has too many triangles to be used…

Problem:

more maps covers the same area, which one is the correct one?

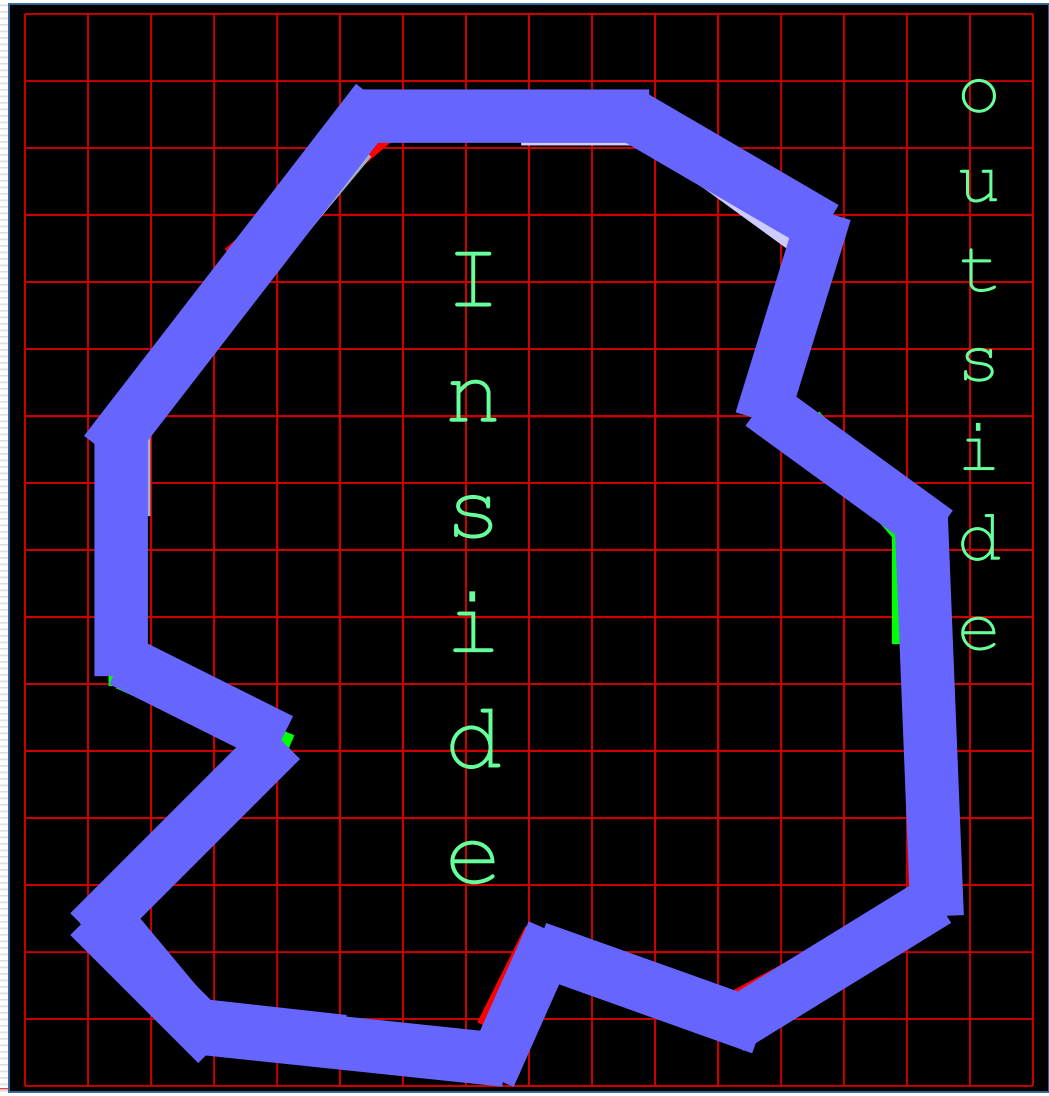


Answer: None

Volumetric Methods

Range maps are immersed in a volumetric grid: the final surface will be built using some criteria that work in each cell that contains some part of the original model.

Inside each non-empty cell the contribution of the various range maps will be combined in order to obtain a consensus surface, extracted then using (generally) a variant of the MARCHING CUBE algorithm



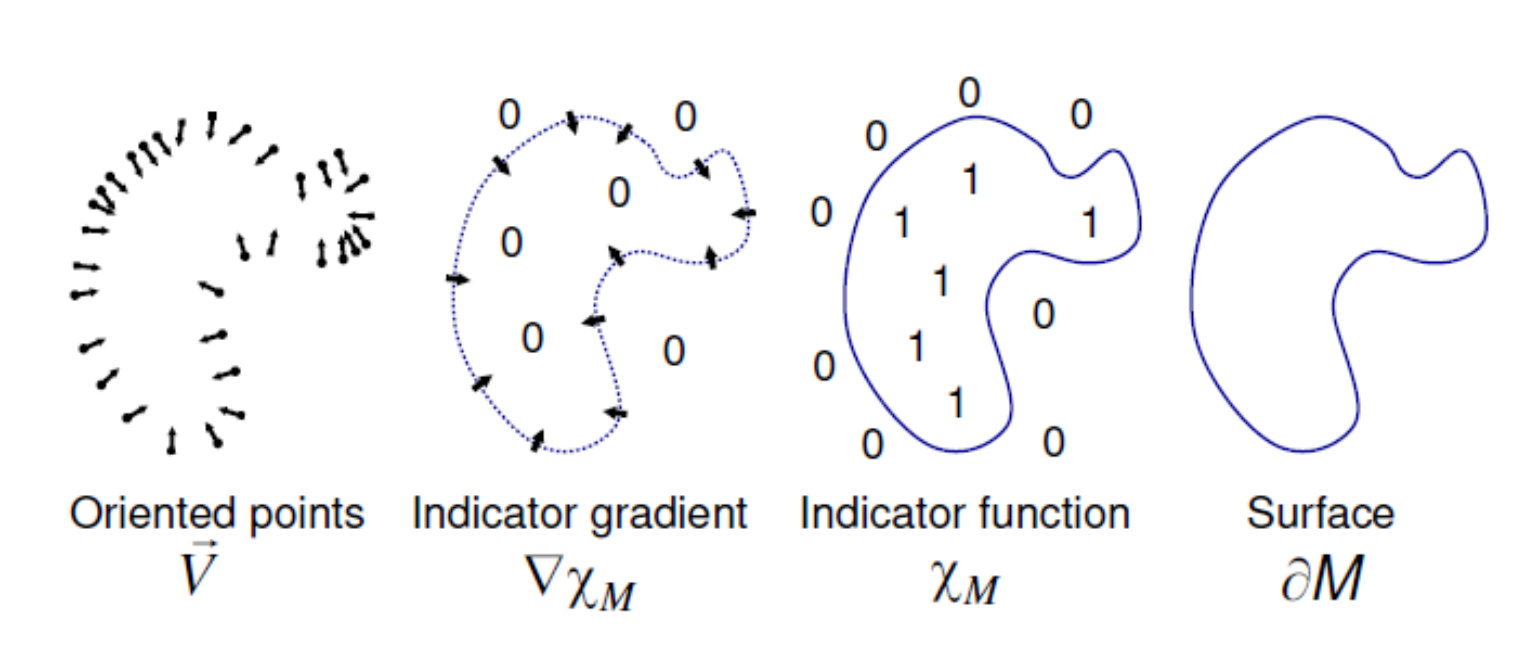
Implicit surfaces

- Another possible approach:
- Use the data to build a mathematical surface of approximation
- Triangulate the mathematical surface using some tessellation OR similarly to the volumetric methods (computing triangulation in each cell)

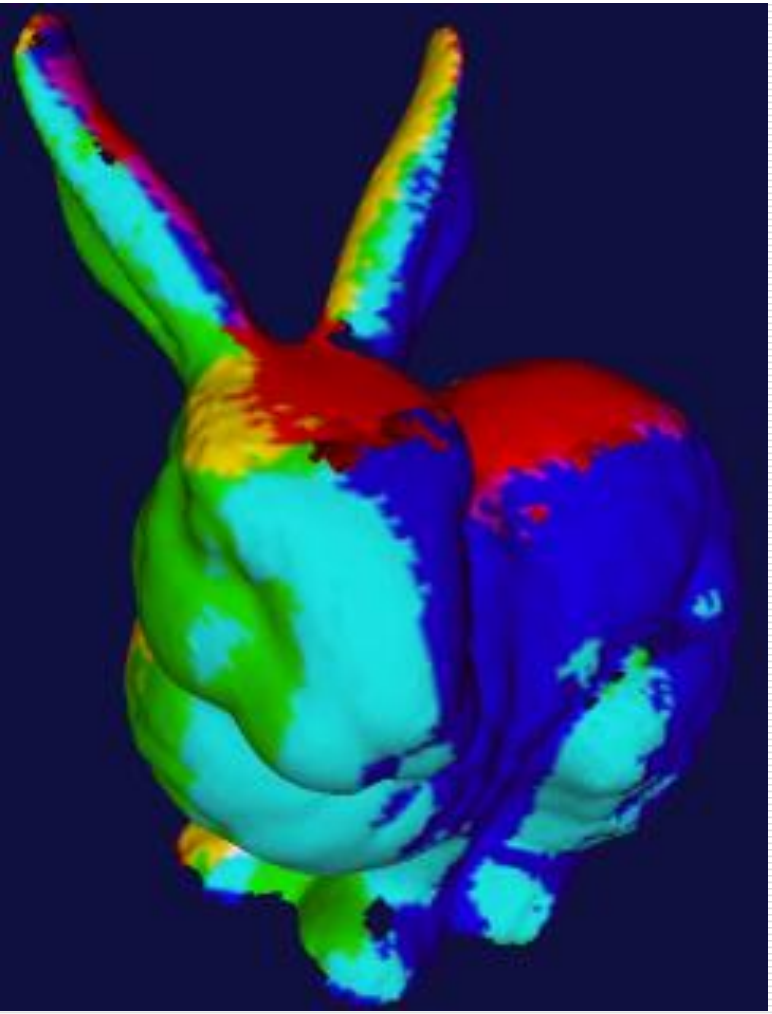
The use of an intermediate mathematical/analytical representation helps creating smoother surfaces and correct problems in the input data (like closing holes)

Poisson reconstruction

A recent (2006) work implementend the Poisson reconstruction. This formulation considers all the points at once, without resorting to heuristic spatial partitioning or blending, and is therefore highly resilient to data noise. -> Closed surface!



Zippering



Quite an old method, but still used in many
tools.

The surface is built using parts of each single scan, simply joined together.

Can be distinguished from triangulation: some areas are covered with a regular triangle grid, joined by strips of triangles (zipper).

It is simple and fast, but does not use the
geometric redundancy to eliminate some of the sampling error

Just an example

Just an example

Just an example

Merging: comments

Regardless of the technical details, three possible merging approaches are shown:

- Volumetric (VCG filter in MeshLab): the user defines the resolution of reconstruction, possibility to “split” the model to handle complexity, only sampled surfaces are reconstructed.

- Zippering: quite simple “puzzle like” approach, bad triangulation.

- Poisson (Poisson filter in MeshLab): the output is always a closed surface, very good results with noisy surfaces, no real possibility to handle complexity.

Big Names

Industrial tool for mesh processing and 3D scanning managements are used also in CH field.
Very powerful, high robustness (industrial grade), not really easy to use for non-trained personnel

RapidForm	generic scanning/mesh processing
GeoMagic	generic scanning/mesh processing
Cyclone (semi-bundle)	time of flight

Hundreds of small companies have their own software… really hard to choose without a proper knowledge. Ideal solution is to find someone of the field to help you decide

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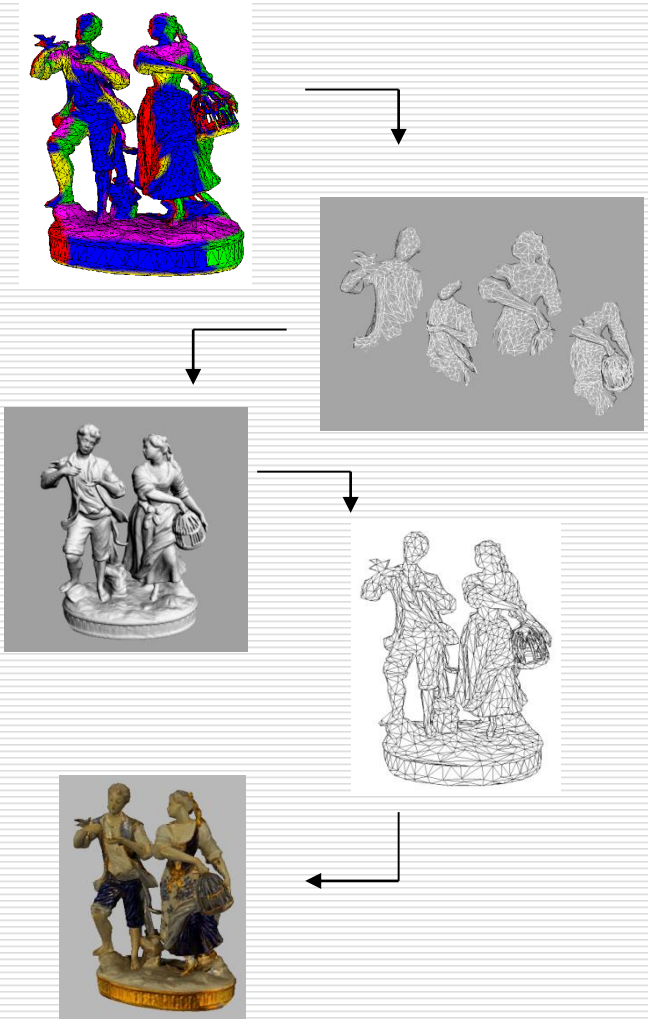

Alignment in Meshlab

The alignment of a number of meshes can be done using a filter in MeshLab

Procedure: 

- Load the range maps as layers
- Glue the first one (hide the others)
- For each mesh, use Point Based Glueing to find the rough alignment
- Every 4-5 range maps aligned, launch Process
- If needed, correct the alignment error
  Parameters: Min. starting dist, Sample number
- Save the aln or mlp file

- Video Tutorial:
  http://www.youtube.com/watch?v=4g9Hap4rX0k&list=PL53FAE3EB5734126E&index=1
- http://www.youtube.com/watch?v=UrJqKIF_tAc&list=PL53FAE3EB5734126E&index=2

Merging in Meshlab (1)

There are several ways to merge the range maps in a unique mesh.

1) Remeshing, simplification and reconstruction -> Surface Reconstruction:VCG

Procedure:

- Load the aln file
- Launch the reconstruction
  Parameters: Voxel Side, SubVol splitting
- If the merging is split, make all the subblocks visible and launch Layer and attribute management -> Flatten visible layers
- Clean!
- Save the final model

- Videotutorial: http://www.youtube.com/watch?v=Ye95yhvjYJM&list=PL53FAE3EB5734126E&index=3

Merging in Meshlab (2)

There are several ways to merge the range maps in a unique mesh.

2) Remeshing, simplification and reconstruction -> Surface Reconstruction: Poisson

Procedure:

- Load the aln file
- Layer and attribute management -> Flatten visible layers
- Launch the reconstruction
  Parameters: Octree Depth, Solver divide
- Clean!
- Save the final model

- Videotutorial: http://www.youtube.com/watch?v=dTkiPsNZg_o&list=PL53FAE3EB5734126E&index=4
- http://www.youtube.com/watch?v=JvTt5VjmWNQ&list=PL53FAE3EB5734126E&index=5

Next in line…

Next lesson:

- Multi view Stereo Matching in MeshLab

Contacts:

Matteo Dellepiane

c/o ISTI-CNR Via G. Moruzzi 1

56124 Pisa (PI)

Tel. 0503152925

E-Mail: dellepiane@isti.cnr.it

Personal website: http://vcg.isti.cnr.it/~dellepiane/

VCG website: http://vcg.isti.cnr.it