

The Digital Michelangelo Project

Marc Levoy



Computer Science Department
Stanford University

Executive overview

*Create a 3D computer archive of the
principal statues and architecture
of Michelangelo*

Scholarly motivations

- pushes technology
- scientific tool
- cultural experiment
- lasting archive

Commercial motivations

- virtual museums
- art reproduction
- 3D stock photography
- 2nd generation multimedia

Outline of talk

- hardware and software
- scanning the David
- acquiring a big light field
- implications of 3D scanning
- lessons learned from the project
- the problem of the Forma Urbis Romae

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Scanners used in the Digital Michelangelo Project



1. Cyberware

- main 3D scanner for statues
- planar light field scanner



2. Faro + 3D Scanners

- for tight spots
- handheld light field scanner?



3. Cyra

- for architecture
- low-res models for view planning?

- All scanners acquire range and color

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Laser triangulation scanner customized for large statues

4 motorized axes



truss extensions
for tall statues

laser, range camera,
white light, and color camera

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Scanning St. Matthew



working in
the museum



scanning
geometry



scanning
color

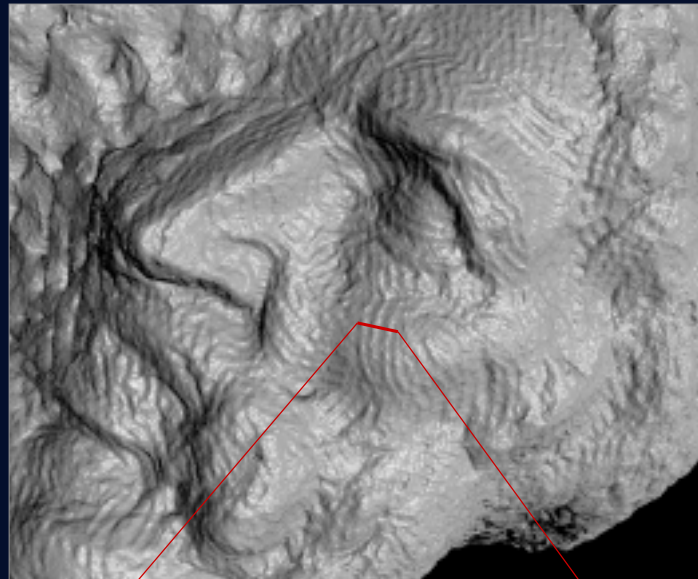
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Our scan of St. Matthew



- 104 scans
- 800 million polygons
- 4,000 color images
- 15 gigabytes
- 1 week of scanning

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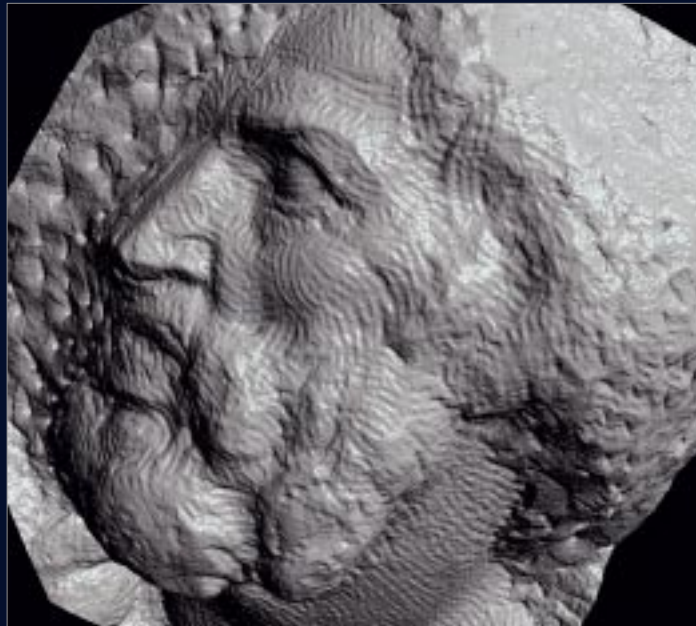


1 mm

Post-processing pipeline

- range data
 - align scans from different gantry positions
 - combine using a volumetric algorithm
 - fill holes using space carving
- color data
 - compensate for ambient lighting
 - discard shadows or reflections
 - factor out surface orientation

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Artificial surface reflectance



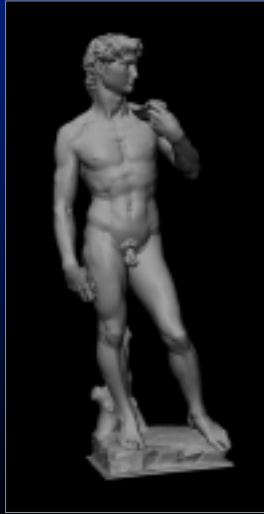
Estimated diffuse reflectance

Scanning the David



maximum height of gantry: 7.5 meters
weight including subbase: 800 kilograms

Statistics about the scan



- 480 individually aimed scans
- 2 billion polygons
- 7,000 color images
- 32 gigabytes
- 30 nights of scanning
- 1,080 man-hours
- 22 people

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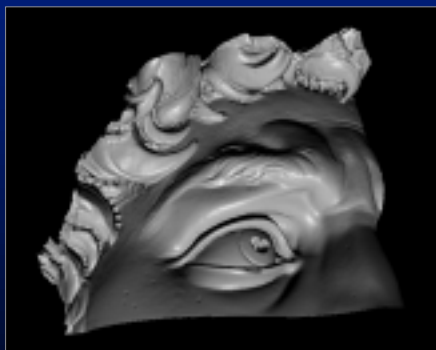
Head of Michelangelo's David



- 2 mm model
- 1 million polygons

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David's hairline and right eye

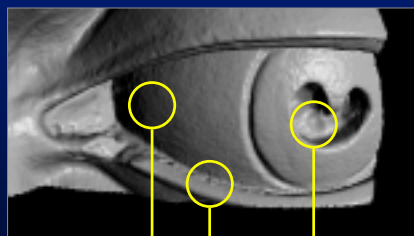


- 1mm model
- 500,000 polygons

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David's left eye

- 0.25mm model
- space carving to fill holes



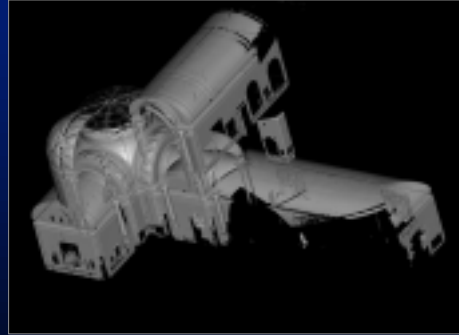
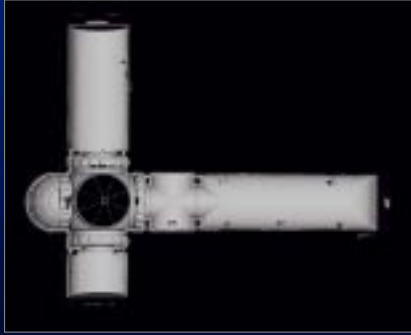
holes from Michelangelo's drill

artifacts from space carving

noise from laser scatter

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Model of Galleria dell'Accademia



- 4mm model
- 15 million polygons
- Cyra time-of-flight scanner

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Computer representations of architectural objects

- unstructured mesh
- line drawings
- structured 3D model

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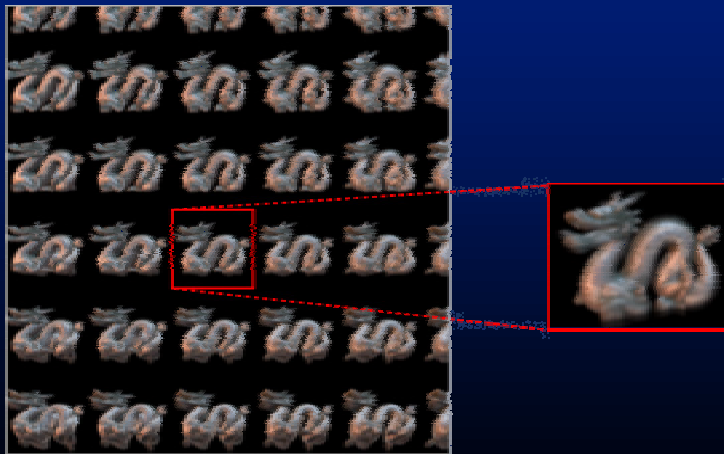
Light field rendering

- a form of image-based rendering (IBR)
- make new views by rebinning old views
- Advantages
 - doesn't need a 3D model
 - less computation than rendering a model
 - rendering cost independent of scene complexity
- Disadvantages
 - fixed lighting
 - static scene geometry
 - must stay outside convex hull of object



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A light field is an array of images



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Our planned light field of the Medici Chapel



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What got in the way of this plan



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Acquiring a light field of Michelangelo's statue of Night



the light field consists of 7 slabs,
each 70cm x 70cm

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each slab contains 56 x 56
images spaced 12.5mm apart



the camera is always aimed
at the center of the statue

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Sample image from center slab

Statistics about the light field

- 1300 x 1000 pixels per image
- $56 \times 56 \times 7 = 21,952$ images
- 16 gigabytes (using 6:1 JPEG)
- 35 hours of shooting (over 4 nights)
- also acquired a 0.25mm 3D model of statue



Implications of 3D scanning on the viewing of art

- type of reproduction
 - scripted computer graphics
 - interactive computer graphics
 - physical copy
- pros and cons
 - + flexible viewing
 - + increased accessibility
 - increased ubiquity
 - separation from context

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Flexible viewpoint



classic 3/4 view



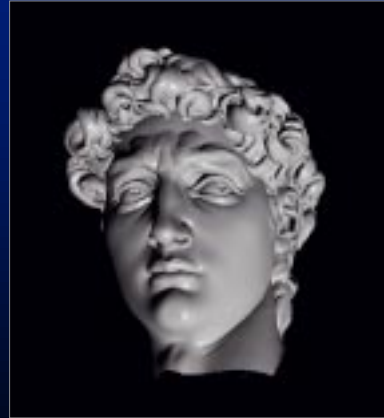
left profile

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Flexible lighting



lit from above



lit from below

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Flexible shading



natural coloring



accessibility shading

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natural coloring



accessibility shading

Implications of 3D scanning for art historians

- restoration record
- permanent archive
- diagnostic maps
- geometric calculations
- projection of images onto statues

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Diagnostic imaging of David



under white light



under ultraviolet light

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Implications of 3D scanning for educators and museums

- virtual exhibitions
- augmented exhibitions
- enhanced documentaries
- interactive multimedia
- physical replicas

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Letting the tourists play with our model of Dawn



They came...

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Letting the tourists play with our model of Dawn



They saw...

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Letting the tourists play with our model of Dawn



They played...

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What really happened?

- Kids immediately crowd around.
Some adults step right up; others need invitations.
- Kids but don't take turns very well.
Some adults don't either.
- A woman will try it only if a man is not nearby.
Same for girls and boys.
- Adults usually rotate the statue slowly.
Kids fly around wildly, but are surprisingly good at it.

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What really happened?

- It's amazing how much trouble people can get into.
Zooming too close is the worst offender.
- People enjoy changing the lighting
as much as they do rotating the statue.
- People are fascinated by the raw 3D points,
which they see when the model is in motion.
- People spend a lot of time looking back and forth
between the screen and the real statue.

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Michelangelo's Pieta

handmade replica

Logistical challenges

- size of the datasets
- access to the statues
- safety for the statues
- intellectual property rights

Lessons learned

- hardware and software
 - variable standoff distance
 - tracking of gantry, not manual alignment of scans
 - autocalibration, not stiff gantry
 - automatic view planning
- logistics
 - scan color quickly - things change
 - need a large team - scanning is tedious work
 - post-processing takes time and people
 - 50% of time on first 90%, 50% on next 9%, ignore last 1%

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Il Plastico: a model of ancient Rome



- made in the 1930's
- measures 60 feet on a side
- at the Museum of Roman Civilization

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the Roman census bureau

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The Forma Urbis Romae: a map of ancient Rome



- carved circa 200 A.D.
- 60 wide x 45 feet high
- marble, 4 inches thick
- showed the entire city at 1:240
- single most important document about ancient Roman topography

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Fragment #10g



© 1000 Marek Tarnowski

Fragment #10g



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Solving the jigsaw puzzle



- 1,163 fragments
 - 200 identified
 - 500 unidentified
 - 400 unincised
- 15% of map remains
 - but strongly clustered
- available clues
 - fragment shape (2D or 3D)
 - incised patterns
 - marble veining
 - matches to ruins

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Scanning the fragments



uncrating...

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Scanning the fragments



positioning...

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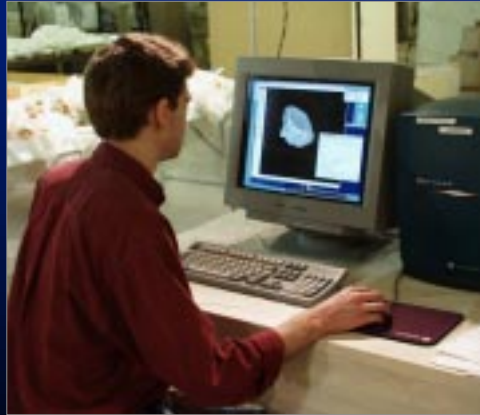
Scanning the fragments



scanning...

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Scanning the fragments



aligning...

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Fragment #642



3D model



color photograph

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Fragment #642



3D model

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levoy@cs.stanford.edu