The IBM Pieta Project: A Historical Perspective

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IBM Pietà 3D Scanning Project: 1998-2000

http://www.research.ibm.com/pieta
• 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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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 basement.
1562-1721

Placed in the Duomo,
1721-1980

Now in the Museum of the Duomo
Florence, Italy
1980-present
Wasserman’s Pietà Book
Pieta Kiosk

Michelangelo's Florentine Pieta

Touch your choice:

- The Florentine Pietà
- Michelangelo’s Mystery
- History of The Statue
- The Digital Pietà Project

← Back
Data Capture: Range + multi-texture

5 point light sources

“Virtuoso” Multi-baseline Stereo camera
Photometric capture

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

Our Addition
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 viewed?
Orthographic and Impossible Views

How was sculpture constructed?
Pieta Project

Other Environments
Pieta ` Project

Changed Geometry
Representation for Interactive Viewing

Simplified, textured model

Camera parameters

Full res model, albedo, normals

Light editor

Polygon Mesh

Albedo, normals (per pixel)

Bump map

Color map
Reconstruction Pipeline
Pieta ` Project

- manual pairwise alignment
- find spots
- align
- ICP
- conform
- BPA
- simplify
- patchify
- depth map
- photometric
- color align
- texture remap
- viewer

point cloud
albedo, normal map (per scan)
corrected albedo
albedo, normal map (per patch)
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

- manual pairwise alignment
- find spots
- align
- ICP
- conform

align

icp

conform
Pieta Project

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

ICP
Pieta `Project

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
Photometric Processing

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

- Color images for five light positions
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Light source

$\Delta \omega$

Surface normal

$\theta$

$n$

Light received by camera

$L_r = \frac{\rho L \cos \theta \Delta \omega}{\pi}$
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
Pieta Project

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
Pieta Project

Remapping Unique Texture
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

Blend textures with weights based on data reliability

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Pieta `Project

Improving Registration:
Using Textures to Refine Alignment
Pieta Project
Pieta Project

Captured

Single photometric

Geometric registration

Texture registration
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
Egyptian Culture Project
www.research.ibm.com/pieta

www.eternalegypt.org