

# Geometry Acquisition

*with applications to*

Image-Based Modeling, Rendering, and Lighting

**Paul Debevec**

Computer Science Division  
University of California at Berkeley

Workshop on Rendering, Perception, and Measurement  
Cornell University Program of Computer Graphics

**April 1999**

<http://www.cs.berkeley.edu/~debevec>



# Geometry Acquisition

What geometry is needed?

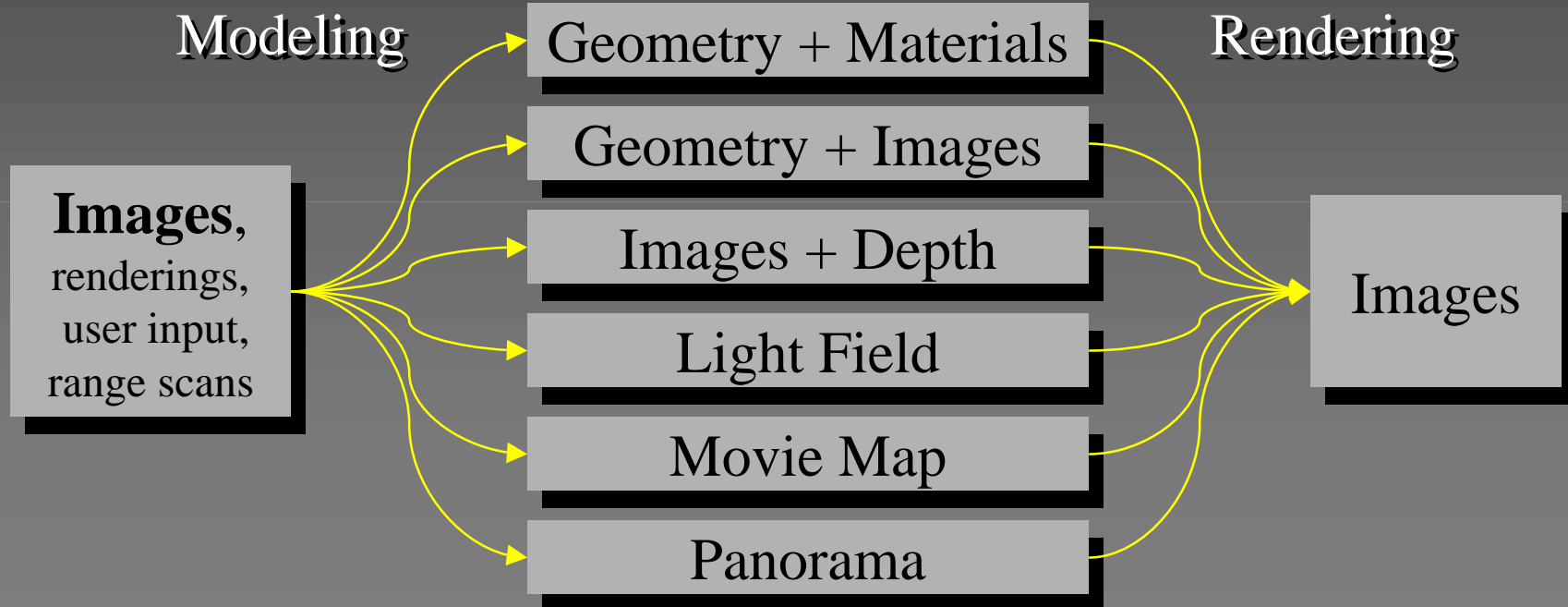
What techniques to use?

How good do we have to be?

*Depends on the application*

- *Site planning, surgical simulation, heritage preservation, IBR...*

# Models in IBR: many forms



# Comparison of Image-Based Representations:

Representation	Movement	Geometry	Lighting
Geometry + Materials	Continuous	Global	Dynamic
Geometry + Images	Continuous	Global	Fixed
Images + Depth	Continuous	Local	Fixed
Light Field	Continuous	None	Fixed
Movie Map	Discrete	None	Fixed
Panorama	None	None	Fixed

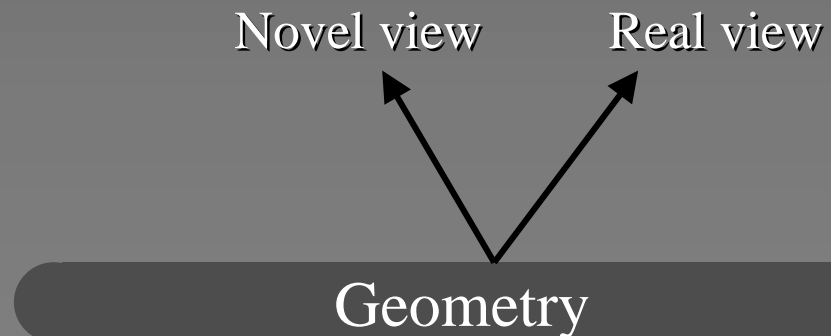
# How is Geometry Useful?

## Predicts novel viewpoints

- *If diffuse, reduces light field from 4D=>2D*

## Resolves occlusions

## Helps recover material properties



## How can we recover geometry?

Silhouettes

Line drawing cues

Stereo

Architectural constraints

Stereo

Motion

Structured light / dark

Laser Scanning

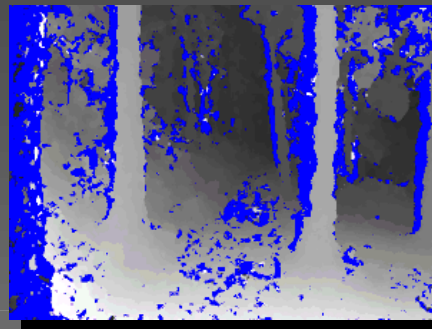




Stereo Image Capture  
Rig



Stereo  
Image  
Pair



Depth  
Map

## Immersion '94

Michael Naimark

John Woodfill

Paul Debevec

Leo Villareal

Ramin Zabih

Interval Research  
Corporation



Synthetic  
Views

Ramin Zabih and John Woodfill. Non-parametric local transforms for determining visual correspondence. ECCV, May 1994.

# Modeling and Rendering Architecture from Photographs (Debevec, Taylor, and Malik)



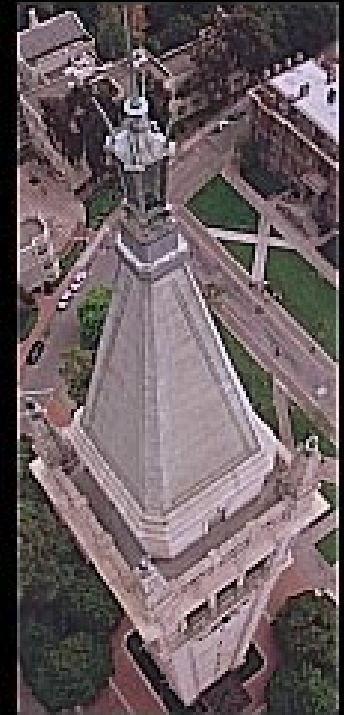
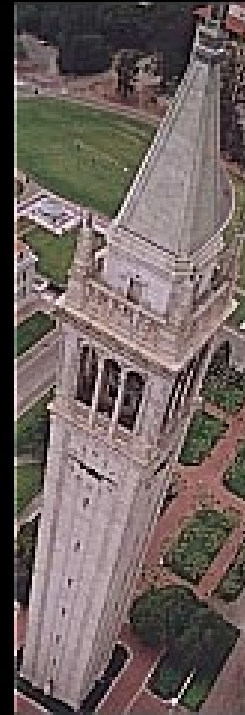
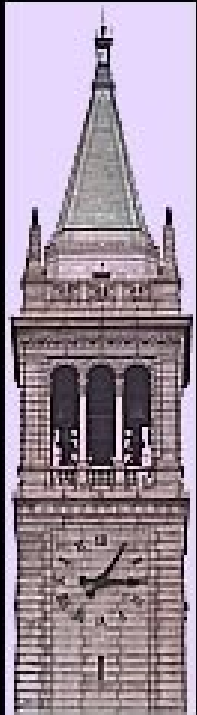
Block Model



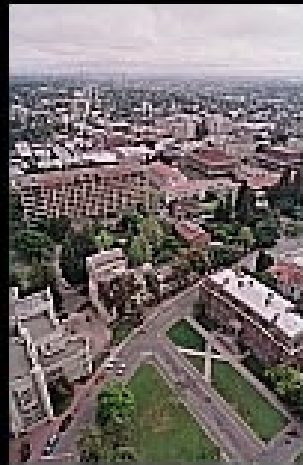
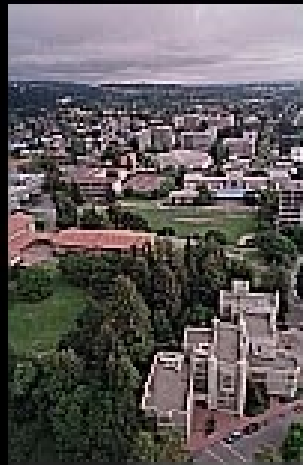
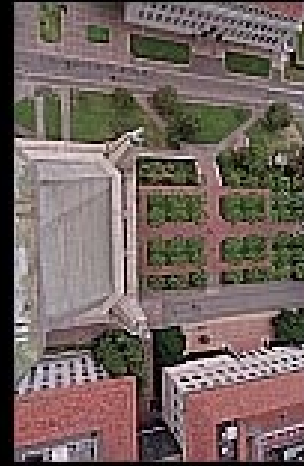
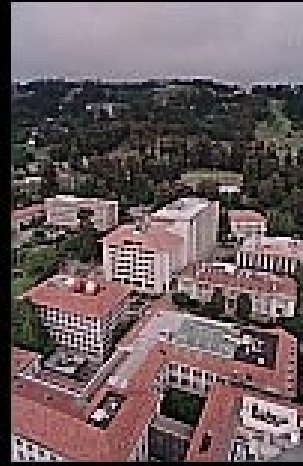
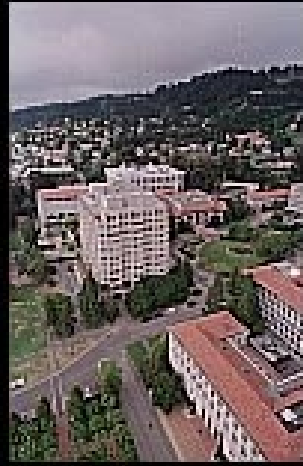
User-Marked Edges



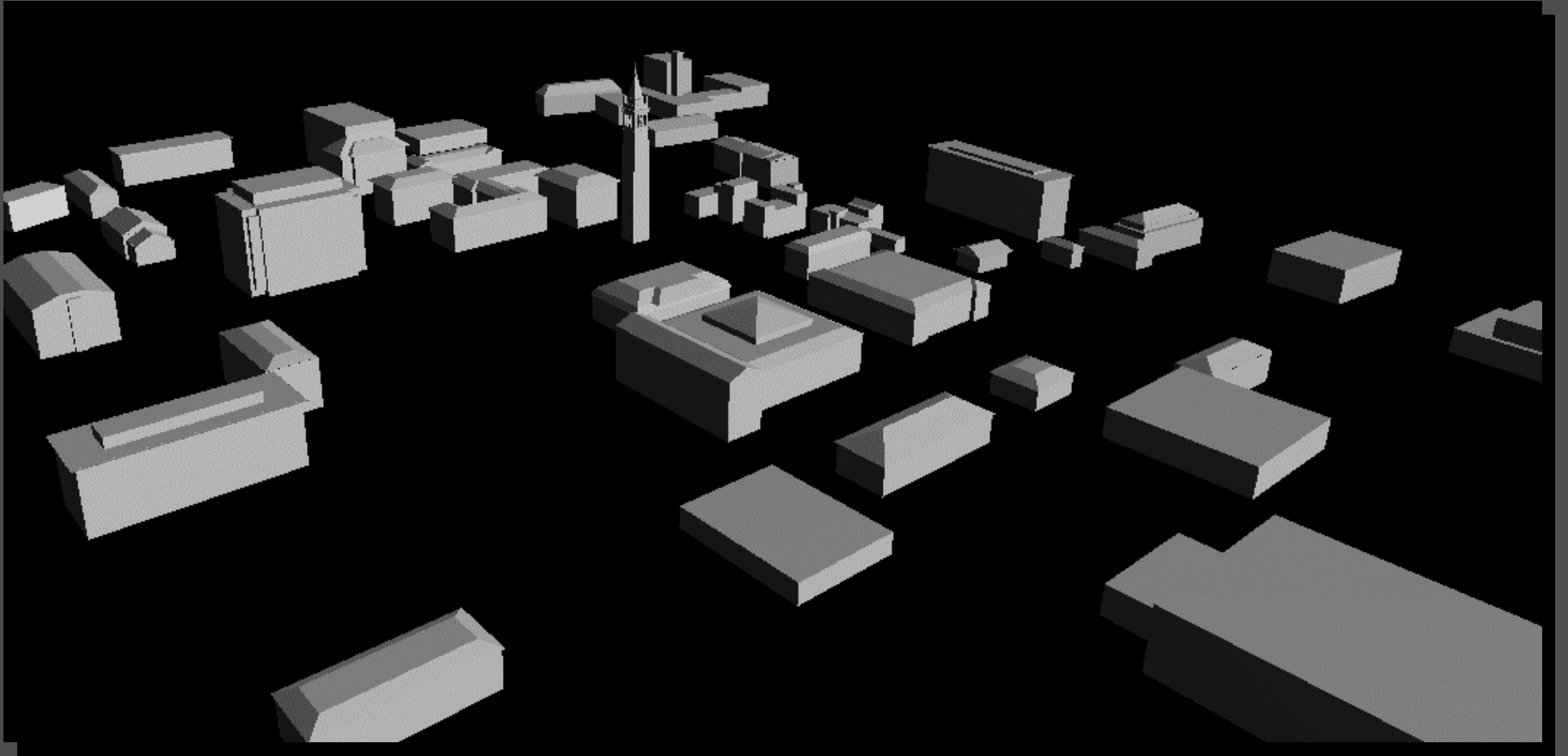
Recovered Model



# Tower Photographs



# Environment Photographs



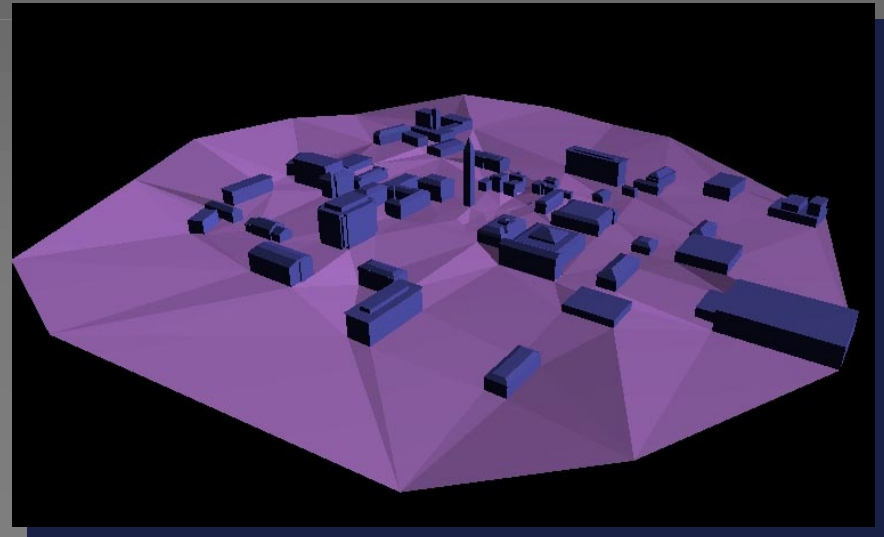
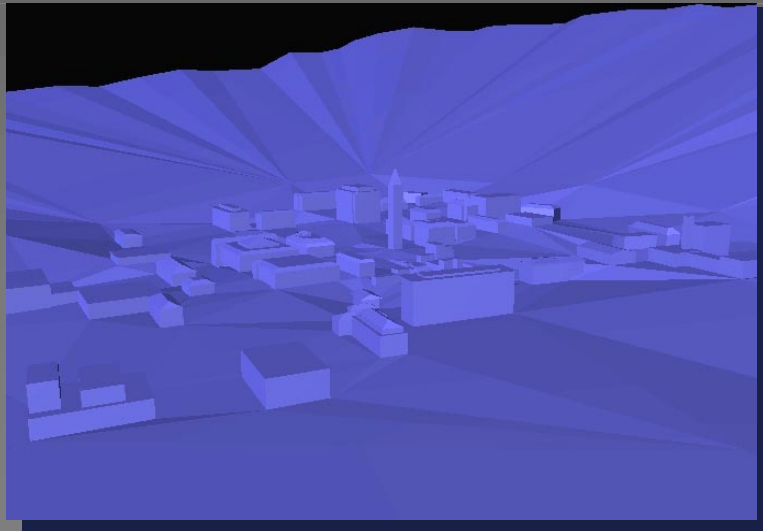
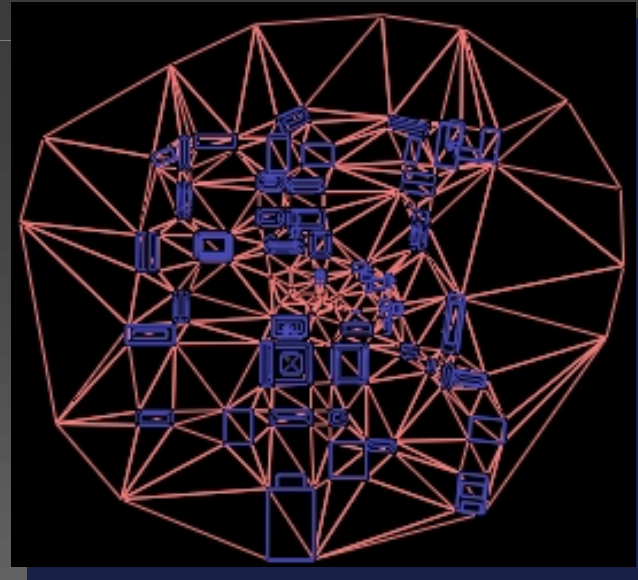
Campus Model (Campanile + 40 buildings)

# Campanile Model

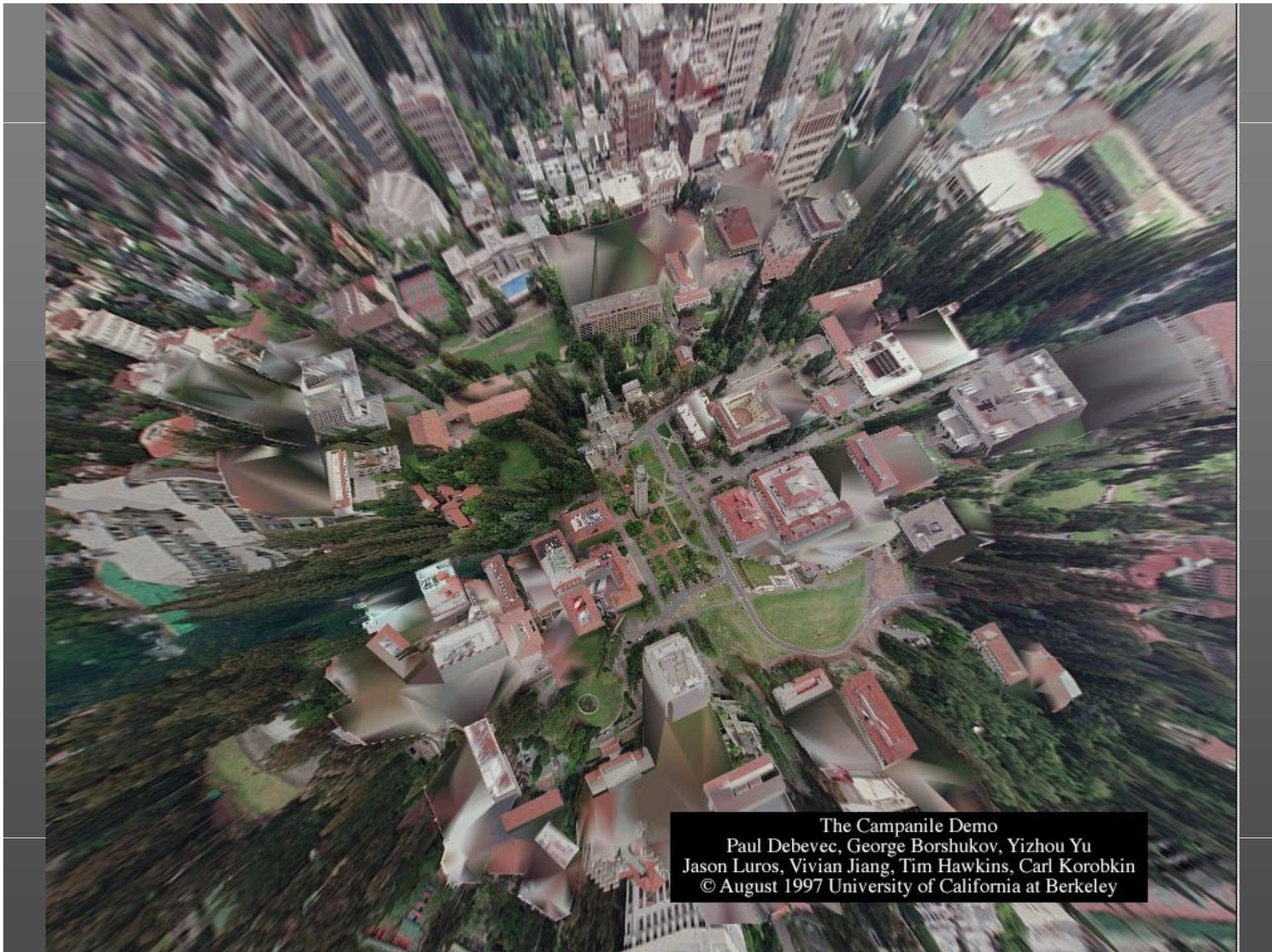


# Terrain Modeling

- *Delaunay triangulation of building bases + other recovered ground points*
- *Extension out to horizon*



# Video



The Campanile Demo  
Paul Debevec, George Borshukov, Yizhou Yu  
Jason Luros, Vivian Jiang, Tim Hawkins, Carl Korobkin  
© August 1997 University of California at Berkeley

# Application: The Matrix

Matrix Shot 1

<http://www.whatisthematrix.com/>

Matrix Shot 2

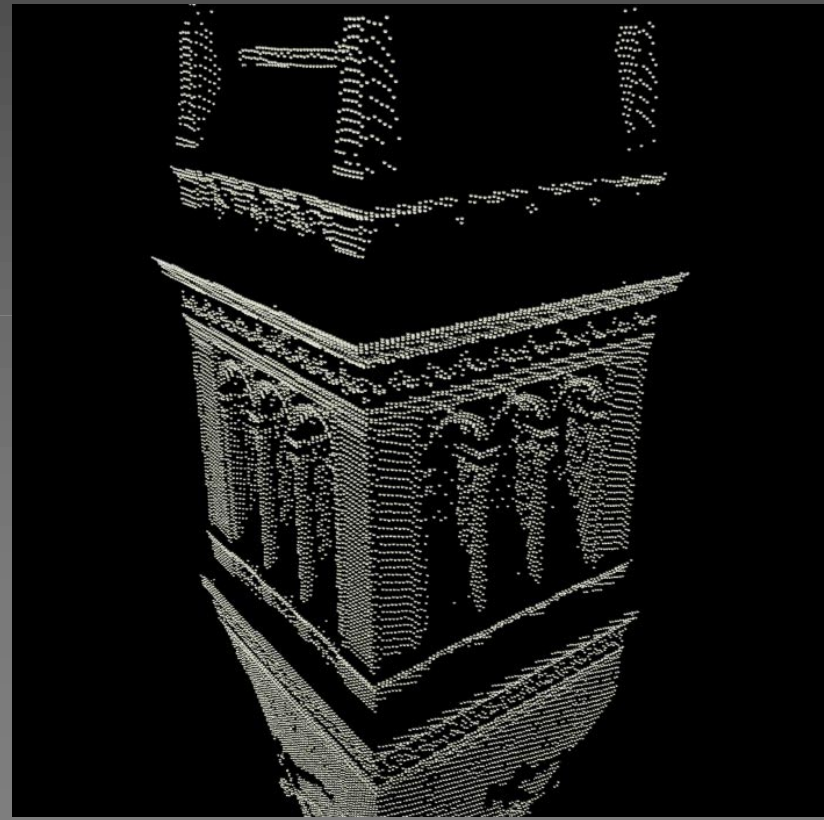
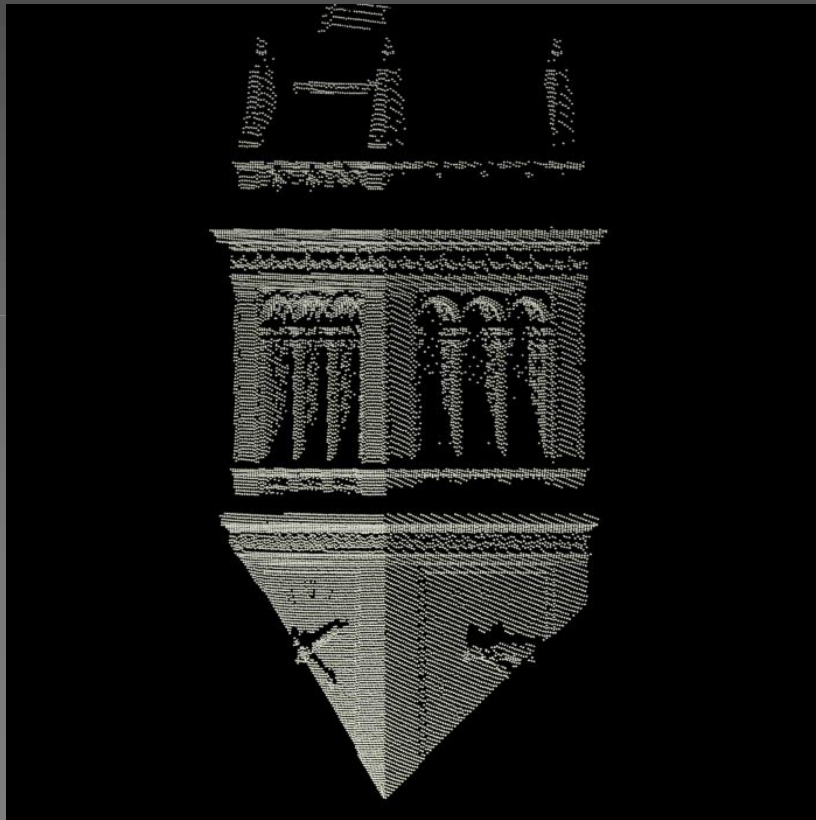
<http://www.whatisthematrix.com/>

Photogrammetric Modeling and Projective Texture-Mapping were used in key shots of the Keanu Reeves film “The Matrix” by Campanile project veteran George Borshukov.

Courtesy of George Borshukov, MANEX Entertainment

# Time-of-flight Laser Scanning

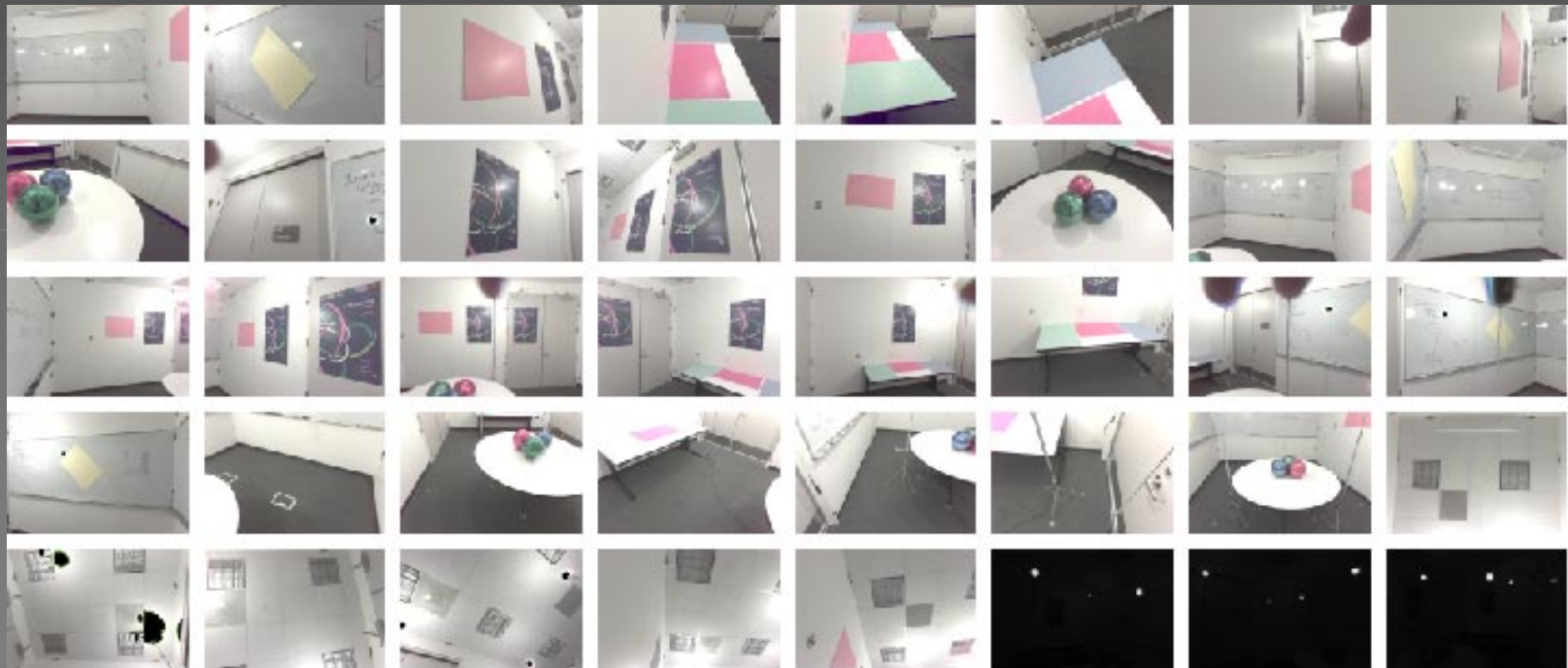
Laser scan of Berkeley's Campanile,  
courtesy of Cyra corporation



# Inverse Global Illumination

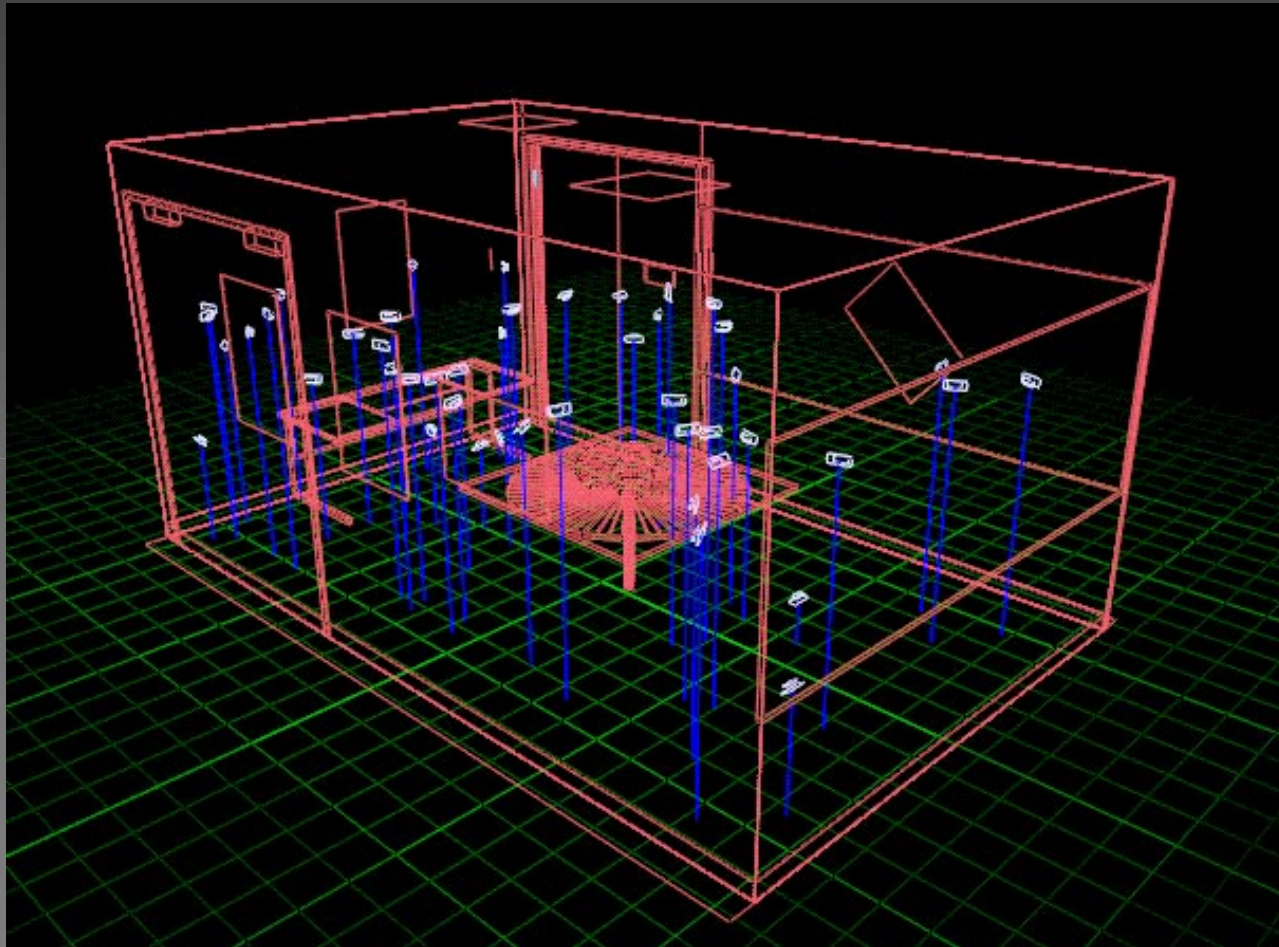
Yizhou Yu, Paul Debevec, Jitendra Malik, Tim Hawkins

SIGGRAPH 99



40 radiance maps of a room

# Recovered Geometry and Viewpoints

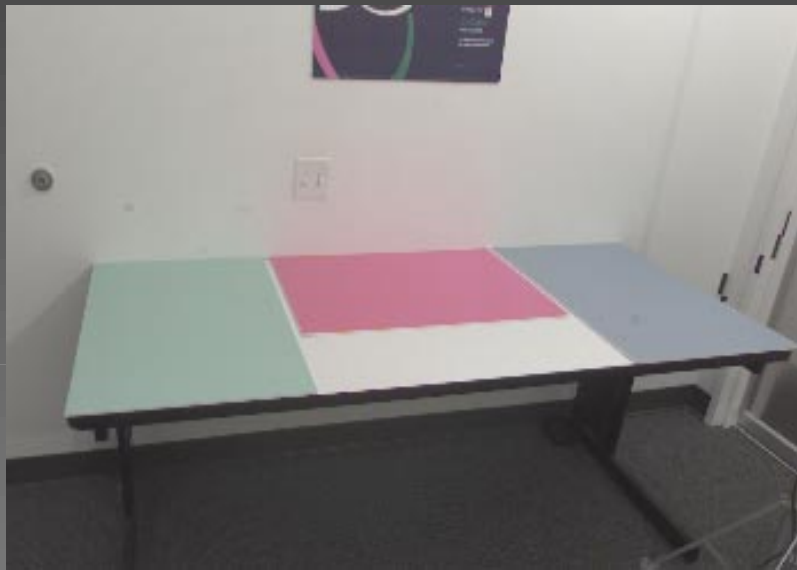


# Overview of Recovery Method

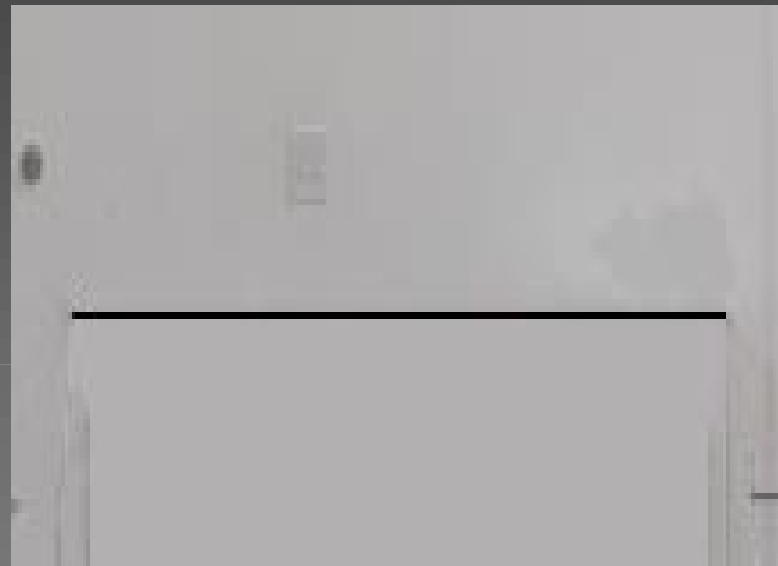
- 1) *Use IBMR to estimate irradiance of each surface patch*
- 2) *Determine diffuse albedo by dividing observed radiance by estimated irradiance*
- 3) *For each polygonal face, determine if a highlight should be visible*
- 4) *If so, estimate specular properties (roughness, intensity) from image of highlight*
- 5) *Iterate*



# Inverting Color Bleed



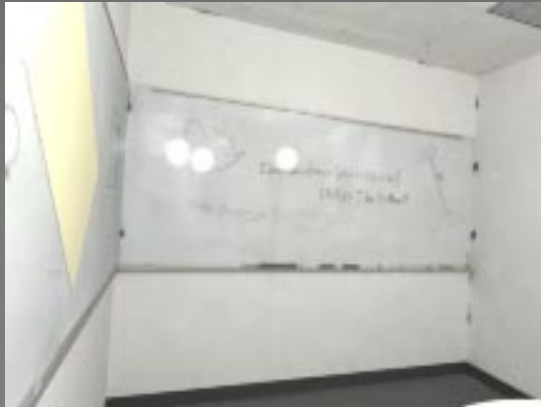
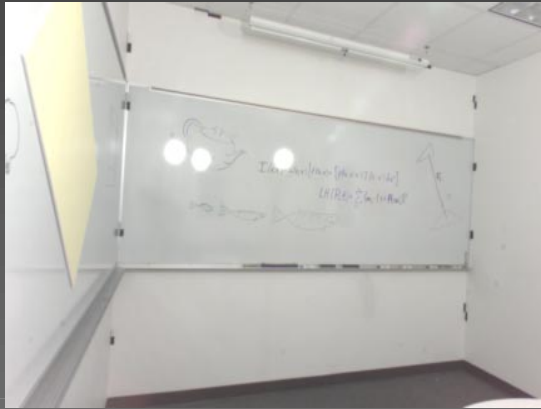
Input Photograph



Output Albedo Map

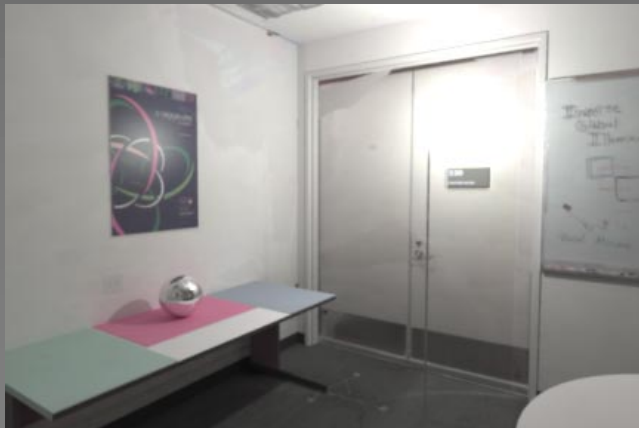
# Real/Synthetic Comparison

Same viewpoints, Same lighting, Same objects



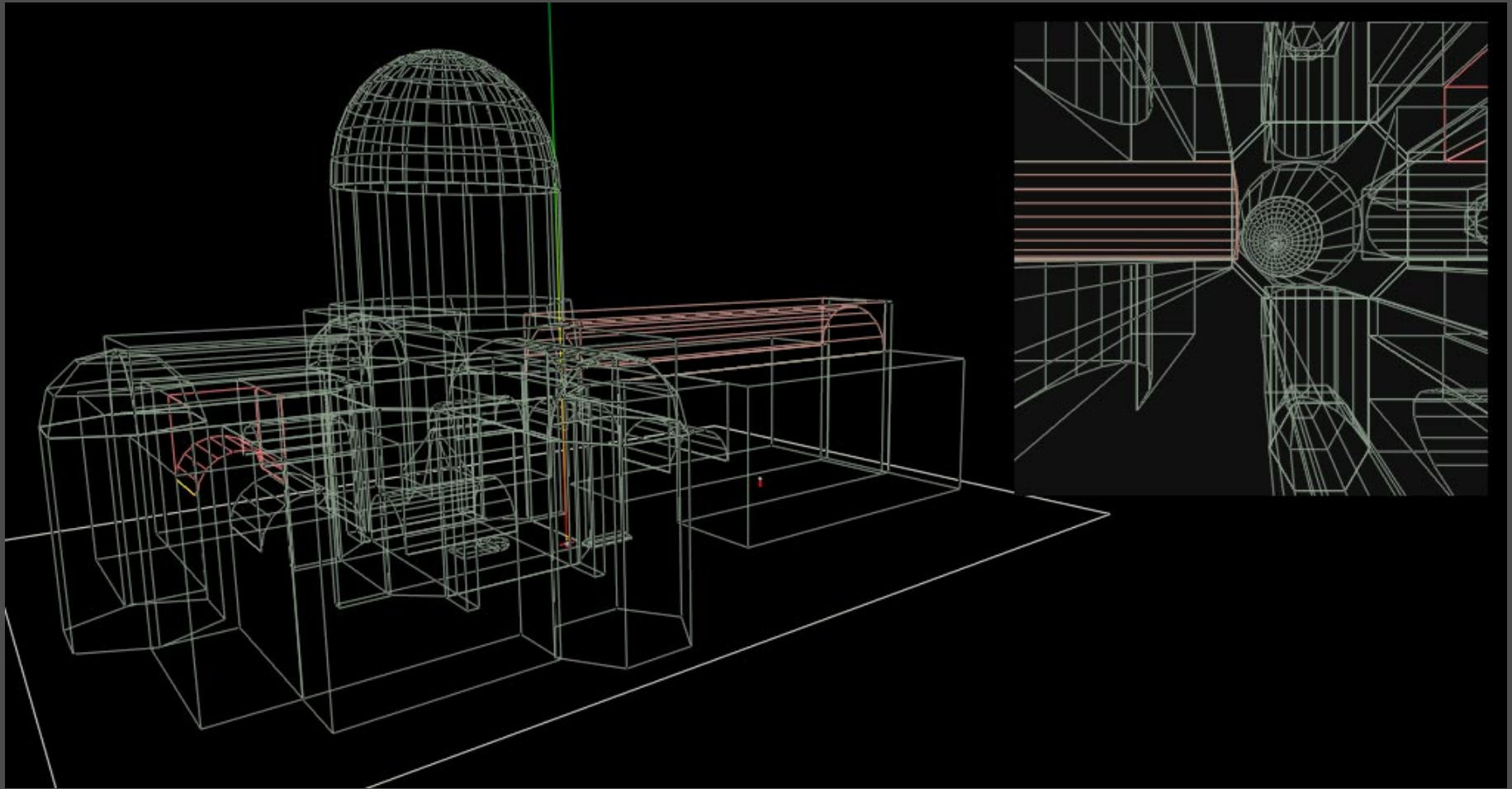
# Real/Synthetic Comparison

New viewpoint, New lighting, New object



# Interior Illumination Model St. Peter's Basilica





Interior of St. Peter's from one Viewpoint

(35 parameters)

# The Campanile Movie

Created by: George Borshukov, Yizhou Yu, Jason Luros, Vivian Jiang, Chris Wright, Sami Khoury, Charles Benton, Tim Hawkins, Charles Ying, and Paul Debevec

Thanks to Jitendra Malik, Jeff Davis, Susan Marquez, Al Vera, Peter Bosselman, Camillo Taylor, Eric Paulos, Michael Naimark, Dorrice Pyle, Russell Bayba, Lindsay Krisel, Oliver Crow, and Peter Pletcher, as well as Charlie and Thomas Benton, Linda Branagan, John Canny, Magdalene Crowley, Brett Evans, Eva Marie Finney, Lisa Sardegna, Ellen Perry, and Camillo J. Taylor.

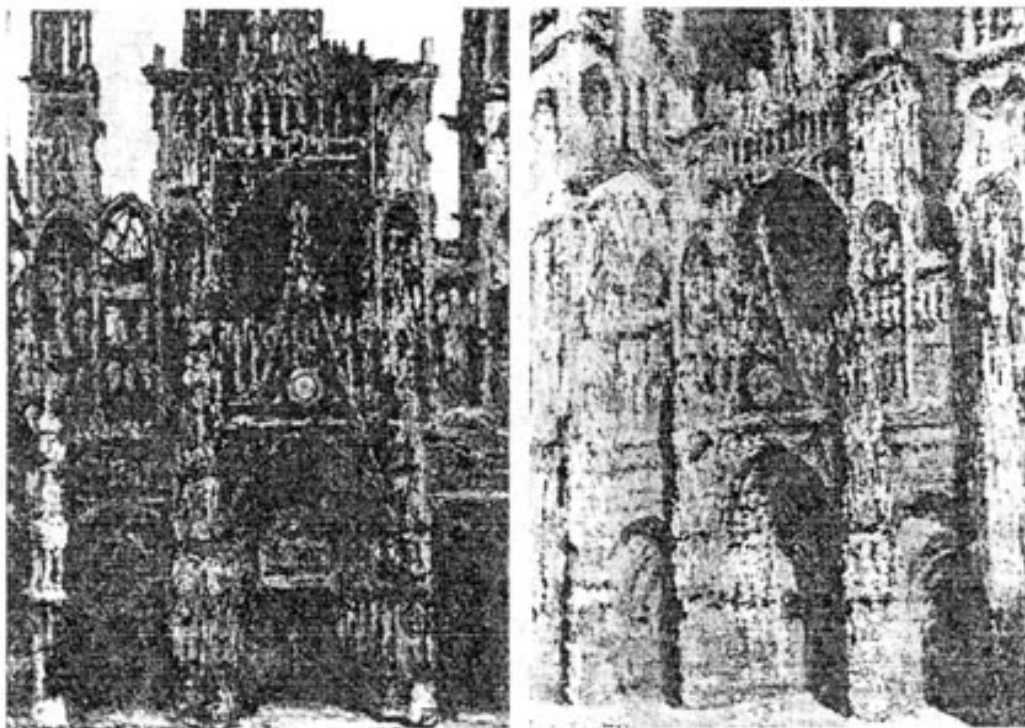
Additional thanks: the Berkeley Computer Vision Group, the Berkeley Multimedia Research Center, the Berkeley Computer Graphics Group, the ONR MURI Program, Interval Research Corporation, and Silicon Graphics, Inc.

# Additional Thanks

George Borshukov, Christine Cheng, H-P  
Duiker, Tal Garfinkel, Tim Hawkins, Jenny  
Huang, Sami Khoury, Jason Luros, Jitendra  
Malik, Westley Sarokin, Camillo Taylor,  
Chris Wright, Yizhou Yu

Silicon Graphics, The National Science  
Foundation, The Berkeley NOW project,  
Interval Research Corporation

The New York Times



Two of Monet's views of the Rouen Cathedral's main facade, painted in the early afternoon from slightly different angles and in different light.

## Monet's Fixation on the Rouen Cathedral

By ALAN RIDING

*Special to The New York Times*  
ROUEN, France, Aug. 16 — By the time Claude Monet set up his easel beside an open window opposite Rouen Cathedral one chilly morning in February 1892, he had long demonstrated his fascination with painting the same subject over and over again, each time under different light or weather conditions.

At 52, he had already made series of studies of haystacks, the Seine, the Thames at Westminster, poplars and

Now, to acknowledge the 100th anniversary of this trial (the works are actually dated 1894 because Monet finished them in Giverny), 16 of the series are on display in Rouen's Musée des Beaux-Arts, bringing more of them together than at any time since 20 were put up for sale in a Paris gallery in 1895.

The exhibition, "Rouen, Monet's Cathedrals," has caused a stir among admirers of the bearded Impressionist. "The series offers the most dazzling and convincing demonstration of Monet's determination to capture instantaneousness," said Sylvie Pa-

Thirty oils offer similar but different views of a Normandy church.

paintings that seem to symbolize Monet's arrival in the city: a rose-tinted "general view" of Rouen from a Gothic belltop and a street scene with

that best illustrates how Monet, working from dawn to dusk, became obsessed by the subject he called his "city." "I am a prisoner and I must go on until the end," he wrote during his 1892 visit.

In two of the paintings, the cathedral stands dark and menacing, solidly rooted to the ground as only appropriate for a vast Gothic edifice dating from the 14th century. But in others, Monet variously saw yellow, orange, pink, green, blue and white playing off the cathedral's facade as the sun moved across the sky or was suddenly lost behind clouds. In one,

# Rouen Revisited

(Golan Levin and Paul Debevec)



Synthetic View:  
1996



Synthetic View:  
1896



Synthetic View:  
Monet Painting