The Digital Michelangelo Project

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and the

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Executive overview

- Goal
  - Create a 3D computer archive of a significant but focused body of the world's cultural treasures for scholarly, educational, and commercial use.
- Which treasures?
  - sculptures of Michelangelo
  - sculptures of Rodin
  - cathedrals of France
  - dinosaur skeletons
- Using what technologies?
  - 3D scanning
  - light fields

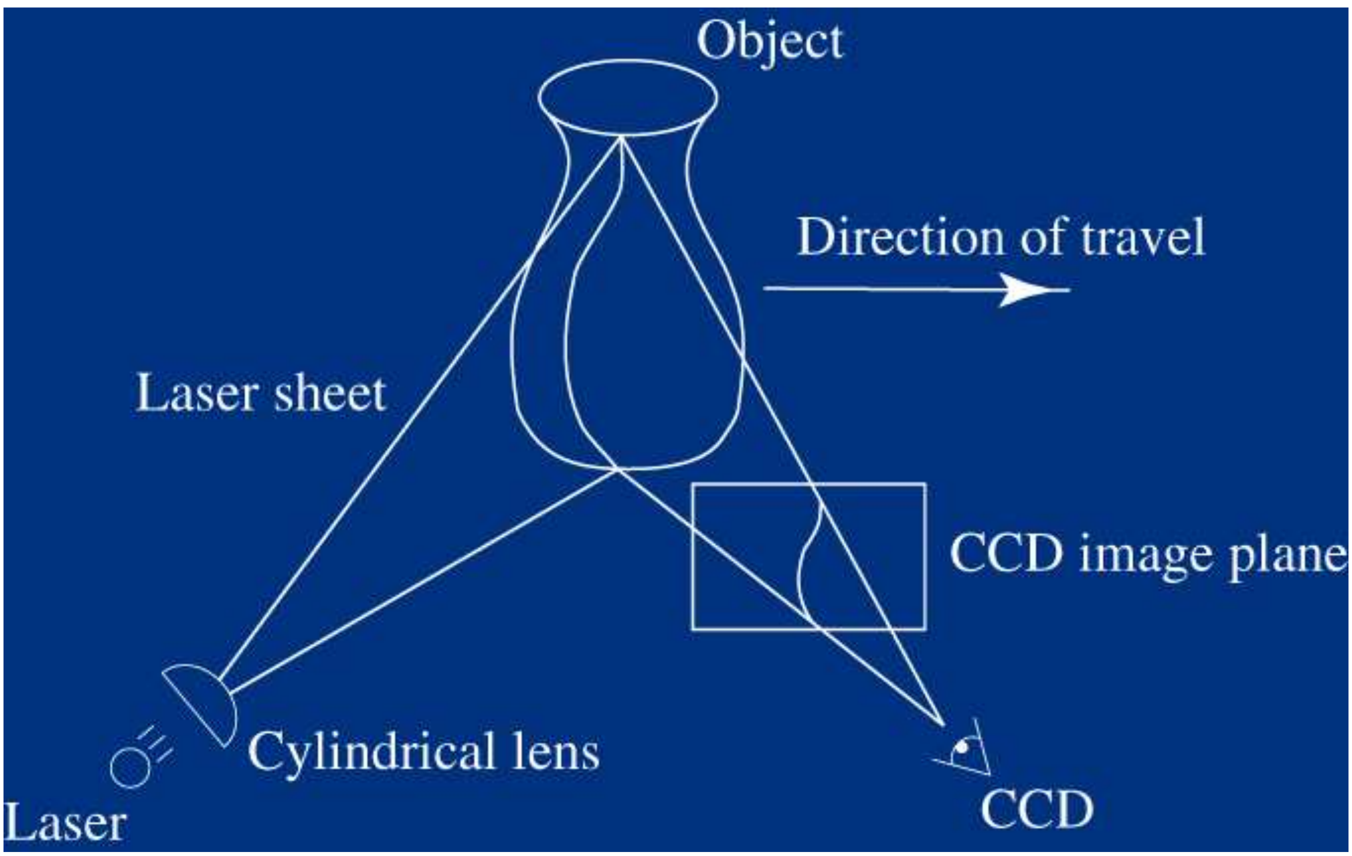
Outline of talk

- the two technologies
- motivations, scholarly and commercial
- scanning methodology
- possible outcomes
- the problem of the Forma Urbis Romae

Technology #1: 3D scanning

- Goals
  - 3D scan: physical object → computer model
  - 3D fax: physical object → email → replica
- Applications
  - rapid prototypes for design and manufacturing
  - models for moviemaking and video games
  - models for online commerce
  - museum applications
- Method
  - laser triangulation scanner
  - move the object or move the scanner
  - algorithm for combining multiple views

Laser triangulation scanning



Happy Buddha

original

computer model

hardcopy

Technology #2: image-based rendering

Flythroughs of 3D scenes from pre-acquired 2D images

Advantages

- low computation compared to classical CG
- cost independent of scene complexity
- imagery from real or virtual scenes

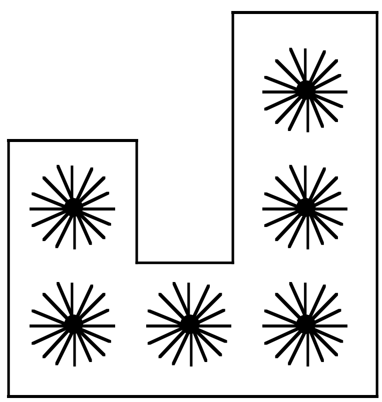
Limitations

- static scene geometry
- fixed lighting
- fixed set of viewpoints

Apple QuickTime VR

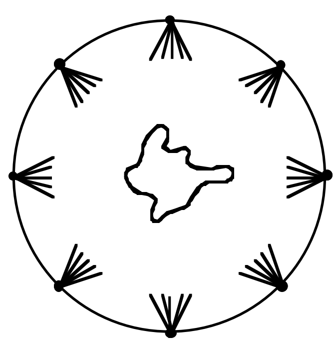
Outward-looking

– panoramic views taken at regularly spaced points

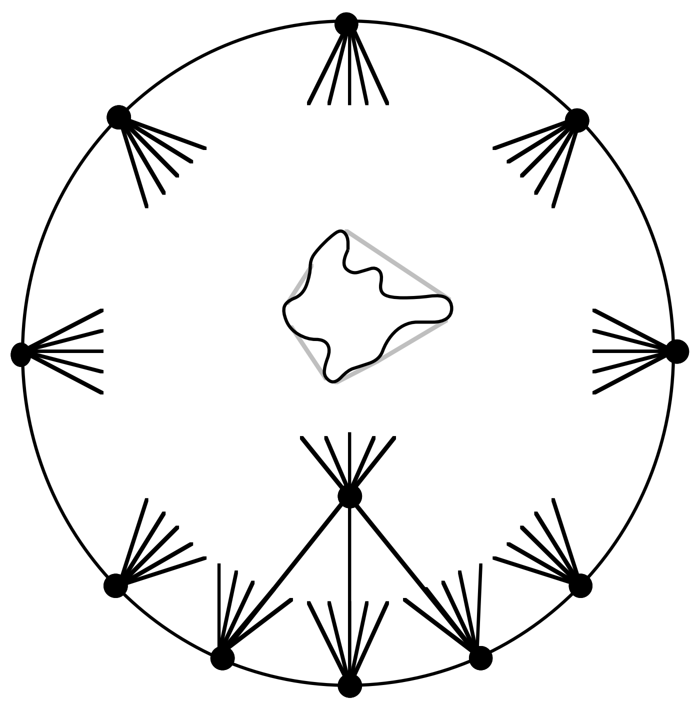


Inward-looking

– views taken at points on the surface of a sphere

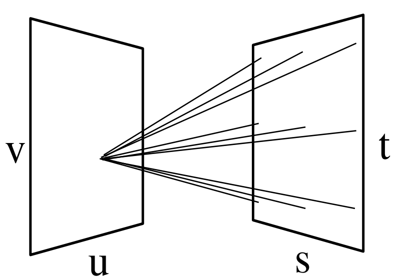


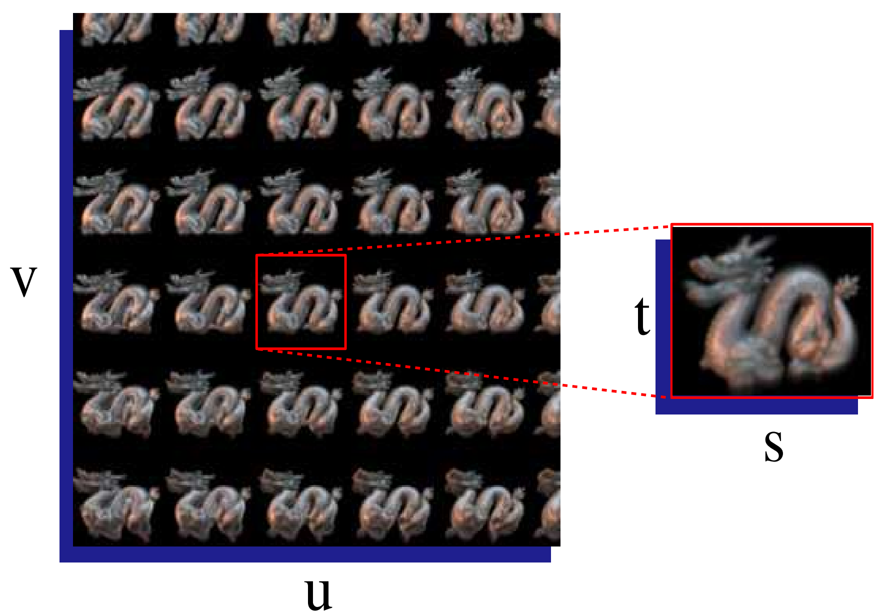
Light field rendering



- Key ideas
  - construct new views by rebinning old views
  - robust because it never builds a 3D model
  - must stay outside the convex hull of the object

A light field is an array of images





Scholarly motivations

- Pushes graphics technology
  - 3D scanning
  - light fields
  - handling complexity
  - empirical methodologies
- Scientific tool
  - art history
  - restoration
  - archeology
- Educational tool
  - “digital plaster casts” for teaching sculpture
  - educating the public
- Other benefits
  - a lasting archive

Commercial motivations

- 2nd generation multimedia
  - content that <u>can't</u> be done better in a book or video
  - new challenges in interaction design
- Art reproduction
  - billion dollar industry
  - current: handmade clay model
    → latex mold → plaster replica ($75)
  - future: 3D scanning → SLA positive
    → latex mold → resin replica ($150)
- Other markets
  - 3D virtual museums
  - 3D stock photography
  - props for moviemakers and game developers
  - avatars

Michaelangelo’s Pieta

handmade replica

The principal sculptures of Michelangelo

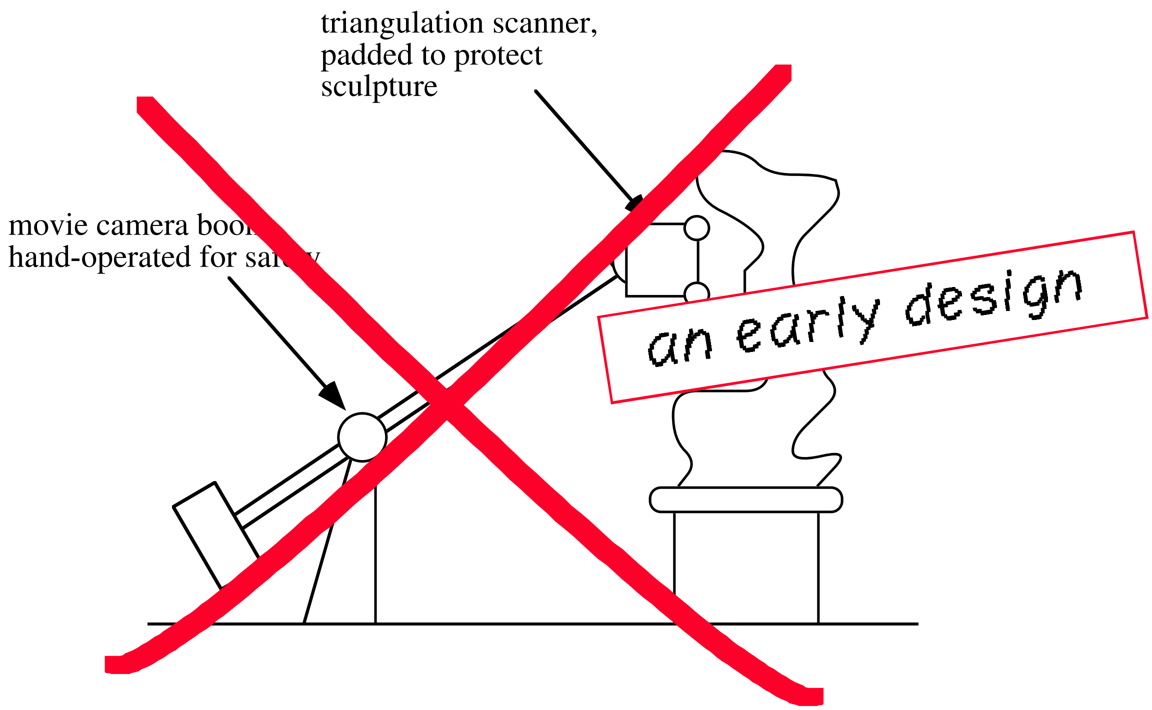
- Florence
  - David
  - Medici Chapel (7 sculptures + architecture)
  - Slaves (4) + St. Matthew
  - Victory
  - The Florence Pieta
  - Bacchus, Brutus, Apollo, Pitti Tondo
- Rome
  - The Pieta in St. Peters
  - Tomb of Julius II (Moses, Rachel, Leah)
  - Rondanini Pieta
- Elsewhere
  - Struggling Captive (Louvre)
  - Dying Captive (Louvre)
  - Bruges Madonna (Belgium)

Intellectual content

- Experiencing the sculptures
  - David — meant to be seen in the round
  - Pieta — visitors now kept back 20 feet
  - Moses — the intricate beard
- Scanning to a storyboard
  - Pieta — distorted for frontal viewing
  - Night — lighting and surface polish
  - Slaves — tools and carving sequence
- Restorations and completions
  - Medici sculptures — 500 years of rancid pig fat
  - Florence Pieta — Christ's missing leg
  - Medici Chapel — the missing Rivers
  - Tomb of Julius II — assemble the Slaves
- Other games
  - Can we write a Michelangelo renderer?

“Night”, showing variations
in surface treatment

3D scanning methodology

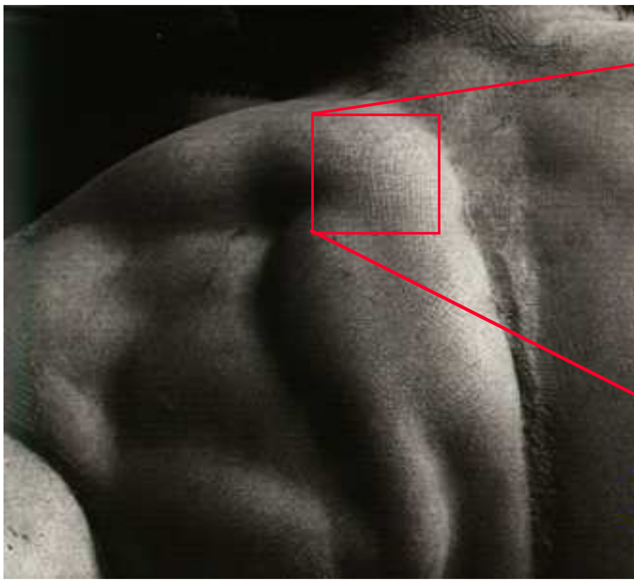


- Technical challenges
  - scanner and gantry design
  - access to and safety of sculptures
  - capturing surface treatments
  - data complexity

Laser triangulation scanner for Michelangelo's statues

- 1m standoff
- range + color
- 0.25mm resolution
- large reach without moving the gantry

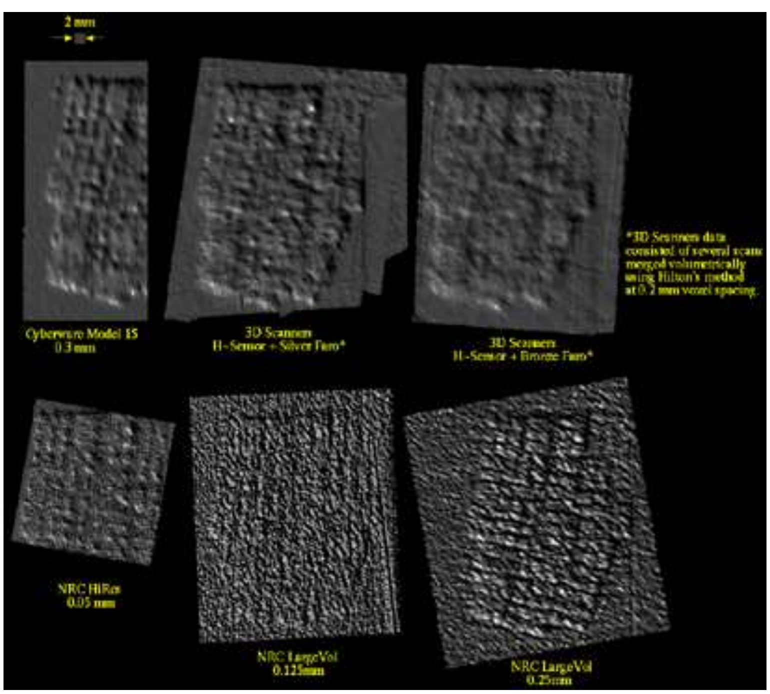
Capturing Michelangelo's chisel marks



“Day”, from the Medici Chapel

2mm

bushing chisel marks



3D models from several triangulation scanners

Alternative triangulation scanner for statues

A Faro digitizing arm in use

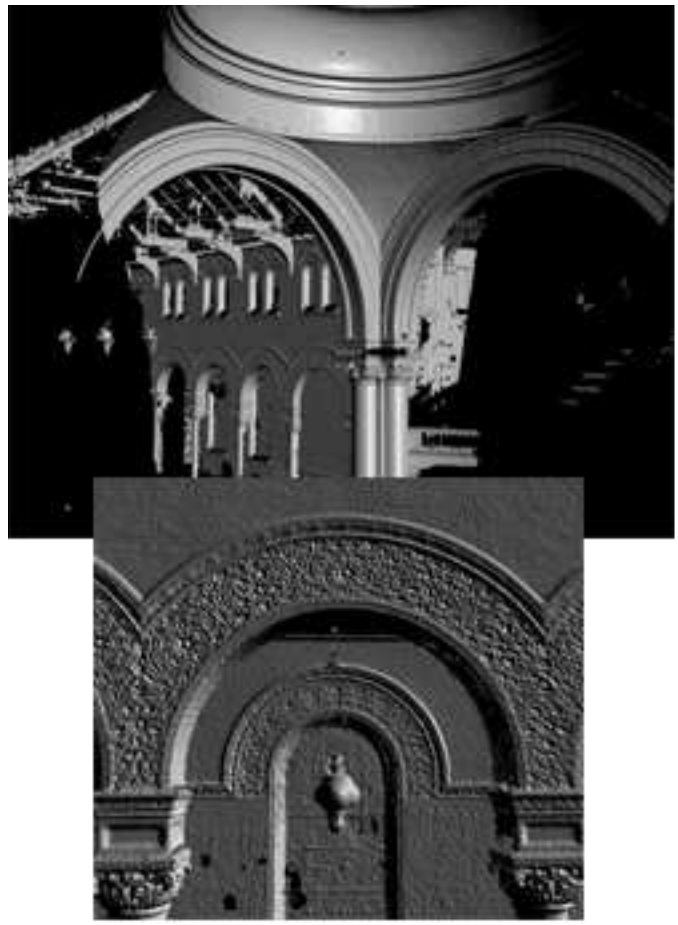
A 3Dscanners Modelmaker in use

The scanning head of the Modelmaker

- color + range
- 0.25mm resolution
- small footprint for “tight spots”
- large reach without moving the tripod

Time-of-flight laser scanner for architectural settings

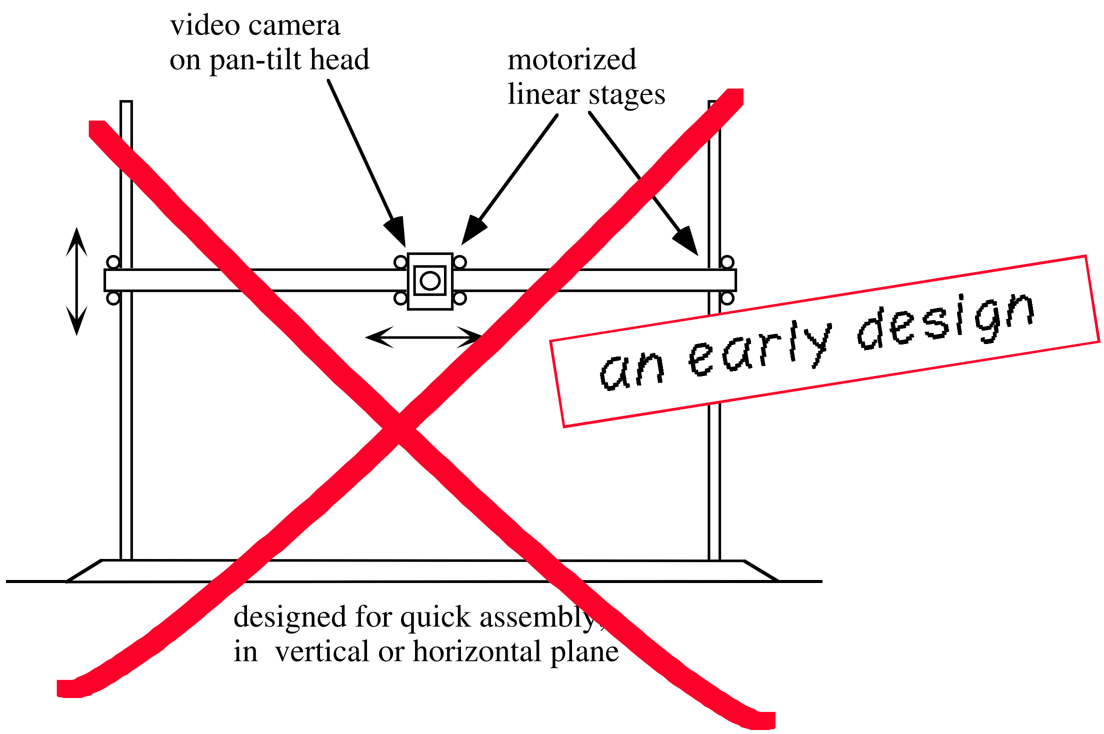
Cyrax scanner



partial 3D model of
Stanford's Memorial Church

– range + color
– 4mm resolution
– 100m maximum range

Light fields methodology



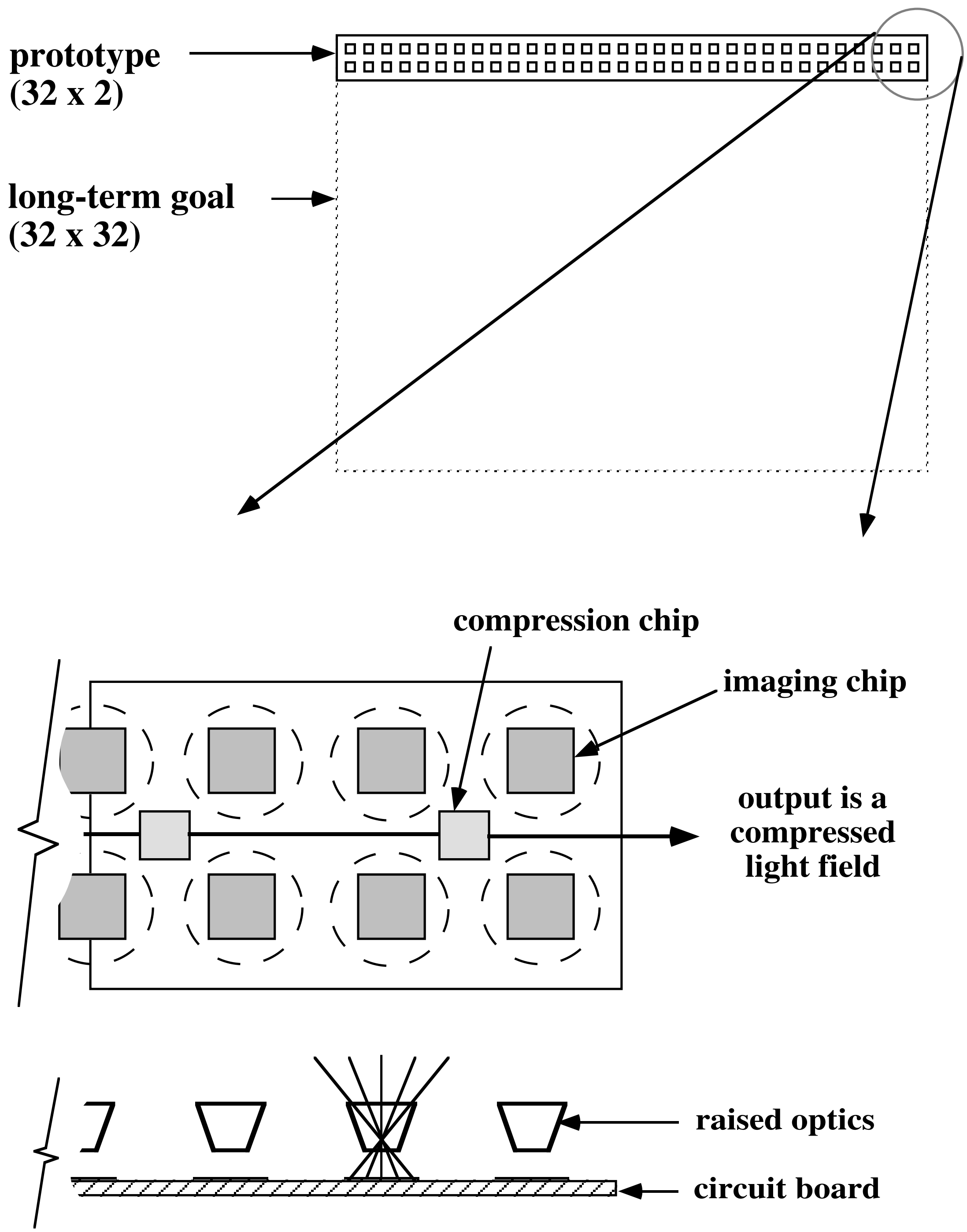
- Technical challenges
  - stiffness and repeatability
  - lighting without blocking gantry
  - data complexity

Spherical 4-DOF gantry for light fields and BRDFs

– 0.03 degree positioning error (1mm)
– 0.01 degree aiming error (1 pixel)
– can acquire video while in motion

Acquiring a light field of the Medici Chapel

A light field camera



CD #1:
The Sculptures of Michelangelo

- For the general public
- Consumer-grade 3D models
  - missing surfaces filled in with plausible geometry
  - multiresolution meshes, lossy compression
  - approximate marble shading
  - viewable in real time on a high-end PC
- Light fields of architectural settings
- Background material
  - “The making of the digital Michelangelo models”

CD #2:
The Digital Michelangelo Models

- For museums, art historians, and content developers
- Industrial-strength 3D models
  - no hole filling, no compression, no games
  - shading from digitized video or BRDFs
- Background material
  - scanning methodology

Forma Urbis Romae

- the marble map of ancient Rome
  - 60’$\times$45’ map
  - incised lines on 3” thick blocks
  - made from Roman census circa 200 A.D.
  - mounted on wall of Temple Sacrae Urbis
- 30% of map still exists, ~1000 fragments
  - fragments vary from 3” to 30” in size
  - 10% have been identified and localized
  - 10% have not been identified
  - 10% contain no incised features
  - long and checkered history
- the importance of the map
  - a Rosetta stone for Roman archeologists
  - scholars have been working on it for 500 years

Solving the jigsaw puzzle

- incised lines and text
- fragment boundaries
  - following the straight edges of blocks
  - 2D fragment lines vrs 3D surfaces
  - beware of chipping
- marble veining
- clamp holes
  - on edges of slabs
  - on back of slabs
- architectural constraints
  - converging lines
  - plausible building layouts

Logistics

- main laboratory in Florence
- satellite laboratory in Vatican
- staff

– Kari Pulli	technical lead
– Brian Curless	visiting scholar
– John Gerth	sysadmin

- students

– David Koller	PhD student
– Lucas Pereira	PhD student
– Szymon Rusinkiewicz	PhD student
– Sean Anderson	PhD student
– Olaf Hall-Holt	PhD student
– Matt Ginzton	undergraduate
– Alex Roetter	undergraduate
– Jeremy Ginsberg	undergraduate

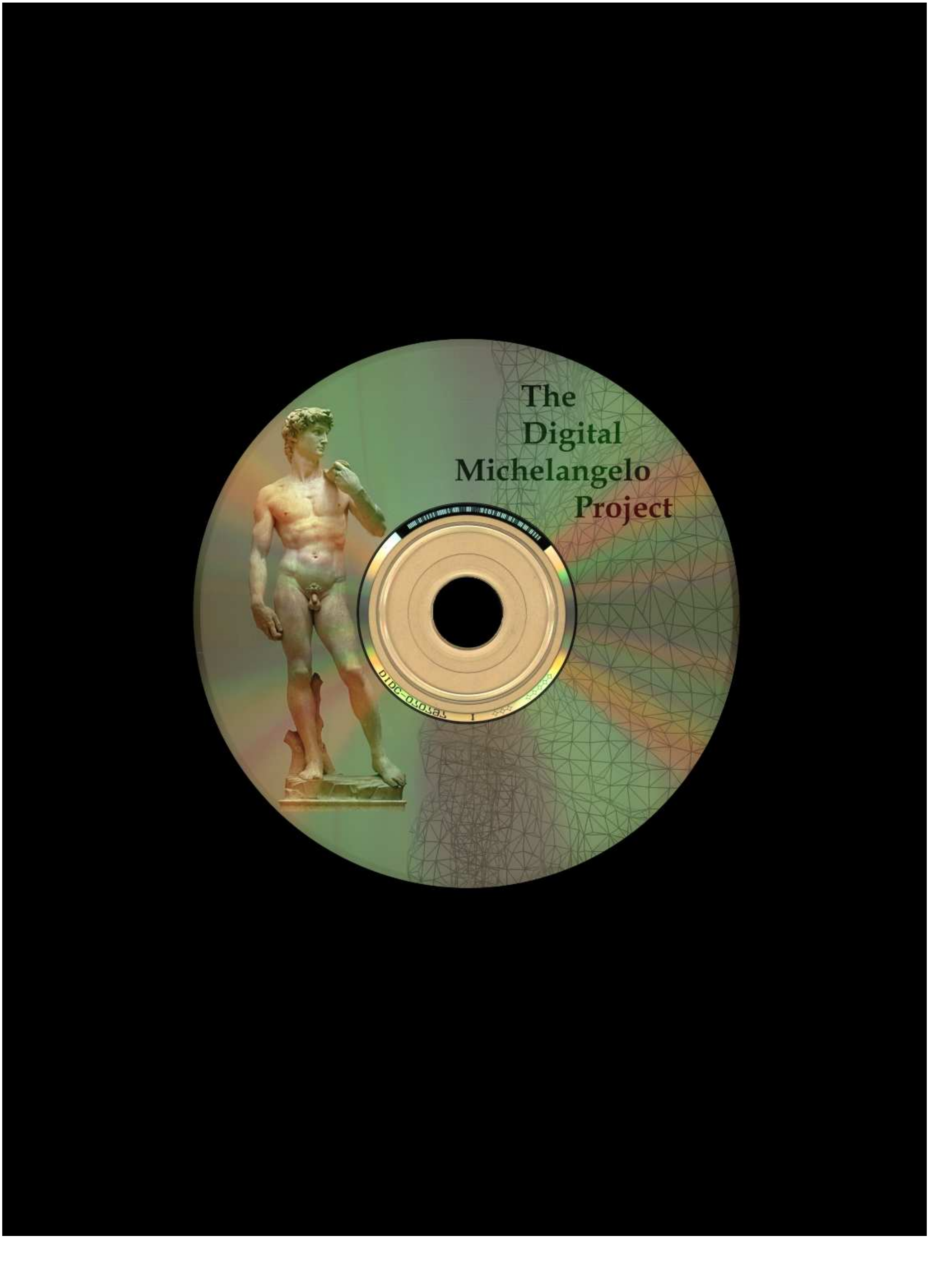
...and the students of the Stanford Center in Florence

How can I get involved?

- 1997-98 academic year
  - develop software in Palo Alto
  - mainly grad students
- Summer, 1998
  - final testing of gantries and software
  - grads and undergrads
- Autumn, 1998, in Florence
  - CS 149 - Field Project in Graphics
- Winter, 1999, in Florence
  - CS 149 - Field Project in Computer Graphics
  - CS 99D - The Science of Art

How do I find out more?

- on the web
  - http://graphics.stanford.edu/projects/mich
  - http://www-osp.stanford.edu/Florence
- in person
  - my office hours are Tue/Thu,
    11:00 - 12:15, room 366,
    1:15 - 2:30 Spring quarter


The
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