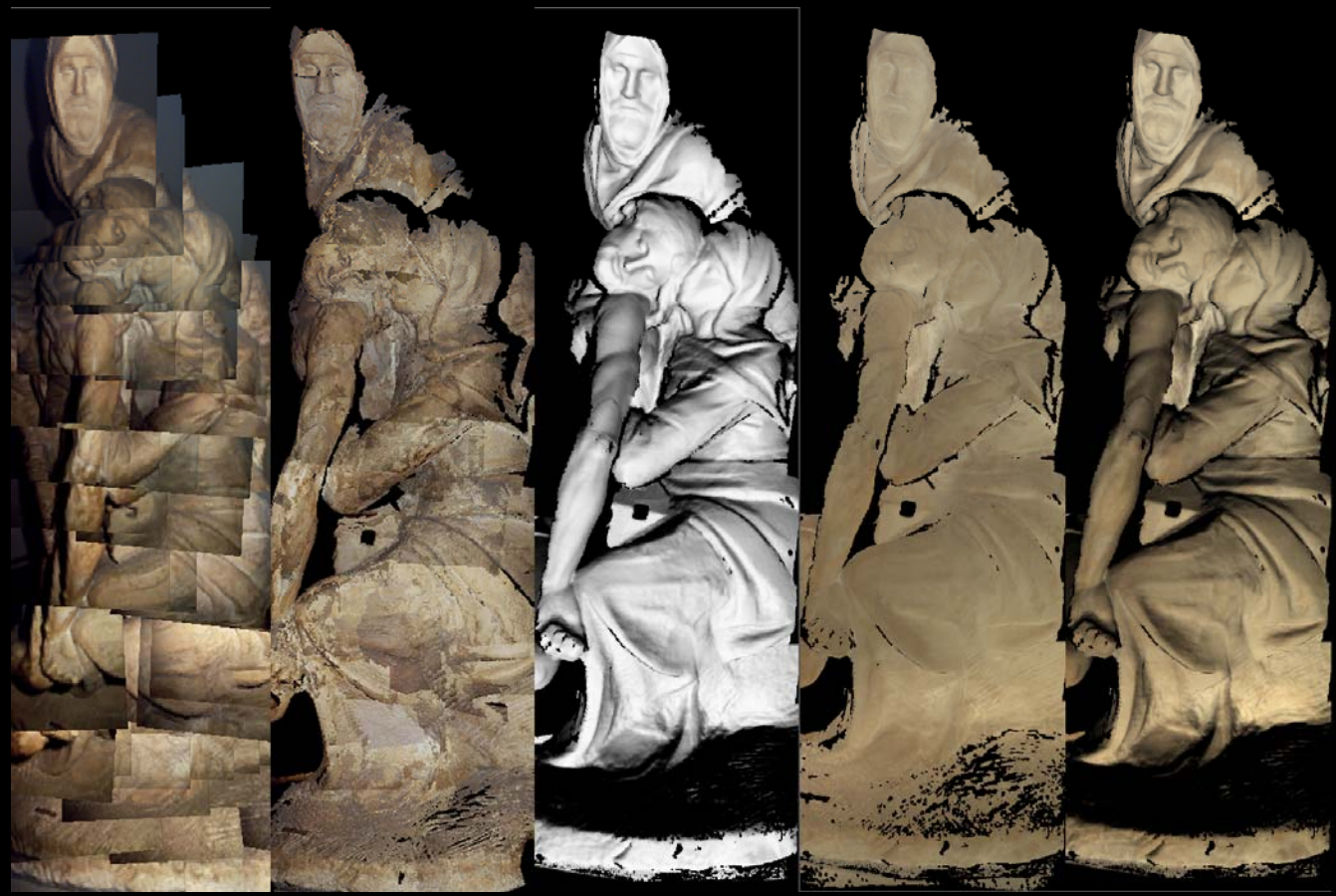
The IBM Pieta Project: A Historical Perspective

Gabriel Taubin
Brown University



IBM Pietà 3D Scanning Project : 1998-2000

Shape

Appearance

http://www.research.ibm.com/pieta

1995-2000

- Mandate
  - Develop technologies to efficiently represent, capture, edit, compress, transmit, and visualize 3D models

- Main projects
  - 3D Scanning → Pieta project
  - 3D Geometry Compression → MPEG-4 3D Mesh Coding
  - Web-centered 3D → IBM HotMedia 3.0+
  - Pervasive 3D → PalmOS / WinCE
  - Mesh Signal Processing → Academic

IBM's Pietà Project Team

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Google

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The IBM Pietà Project

A Comprehensive Study

By Art Historian Jack Wasserman

Created by Michelangelo late in his life
1550

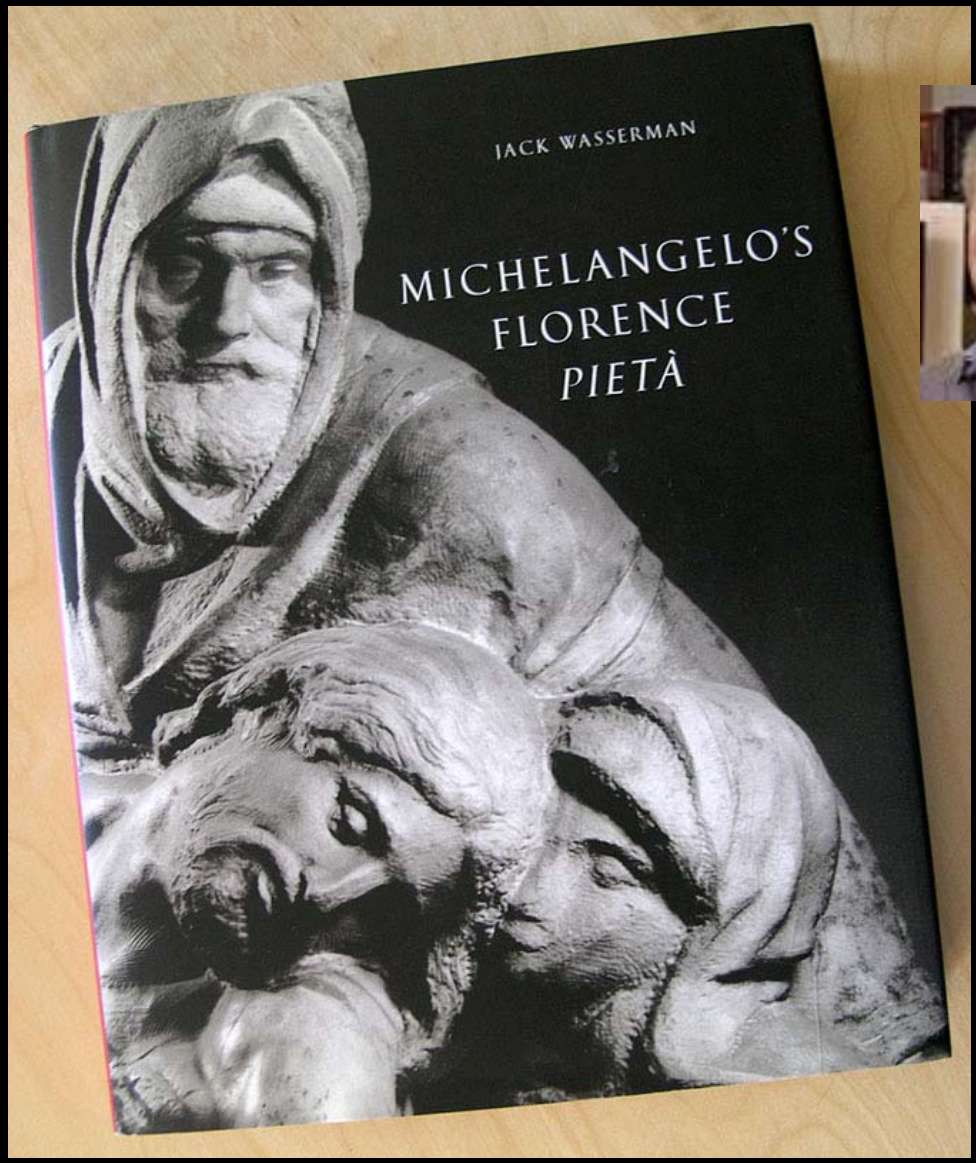
Michelangelo broke off pieces, repaired by Calcagni 1555-56

Placed outside, in a a basement.
1562-1721

Placed in the Duomo,
1721-1980

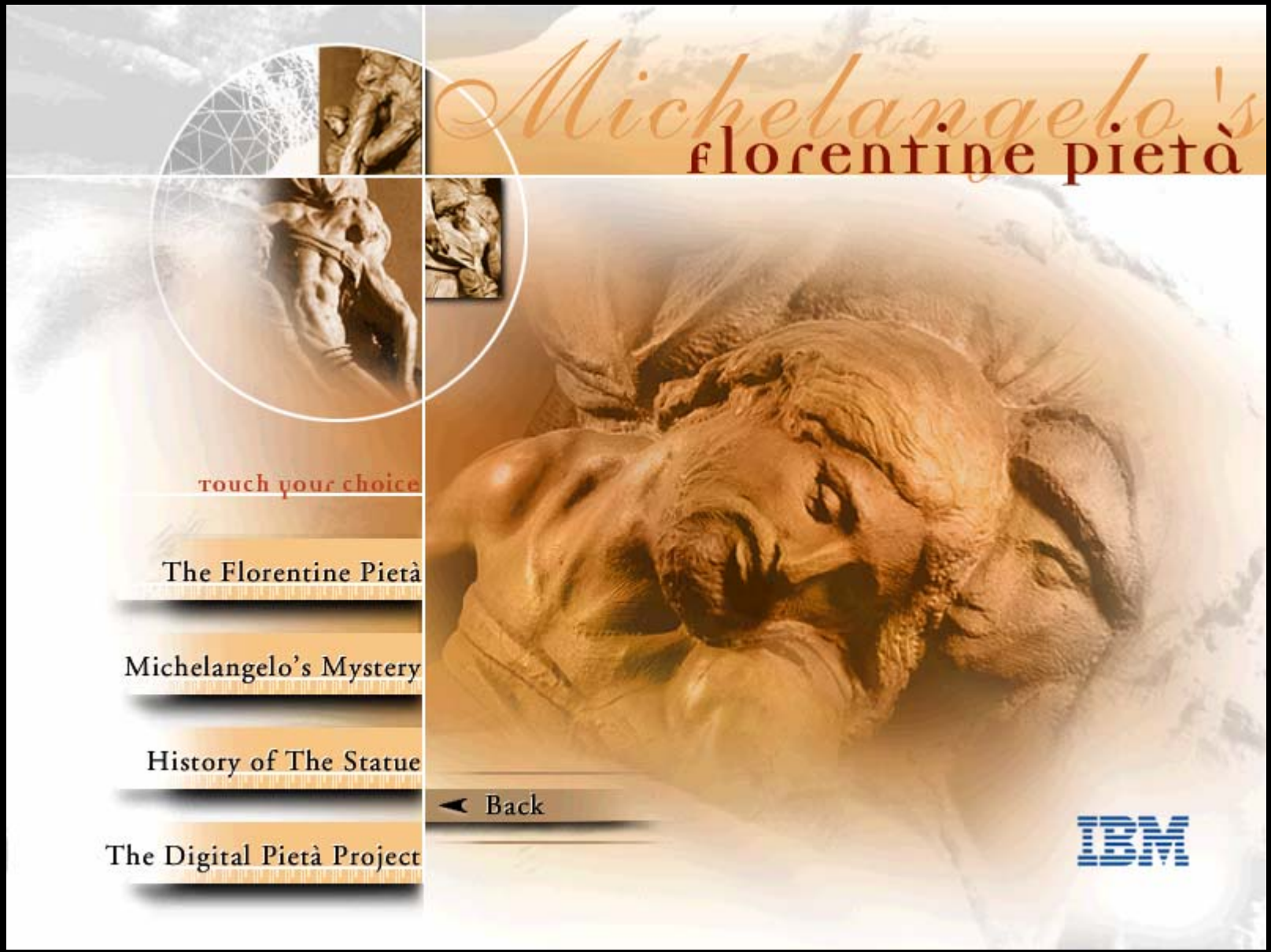
Now in the Museum of the Duomo
Florence, Italy
1980-present

Wasserman's Pietà Book



Princeton University Press 2003

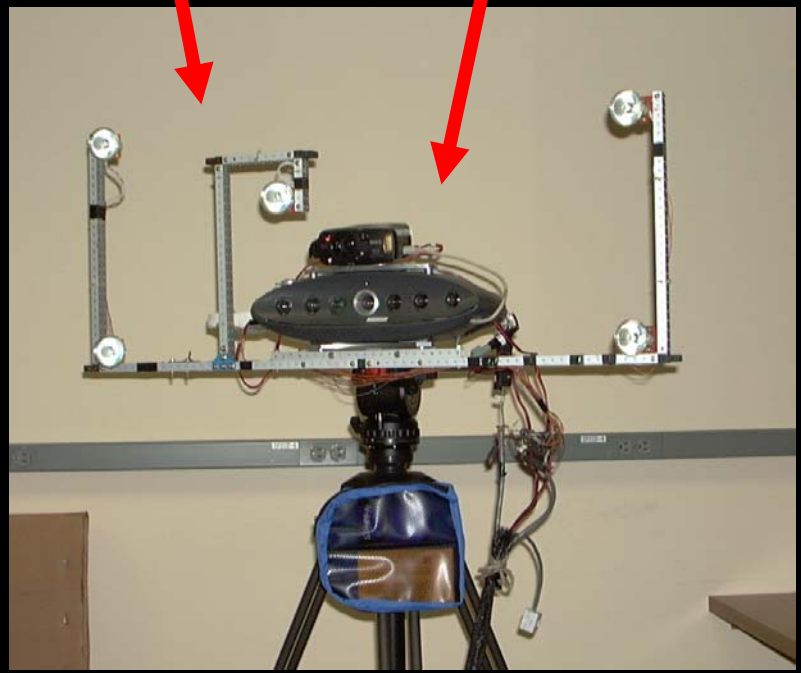
Pieta Kiosk

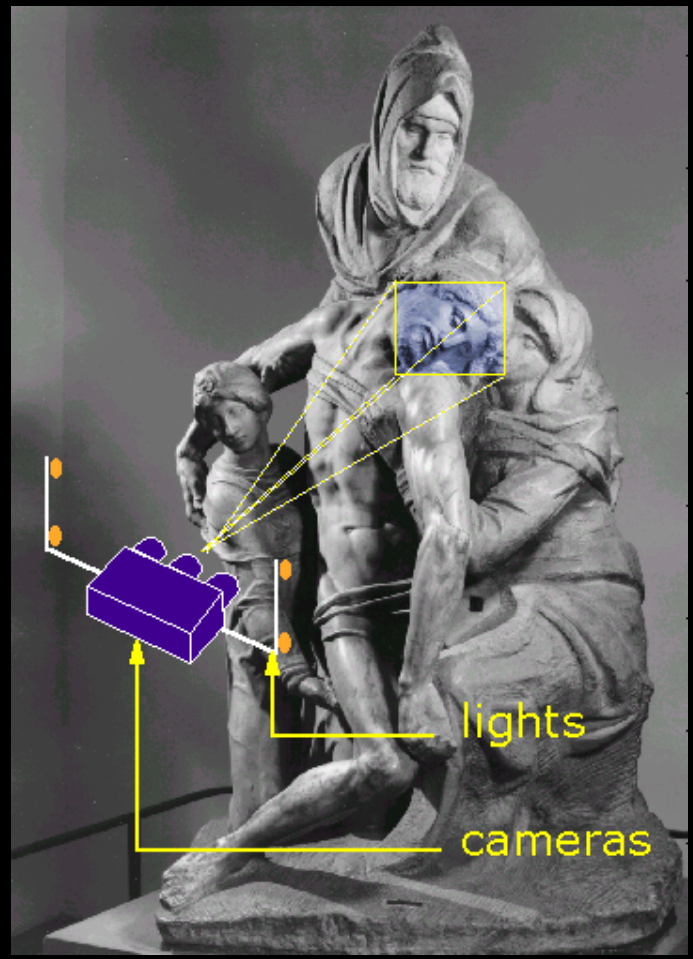

Michelangelo's
florentine pietà
touch your choice
The Florentine Pietà
Michelangelo's Mystery
History of The Statue
The Digital Pietà Project
Back
IBM

Data Capture: Range + multi-texture

5 point light sources

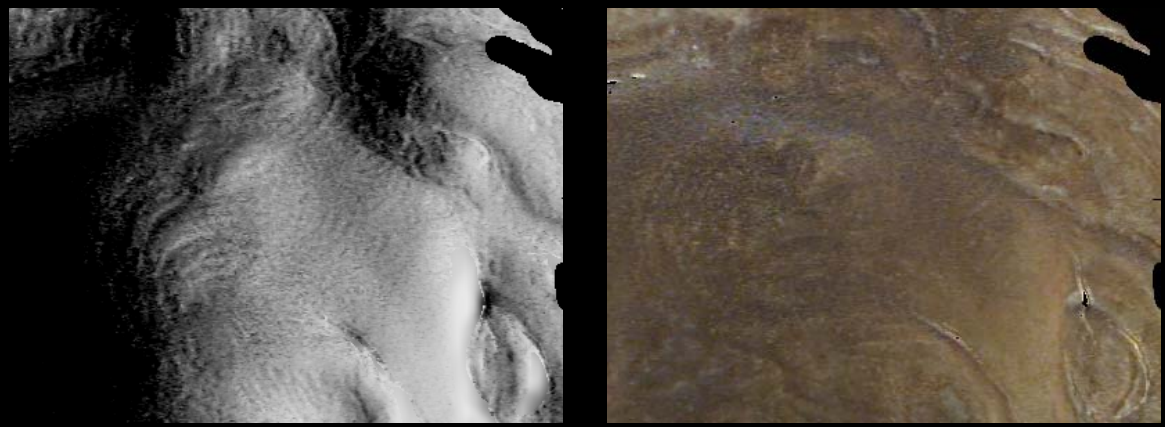
“Virtuoso” Multi-baseline
Stereo camera





Photometric capture Our Addition

- Same viewpoint, different lighting
- Resolution of .5mm with Virtuoso built-in camera
- Compute reflectance and normals per pixel

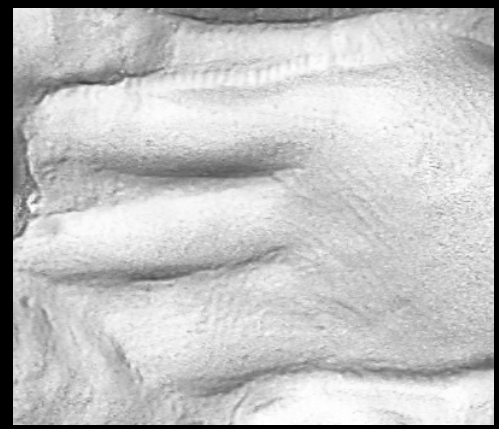


Capturing ~800 scans (1998)

Design Considerations: Length Scales

Examine on the scale of Meters to study proportion, design

Examine on the scale of millimeters to study Tool marks



Controlled Views

How was sculpture supposed to be view?

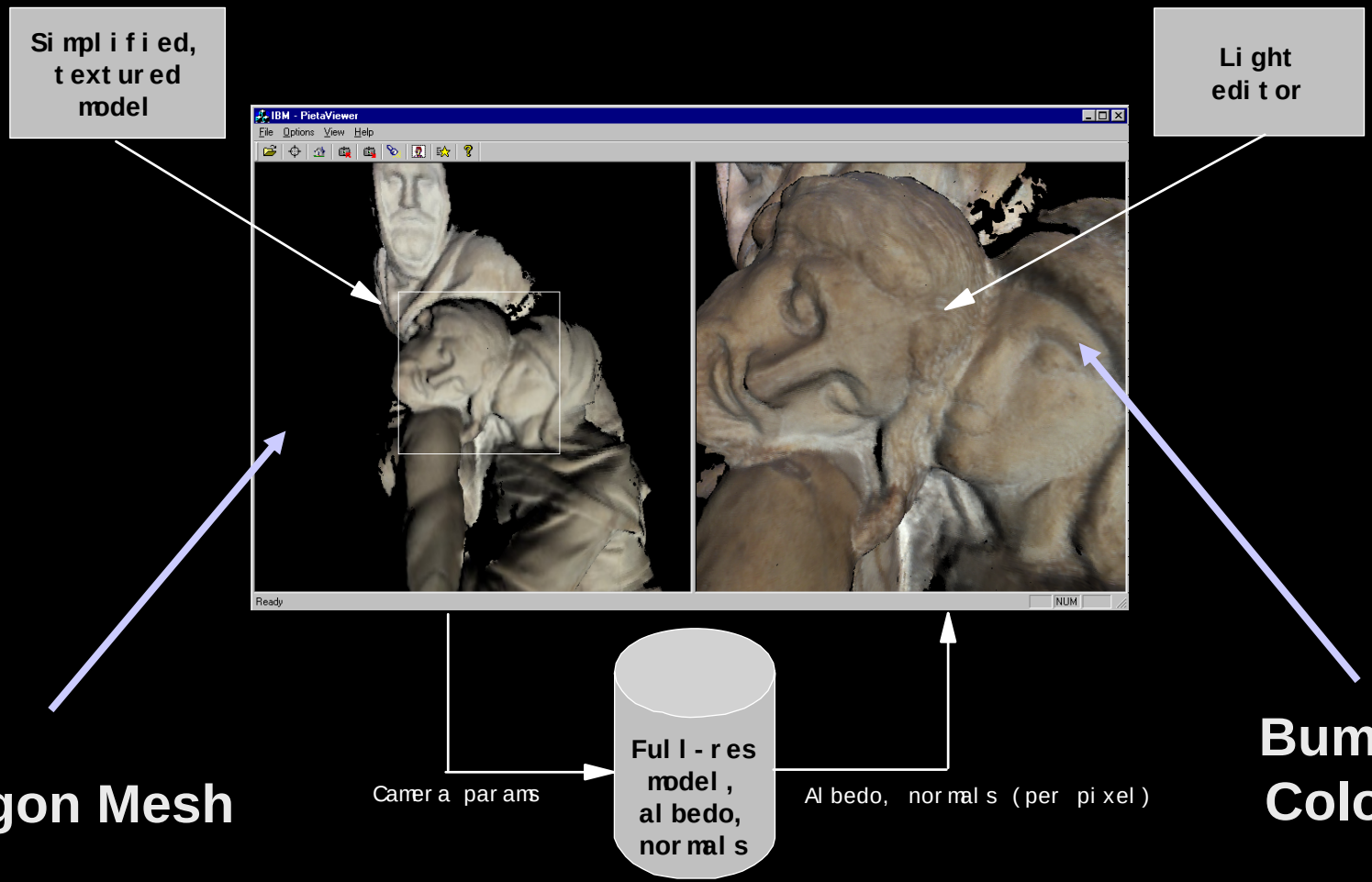
Orthographic and Impossible Views

How was sculpture constructed?

Other Environments

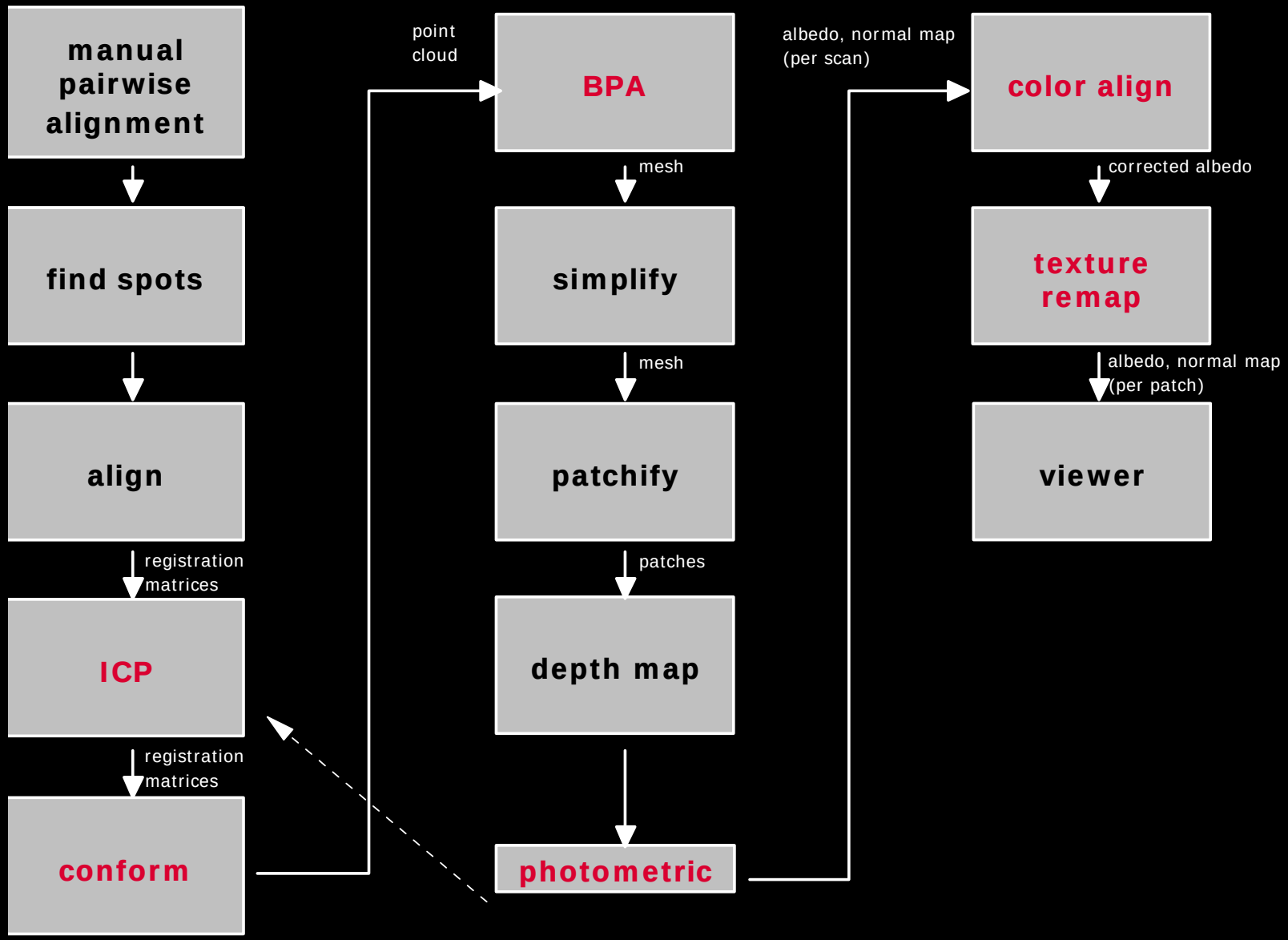
Changed Geometry

Representation for Interactive Viewing



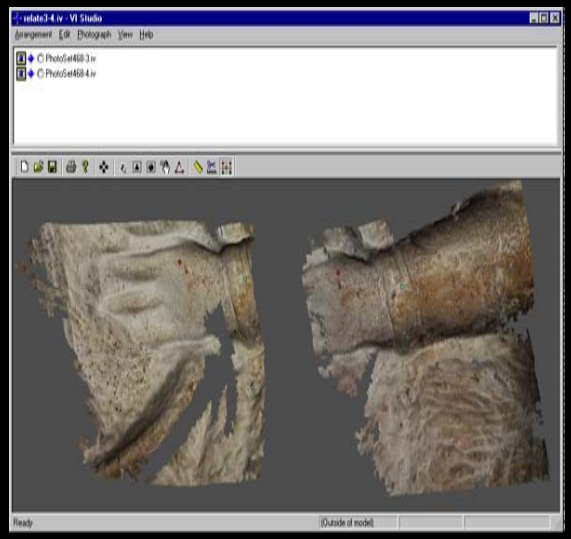
Reconstruction Pipeline

Pieta` Project

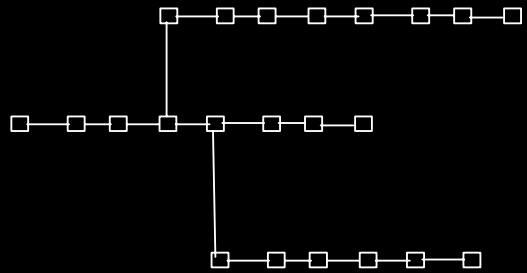


Pieta` Project

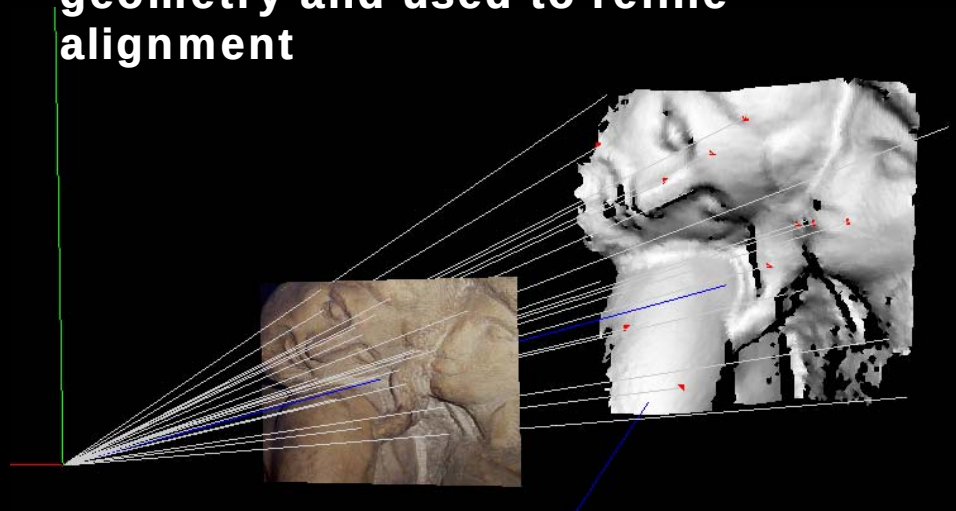
Pairwise alignment in VI Studio



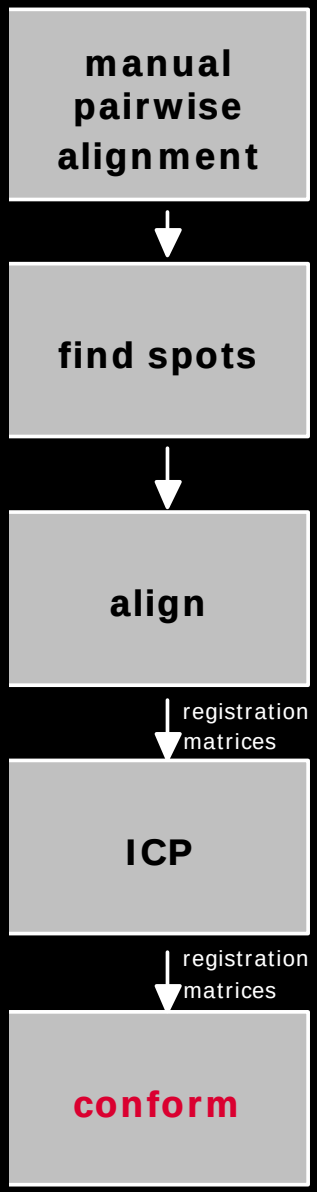
Pairs of matrices form tree of mesh relationships

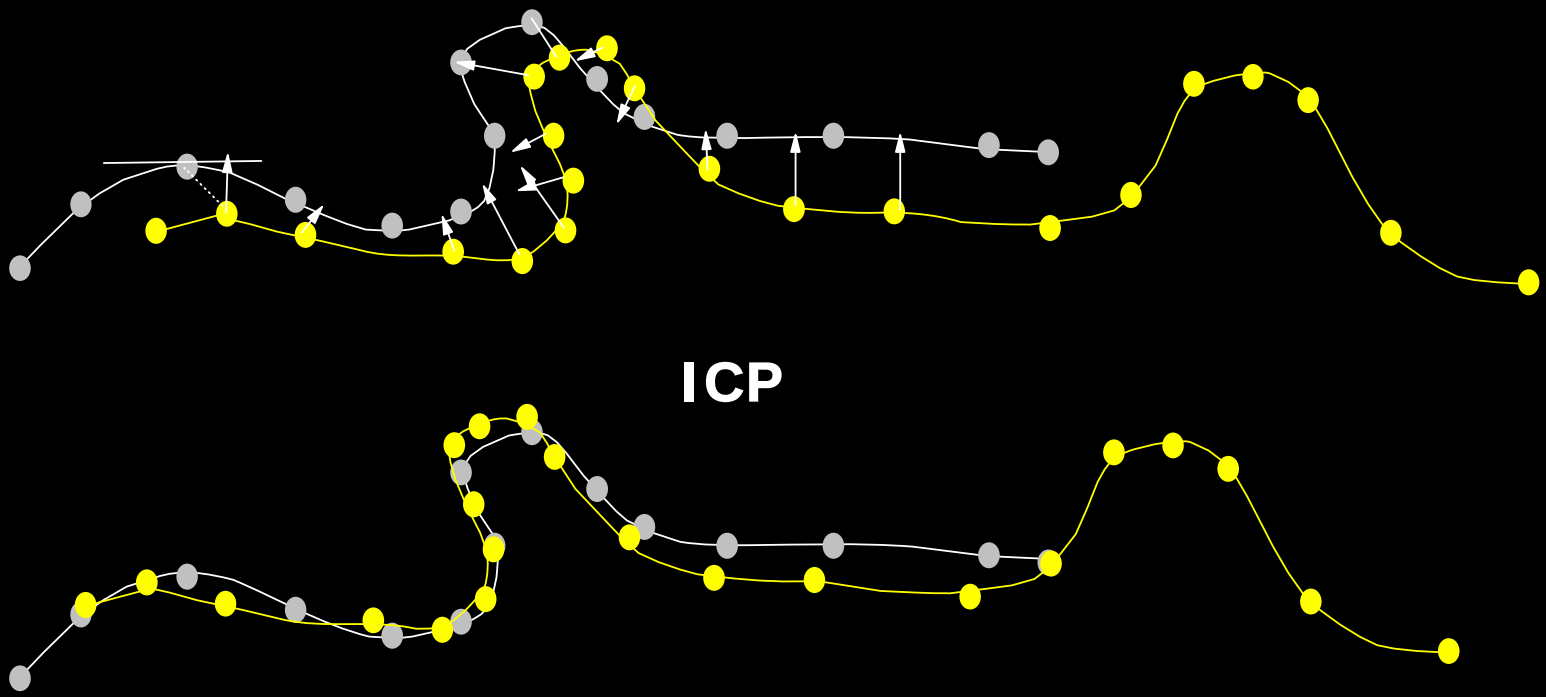


Laser dots are mapped onto geometry and used to refine alignment



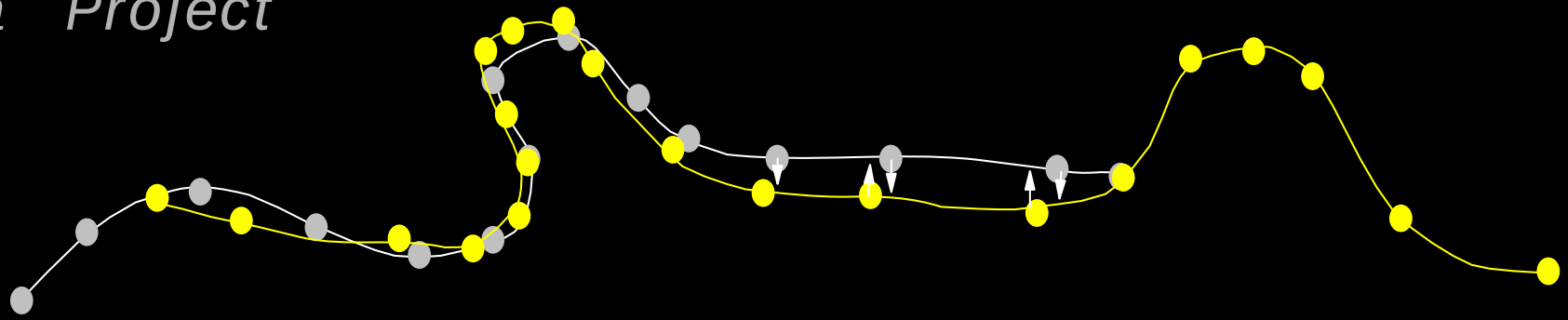
Pieta` Project



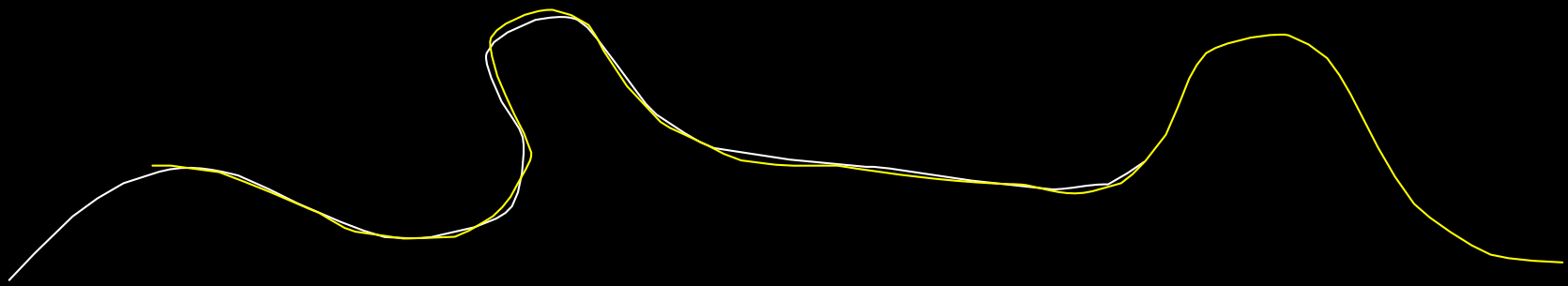


Iterate

- **Find matching pairs**
- **Determine displacement vectors**
- **Solve LS system for optimal T and Q**



Conformance

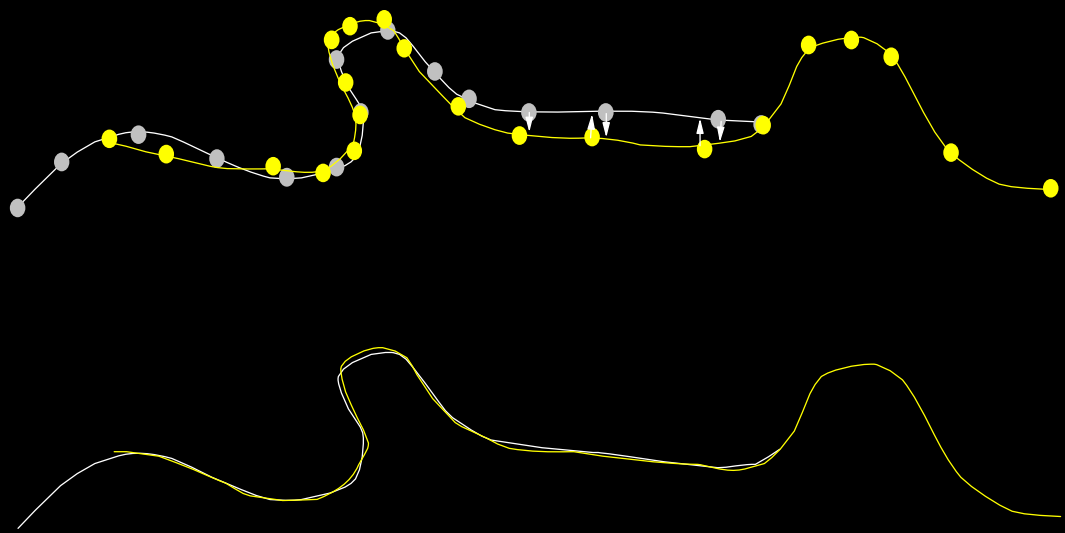


Iterate

- **Find matching pairs**
- **Determine displacement vectors**
- **Smooth and apply**

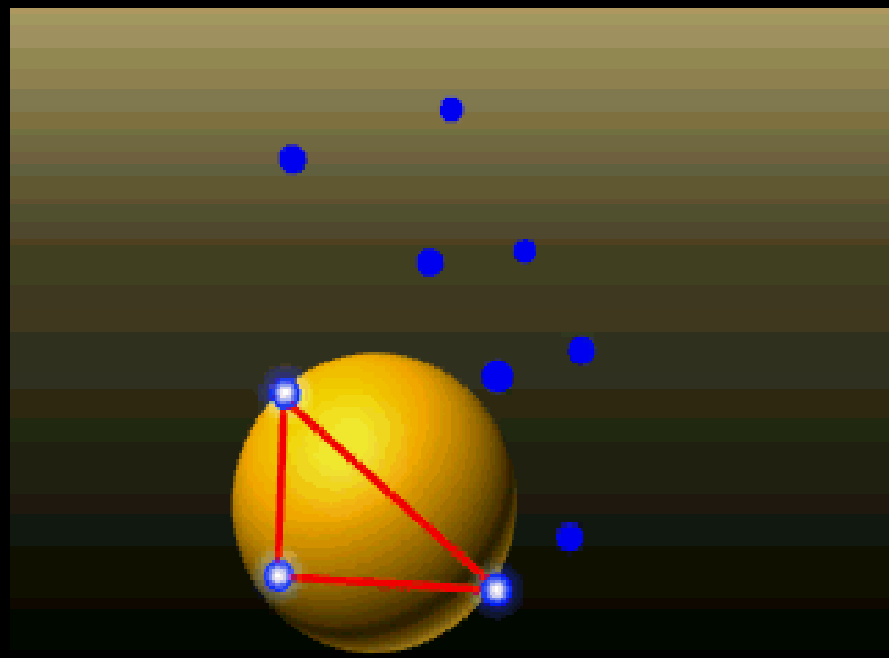
After conformance, integrate meshes

Line of sight error corrected:
We want a mesh that interpolates points
(rather than volume extraction from signed
Distance function)



Ball Pivoting

- **A ball "walks" over the point cloud, creating a triangle for every three points it touches**



Pieta` Project

Fast surface reconstruction from scans

- Interpolating triangle mesh
- Linear-time algorithm
- Robust
- Easy to implement

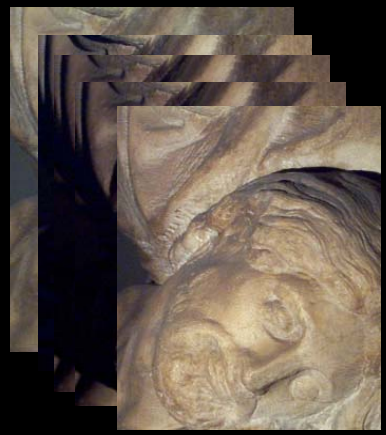
Results

- Real data: Pieta', Stanford repository
- Generates 1M triangle mesh in 3 minutes on a PC
- Out-of-core implementation, Pieta' (13M tris) is meshed in 40 mins on a Pentium II PC with 256MB of RAM

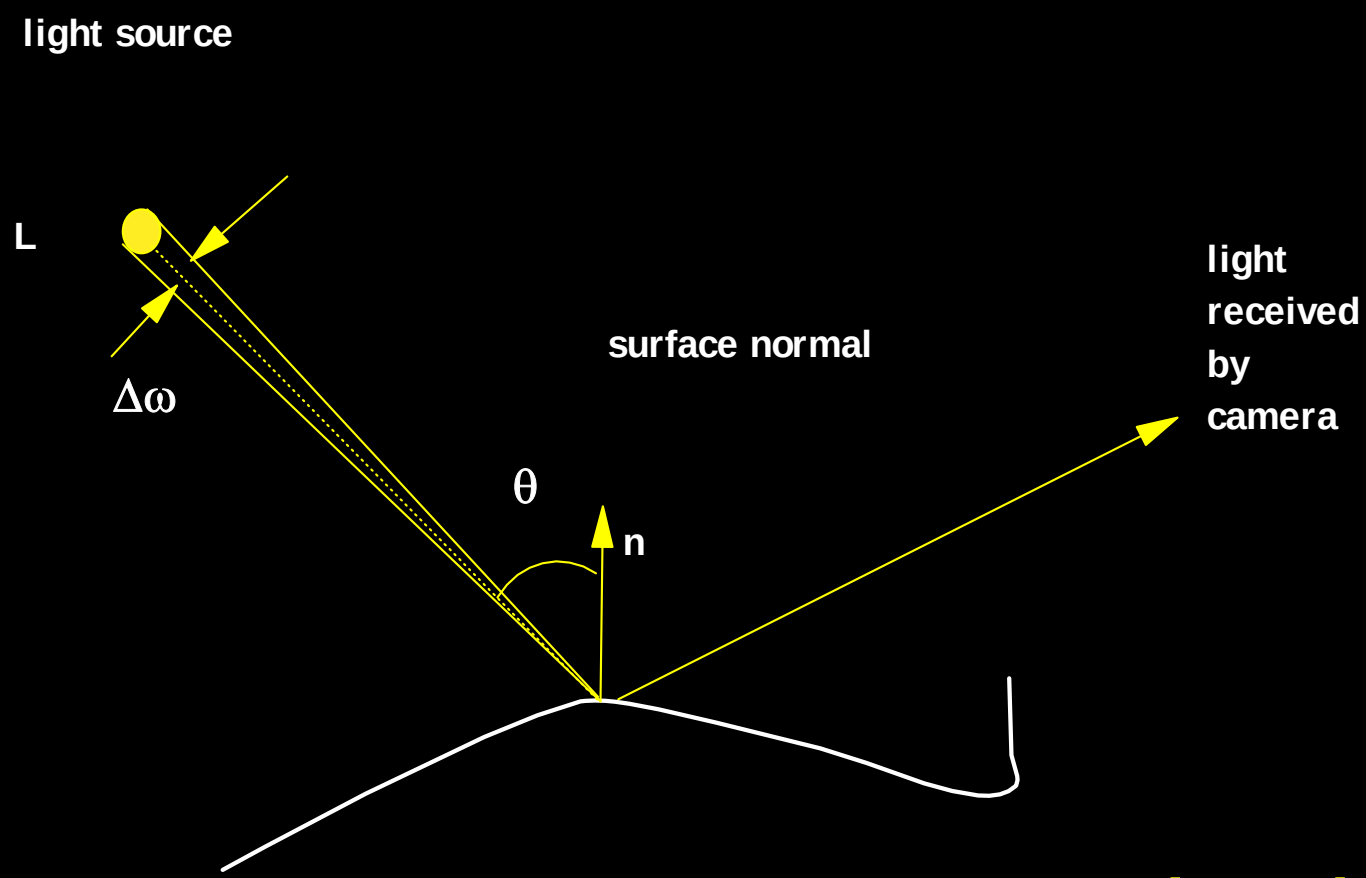
Pieta` Project

Photometric Processing

- Computing colors and normals consistent with underlying geometry and each other



color images for
five light positions



$$L_r = \rho L \cos\theta \Delta\omega / \pi$$

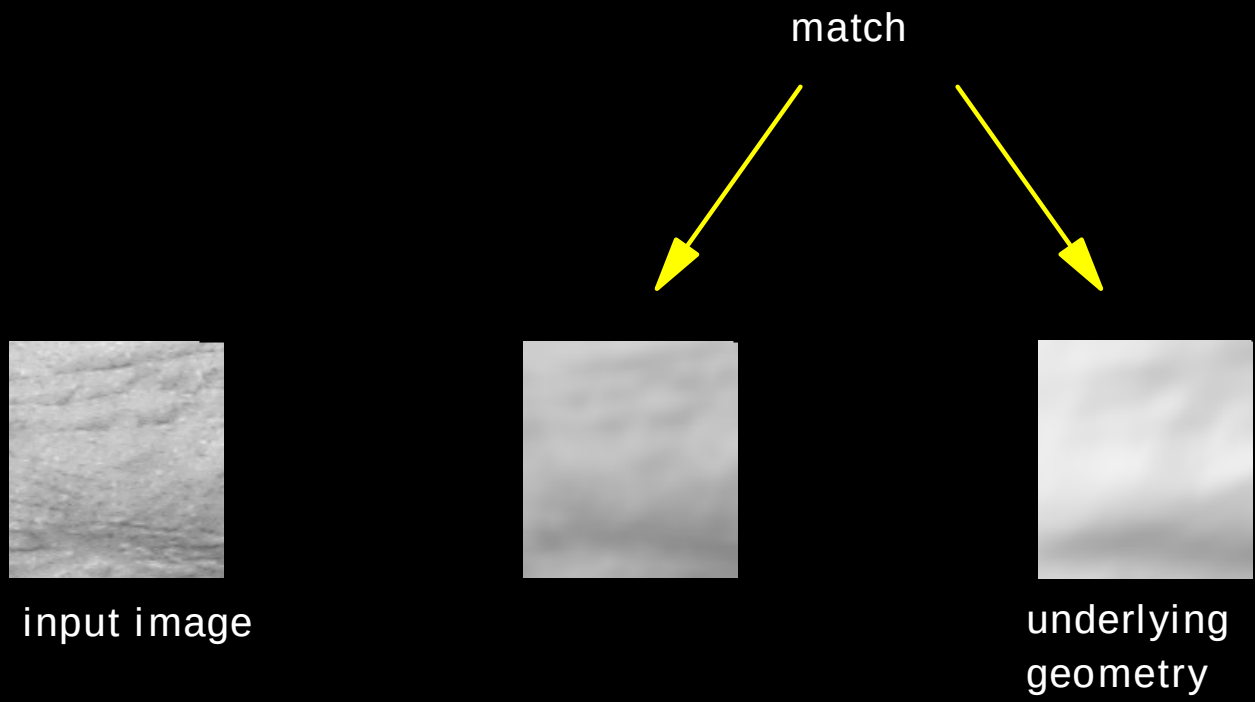
Problems with Photometric Data

- Lights not identical
- Lights not isotropic
- Temporal variations
- Varying electrical power level
- Short distances
- Non-Lambertian Surfaces

Photometric normals won’t be consistent with each other or underlying surface – seams between normals maps will be visible

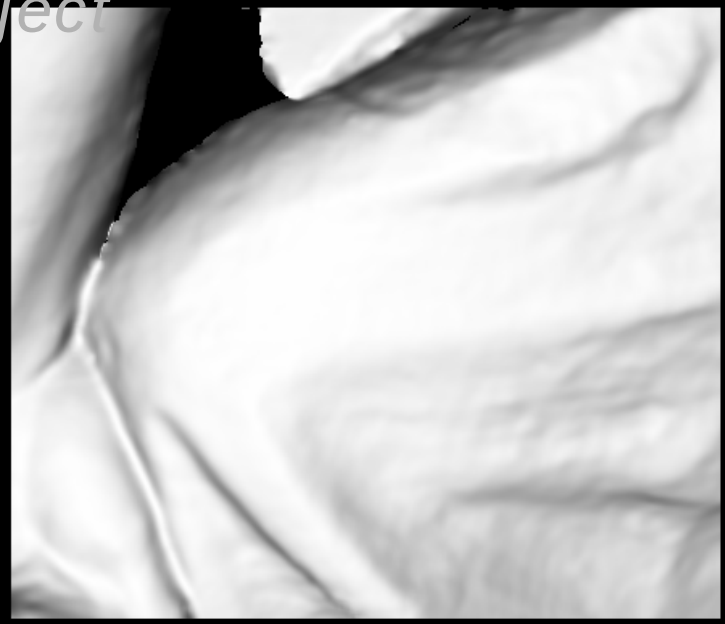
Approach

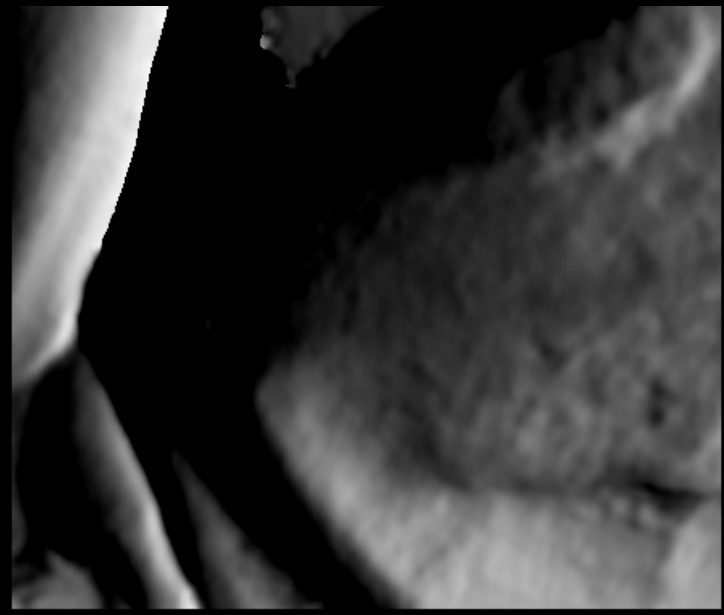
- Use underlying geometry to adjust relative light levels in images



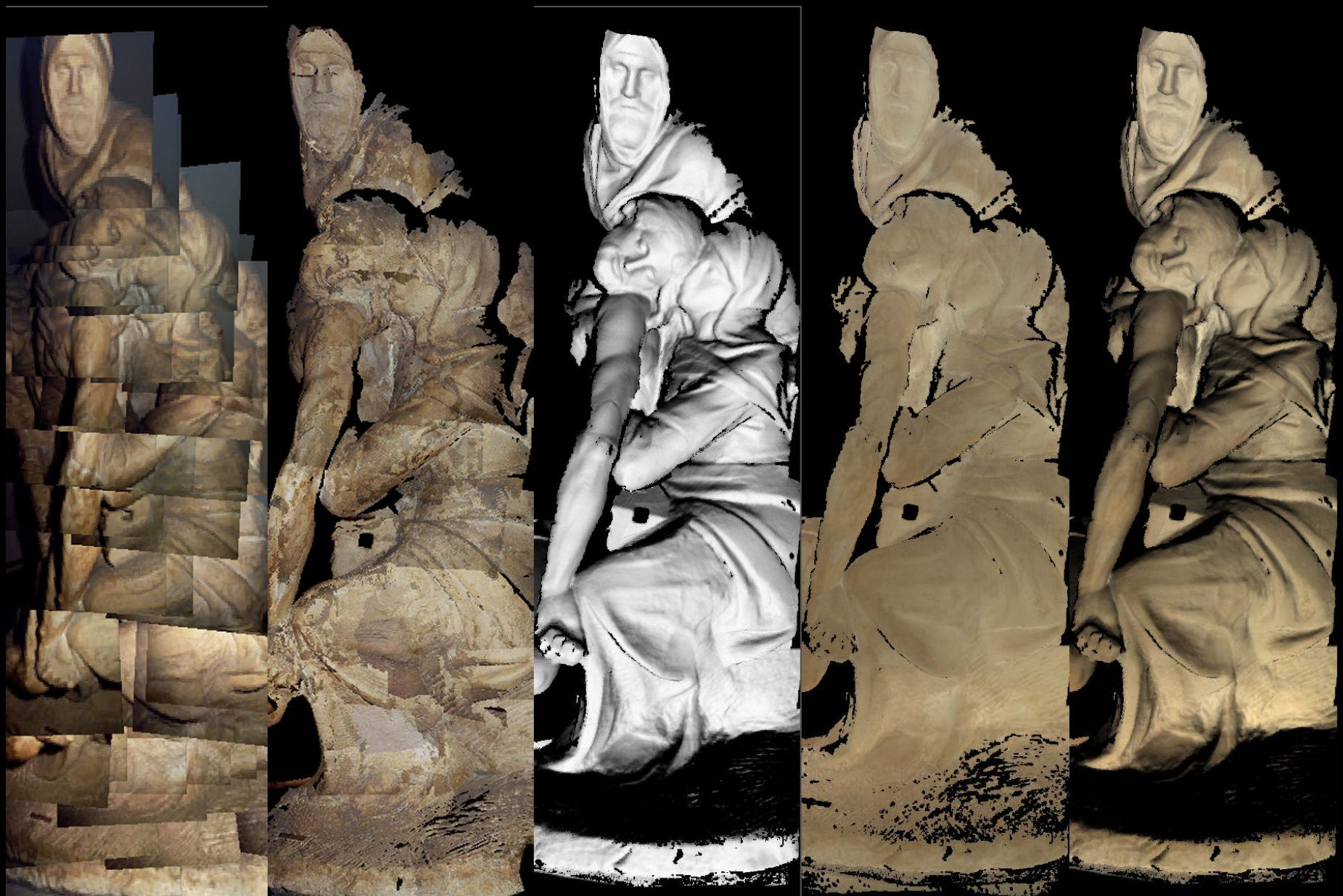
Essentially only use images to compute perturbations in normals of underlying mesh.

Pieta` Project

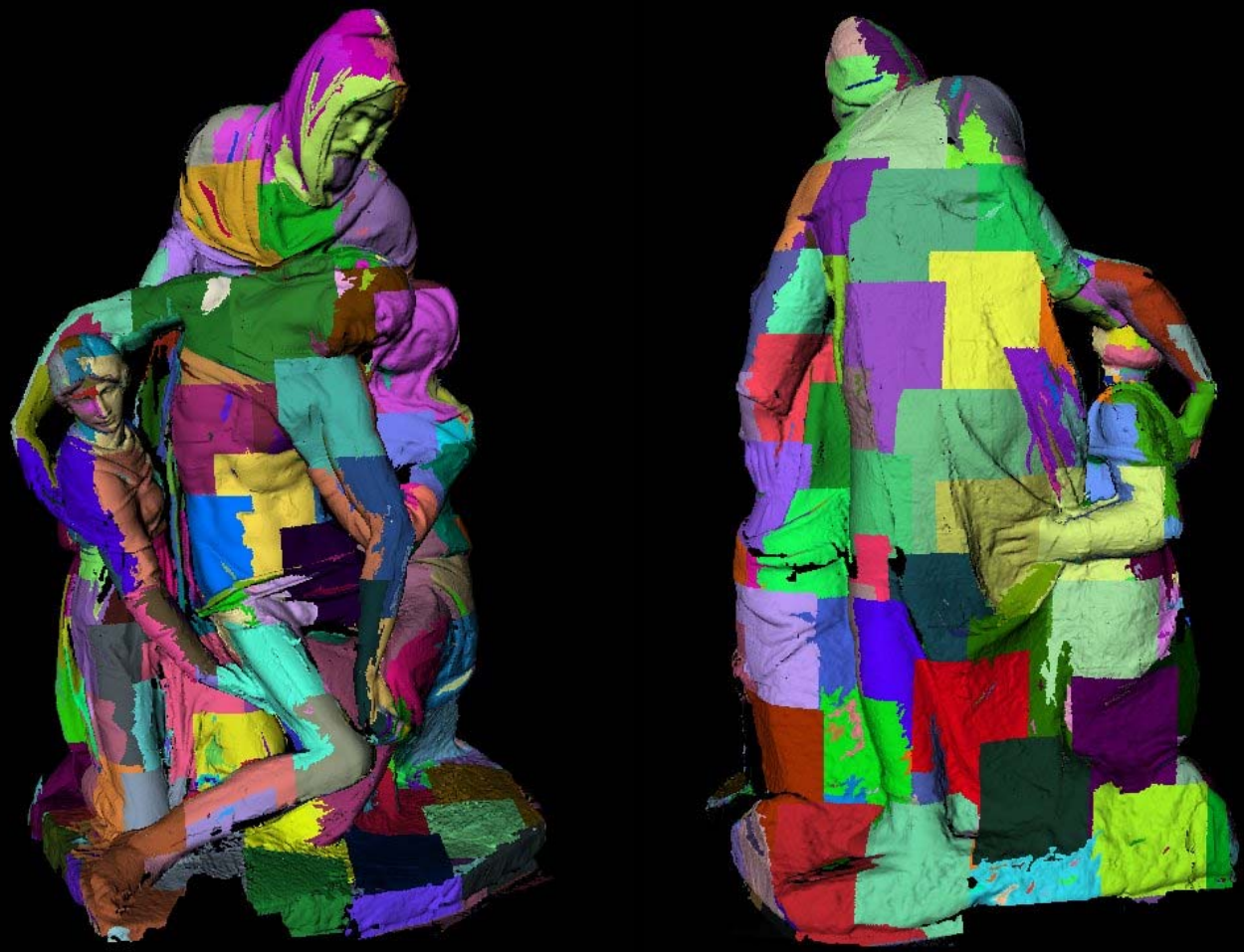




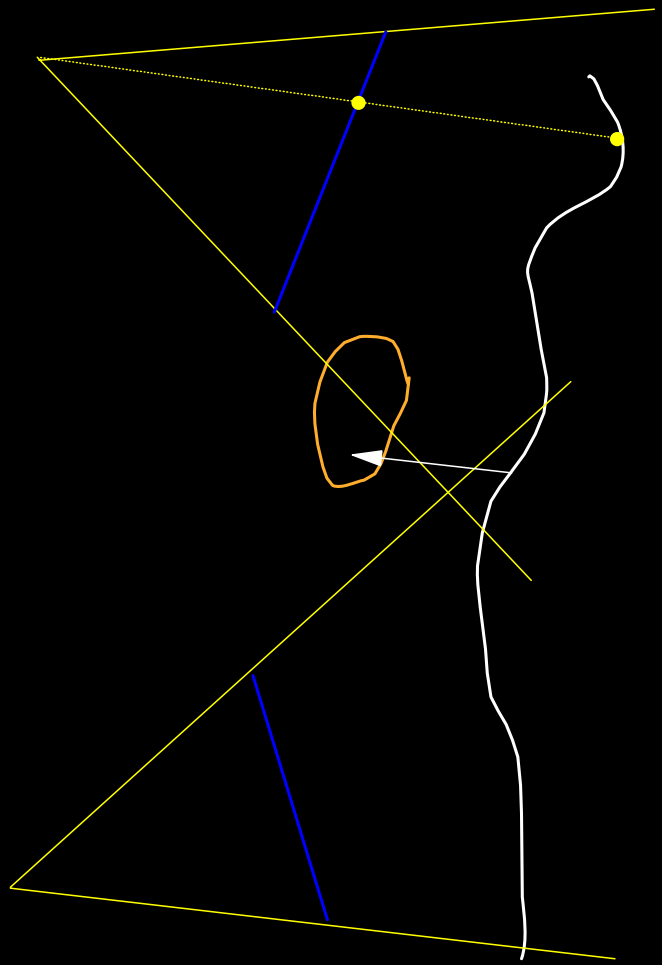
Pieta` Project



Remapping Unique Texture

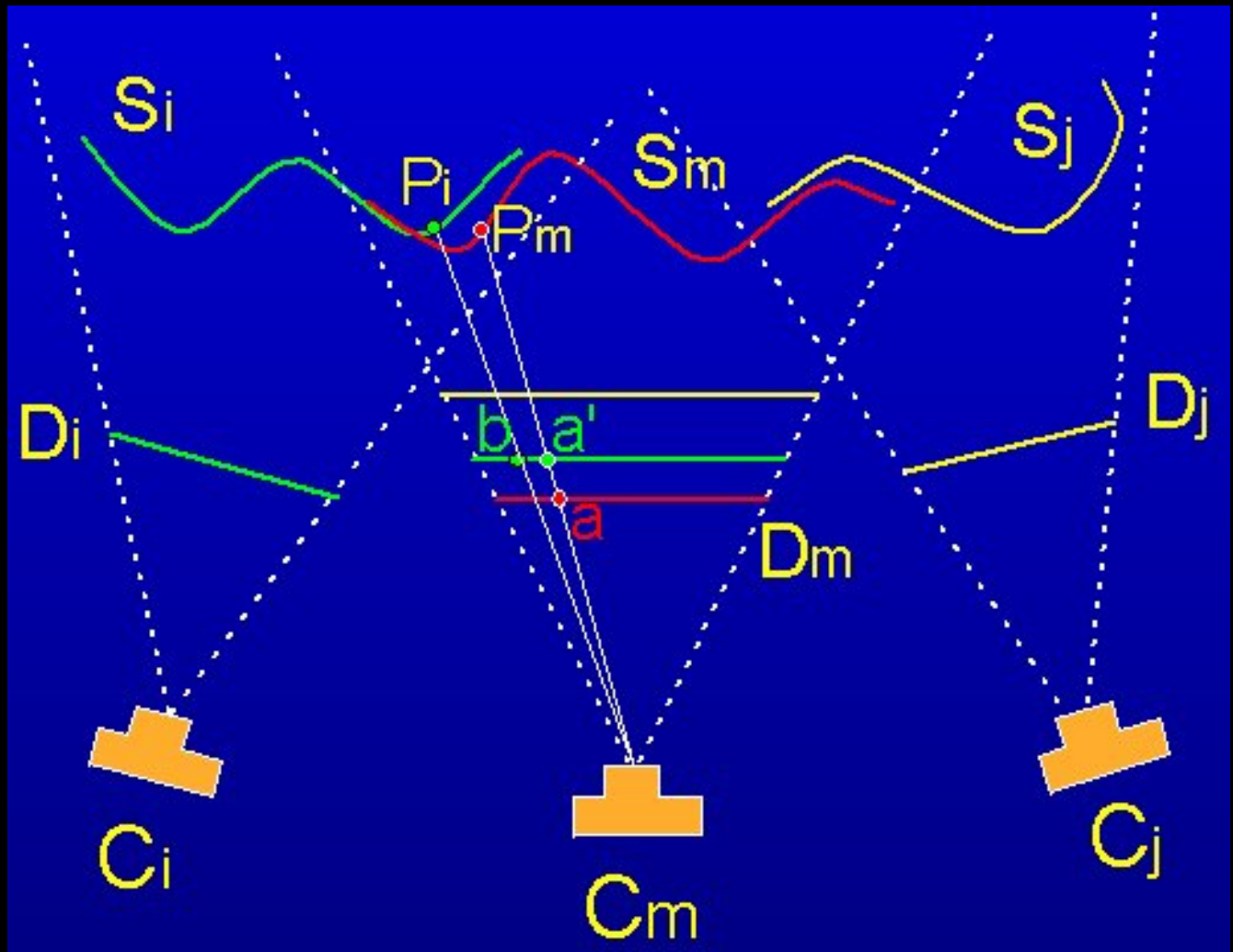


Blend textures with weights based on data reliability

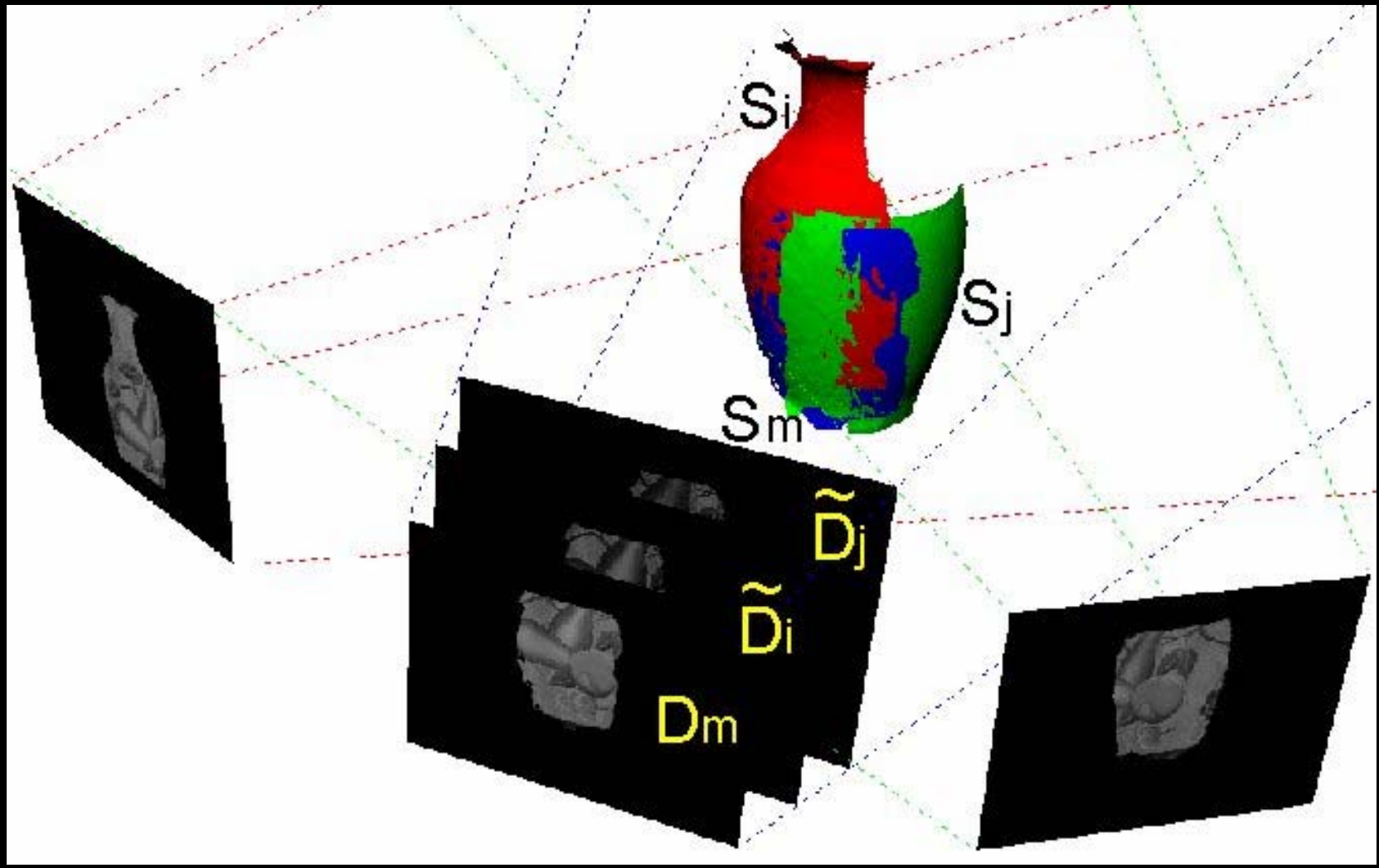


```
for each patch
  for each camera pos
    compute tex coords
    init z-buffer with depth map
    render weights
    for tex in {alb, np, nm}
      render textured patch
      acctex += rendered*weight
      accwgt += weight
    end
  end
  normalize
  save the three images
end
```

Improving Registration:
Using Textures to Refine Alignment



Pieta` Project



Pieta` Project

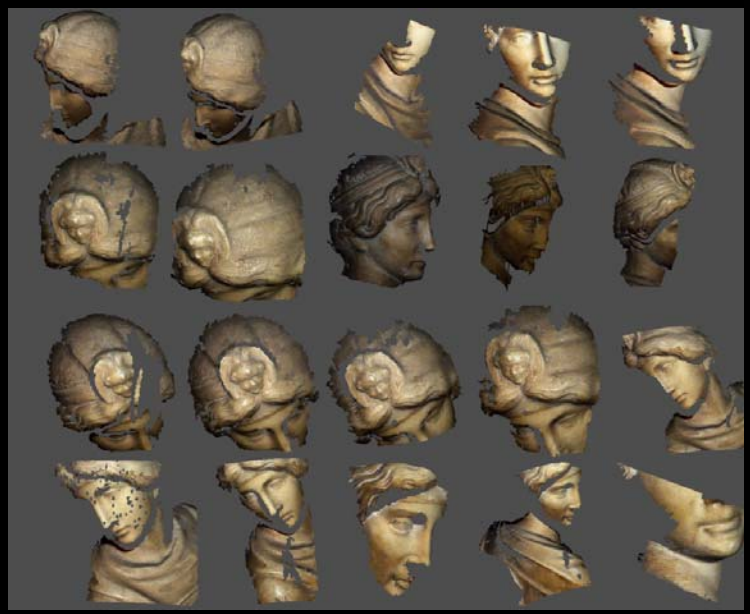
Captured

Single photometri

Geometric registration

Texture registrat ion

Pieta` Project



What did we learn?

Photometric stereo enhanced resolution for low $

Hardest problem: registration

Better points, easier registration: better to have less data than questionable data.

Calibrate to minimize the questionable data.

Use all the types of data you can get reliably: normals, colors

Egyptian Culture Project: 2001-2004

Development of www.eternalegypt.org

Communicating the culture of Egypt using multimedia technology

CultNat

IBM

Egyptian Culture Project

www.research.ibm.com/pieta

www.eternalegypt.org