Modeling and Rendering Architecture from Photographs

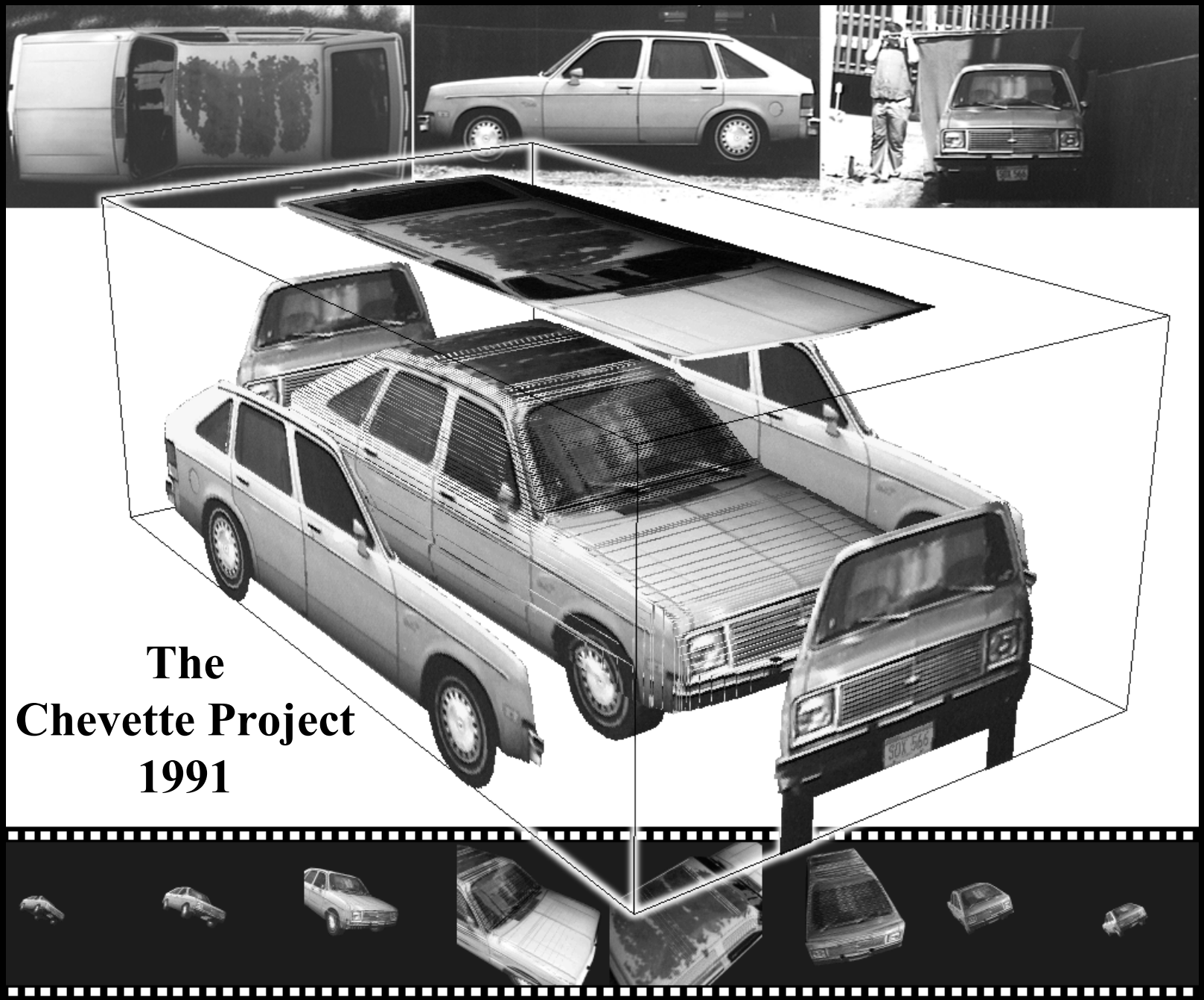
Paul Debevec

University of Southern California
Institute for Creative Technologies

SIGGRAPH 2000 Course #19, 3D Photography
Brian Curless and Steve Seitz, organizers

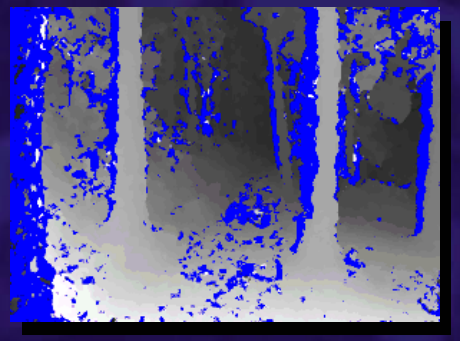
July 24, 2000

www.debevec.org


The
Chevette Project
1991

Stereo Image Capture Rig

Stereo Image Pair



Depth Map

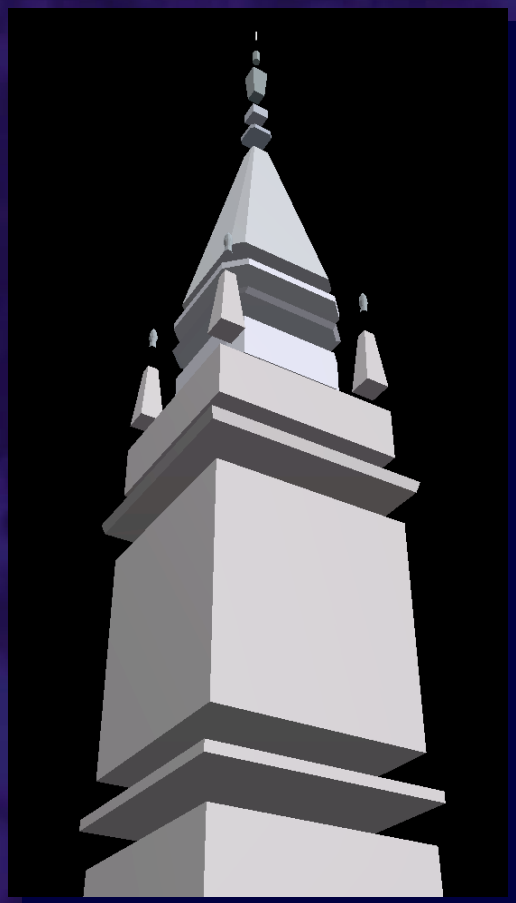
Synthetic Views

Immersion '94

Michael Naimark
John Woodfill
Paul Debevec
Leo Villareal
Ramin Zabih
Interval Research Corporation

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

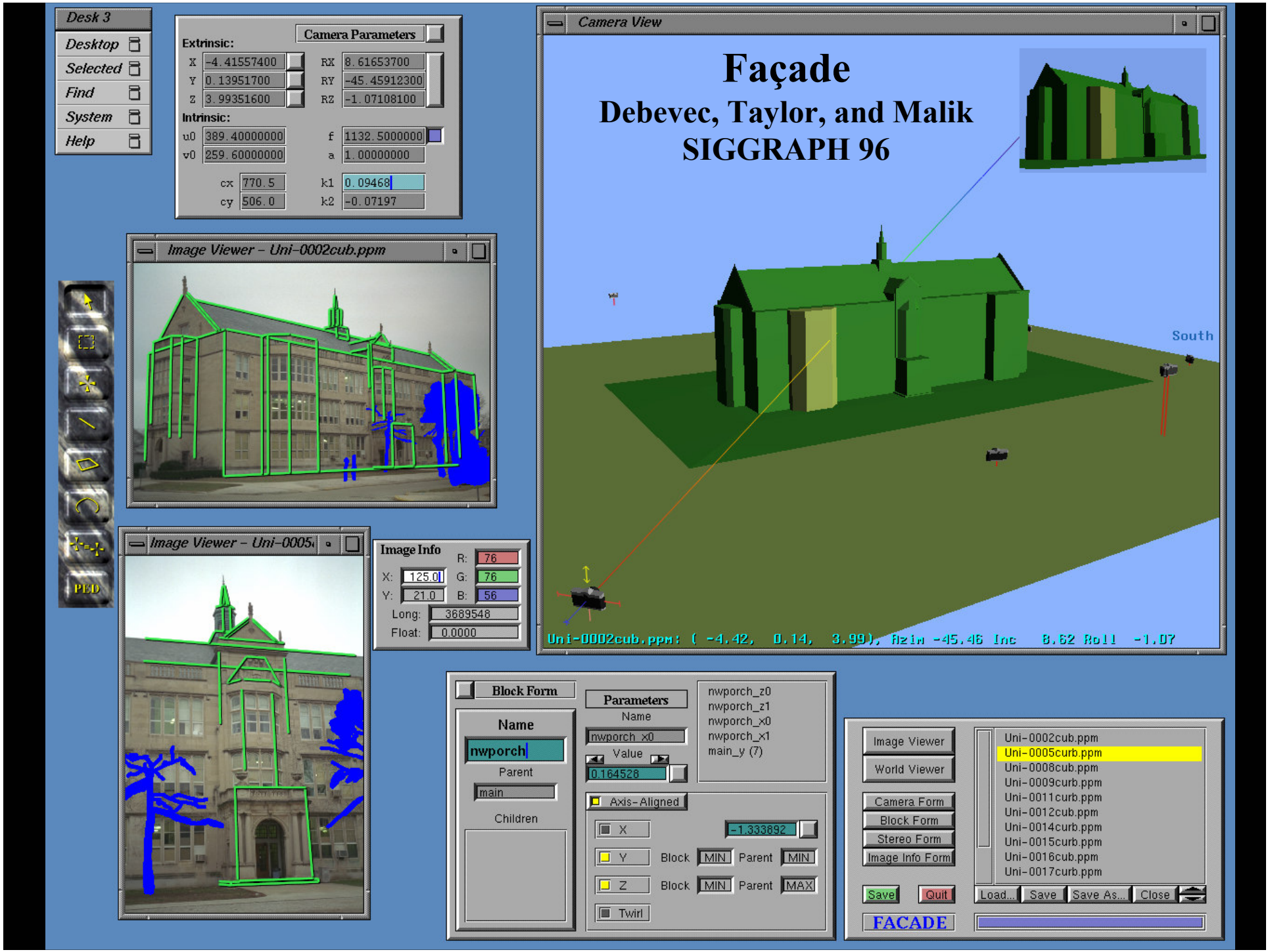
Modeling and Rendering Architecure from Photographs (Debevec, Taylor, and Malik 1996)



Block Model

User-Marked Edges

Recovered Model


Façade
Debevec, Taylor, and Malik
SIGGRAPH 96
Desk 3
Desktop
Selected
Find
System
Help
Camera Parameters
Extrinsic:
X -4.41557400
Y 0.13951700
Z 3.99351600
RX 8.61653700
RY -45.45912300
RZ -1.07108100
Intrinsic:
u0 389.40000000
v0 259.60000000
f 1132.5000000
a 1.00000000
cx 770.5
cy 506.0
k1 0.09468
k2 -0.07197
Camera View
South
Uni-0002cub.ppm: (-4.42, 0.14, 3.99), Azim -45.46 Inc 8.62 Roll -1.07
Image Viewer - Uni-0002cub.ppm
Image Viewer - Uni-0005
Image Info
X: 125.0
Y: 21.0
R: 76
G: 76
B: 56
Long: 3689548
Float: 0.0000
Block Form
Name
nwporch
Parent
main
Children
Parameters
Name
nwporch_x0
Value
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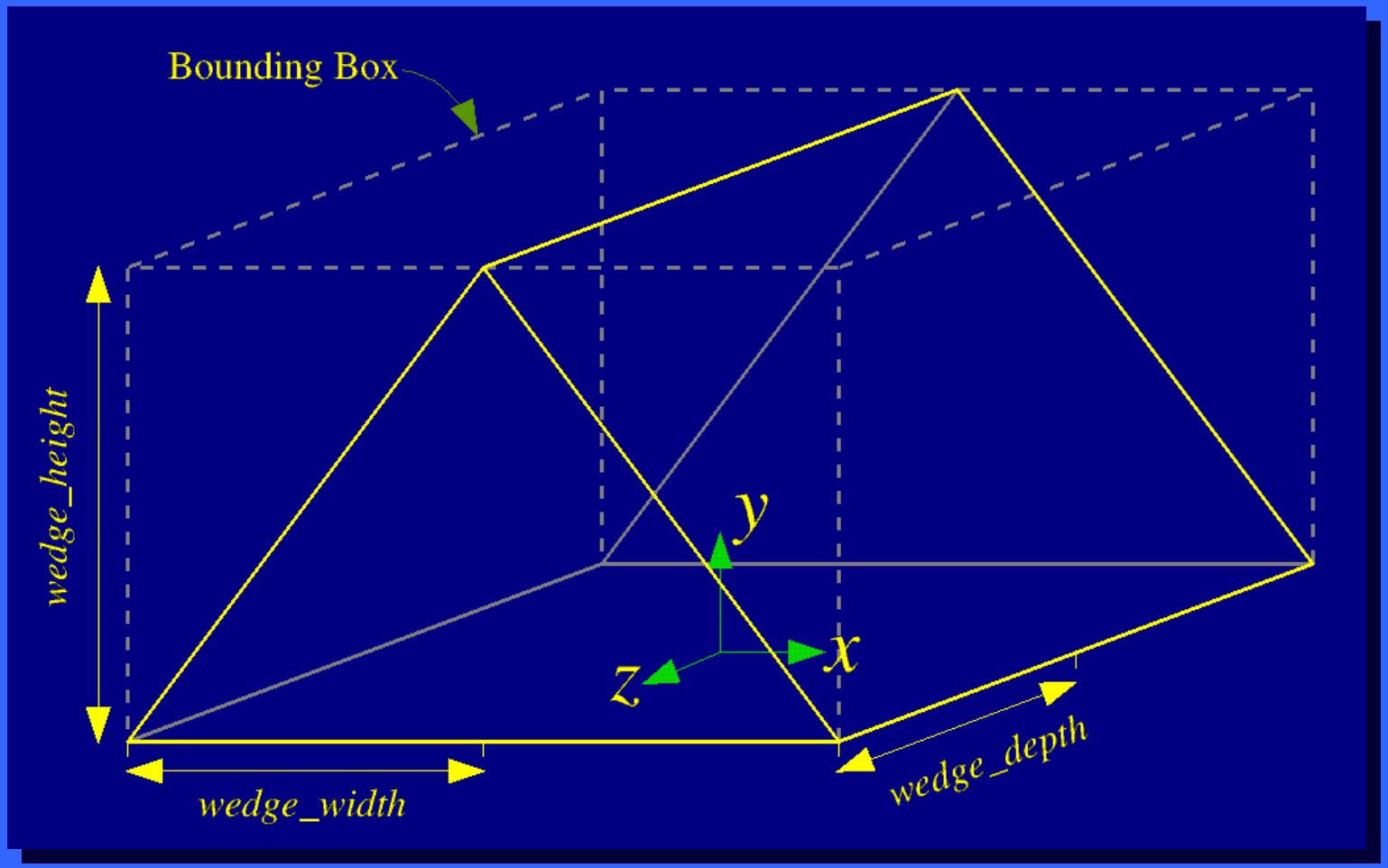
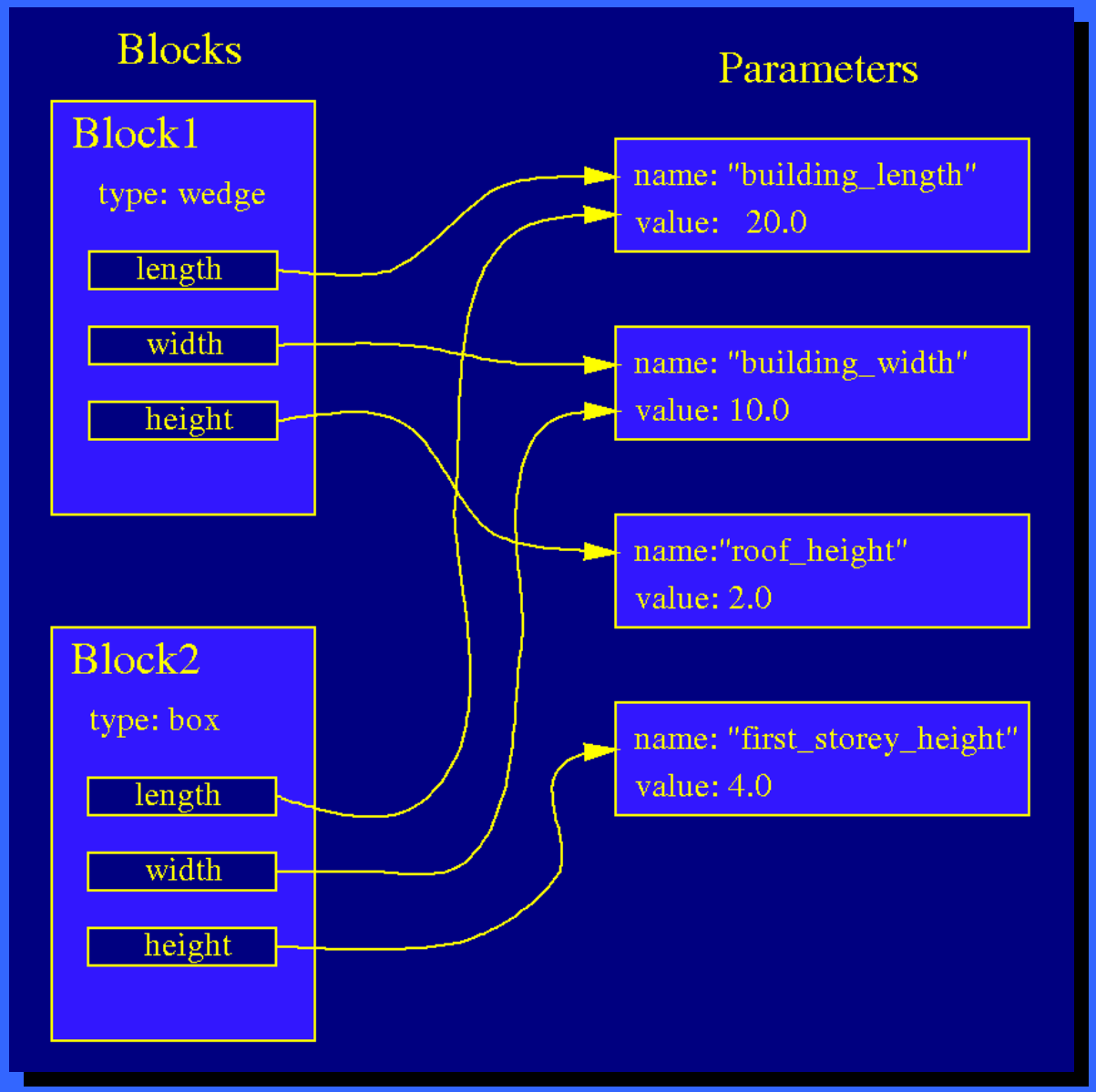
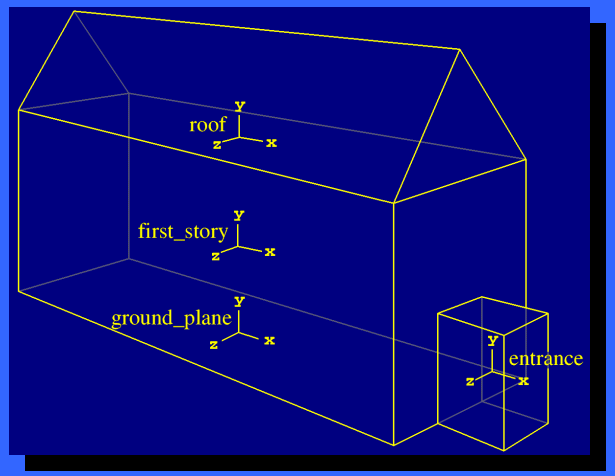
nwporch_z0
nwporch_z1
nwporch_x0
nwporch_x1
main_y (7)
Axis-Aligned
X
-1.333892
Y Block MIN Parent MIN
Z Block MIN Parent MAX
Twirl
Image Viewer
World Viewer
Camera Form
Block Form
Stereo Form
Image Info Form
Save
Quit
FACADE
Uni-0002cub.ppm
Uni-0005curb.ppm
Uni-0008cub.ppm
Uni-0009curb.ppm
Uni-0011curb.ppm
Uni-0012cub.ppm
Uni-0014curb.ppm
Uni-0015curb.ppm
Uni-0016cub.ppm
Uni-0017curb.ppm
Load...
Save
Save As...
Close

Façade Blocks



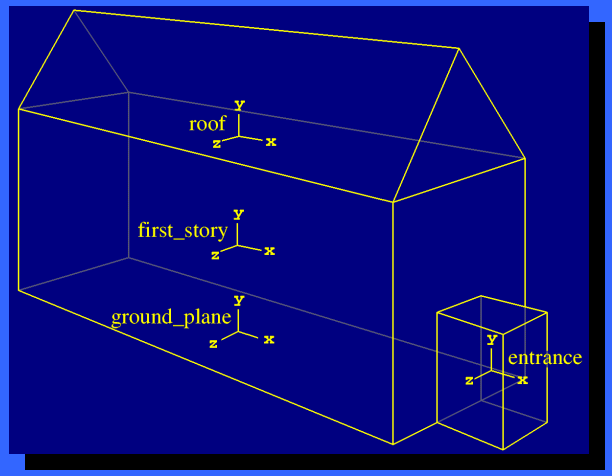
Parameterized Block

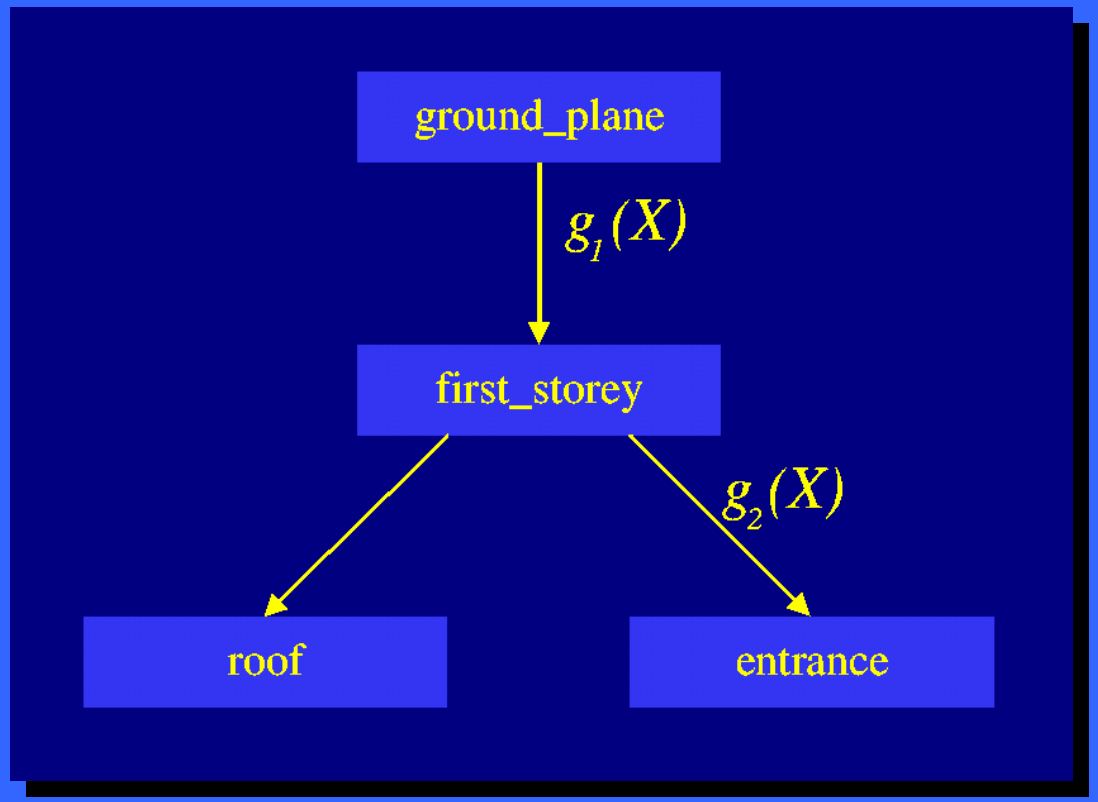




Parameter References

Model Hierarchy





Relation can be:

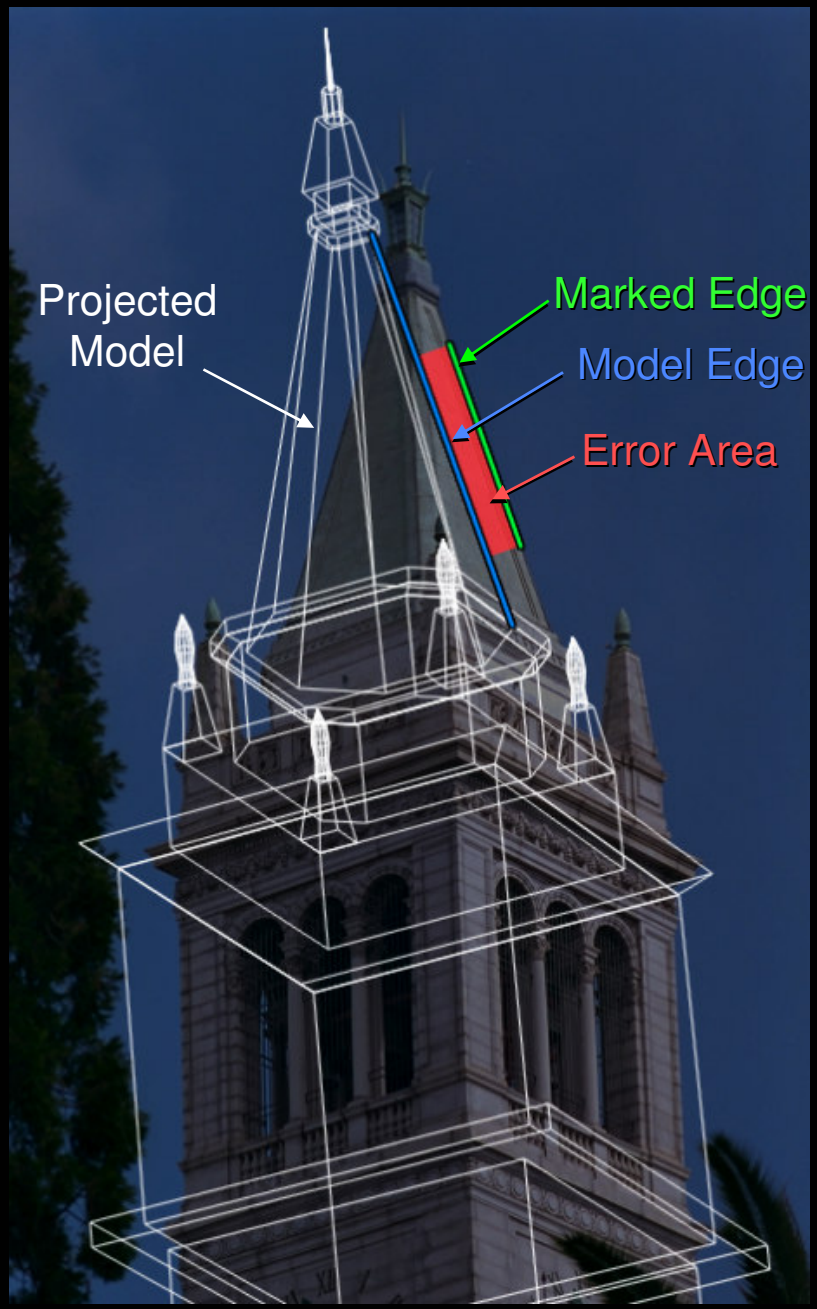
* Arbitrary 6 DOF
* Fixed Rotation
* Fixed Translation
* Geometric Relationship

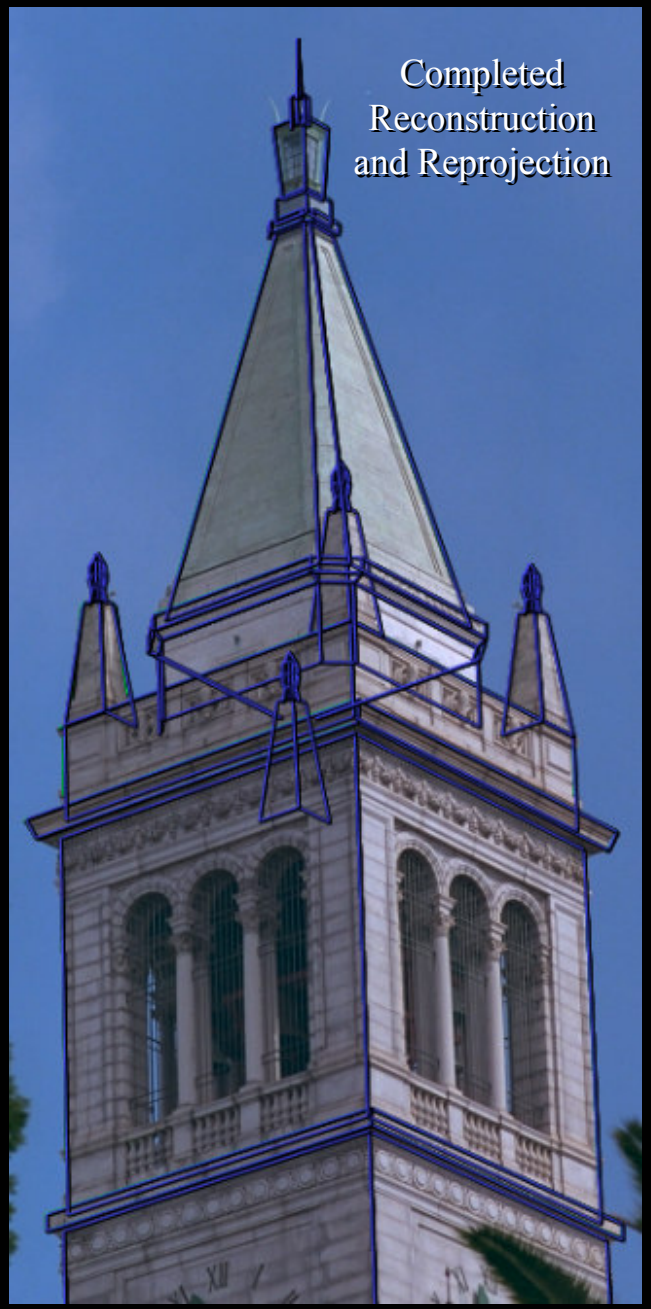
Reconstruction Algorithm

An objective function O measures the misalignment between the marked edges and the corresponding projected edges of the model

O is minimized with respect to the model parameters and camera positions

An initial estimate is obtained by a separate procedure


Projected
Model
Marked Edge
Model Edge
Error Area


Completed
Reconstruction
and Reprojection

Algorithm with Initial Estimate Procedure

1. Solve for camera rotations, independently, based on edge orientations
2. Hold camea rotations fixed; solve for other parameters (often linear)
3. Perform full non-linear optimization, starting from near the solution

Video

Photogrammetric Modeling Summary

Modeling with blocks works because:

Convenient for architecture

Recovers Complete Models

Reduces number of model parameters, e.g.

Campanile model has:

2,896 parameters as independent edges

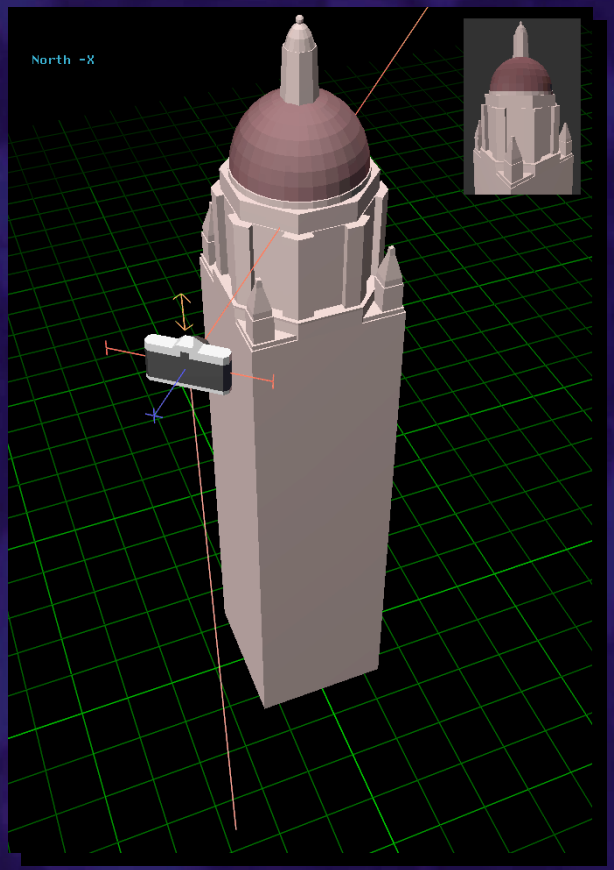
240 parameters as independent blocks

33 parameters as constrained blocks

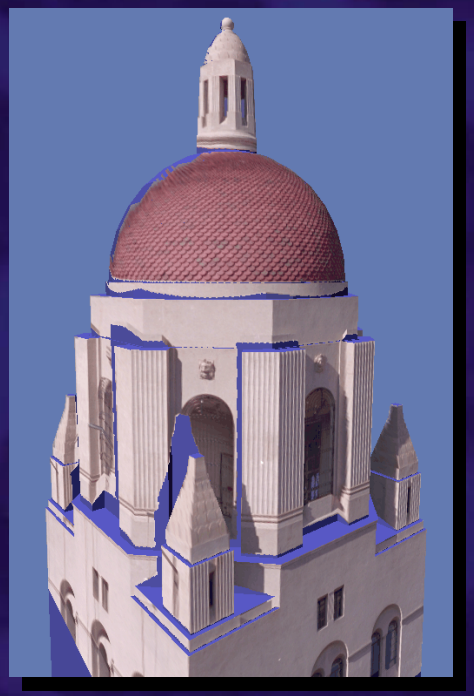
- → Few marked features required
- → Easier to solve

Surfaces of Revolution

Photograph

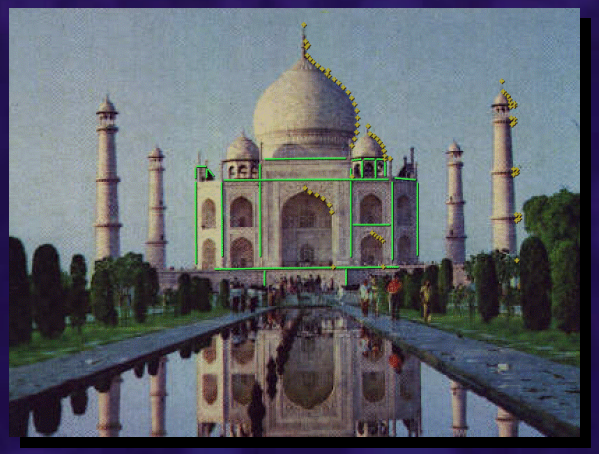


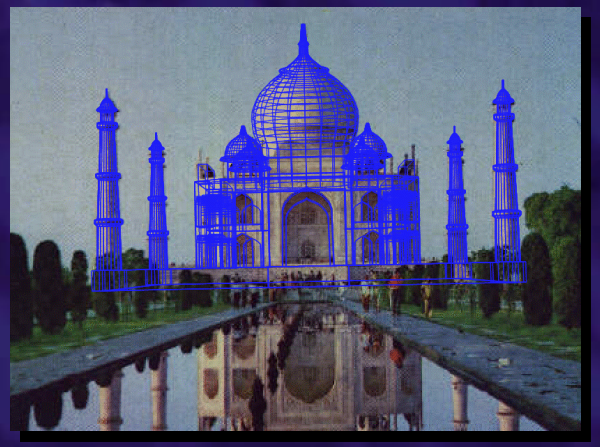
Recovered Model



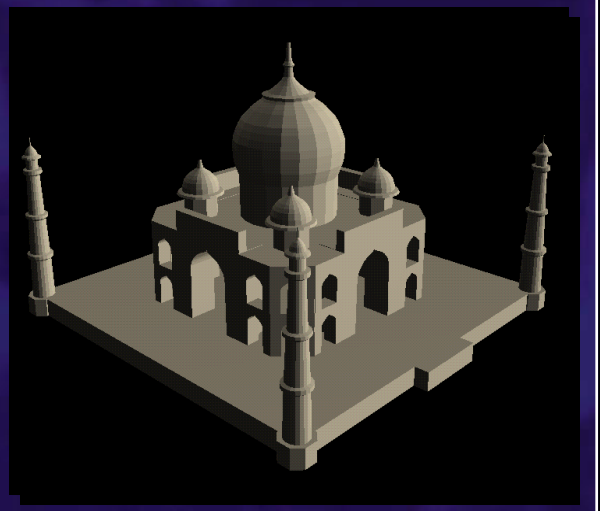
Synthetic View

Arches and Surfaces of Revolution

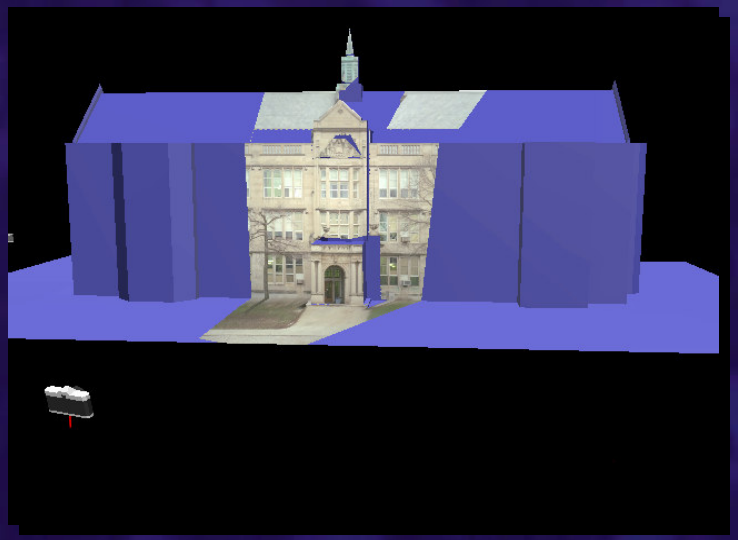


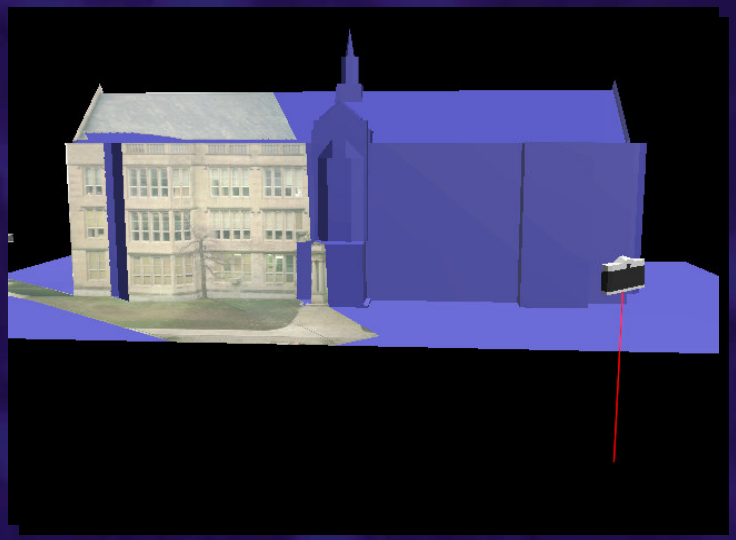


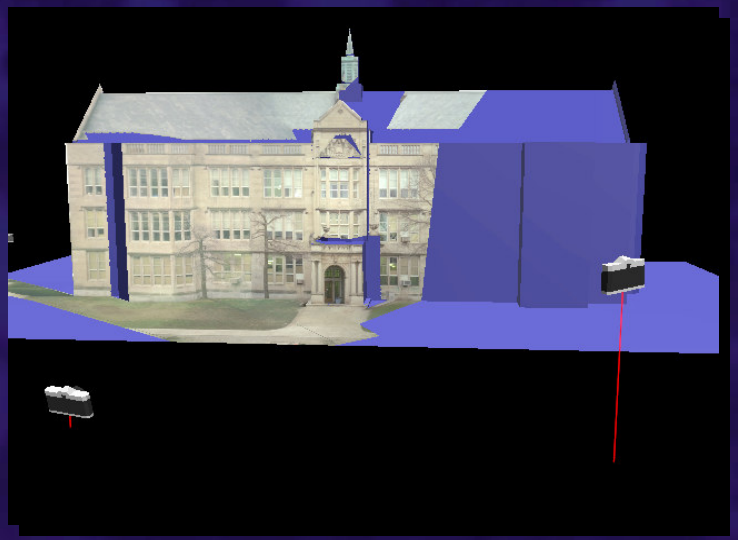
Taj Mahal modeled from one photograph

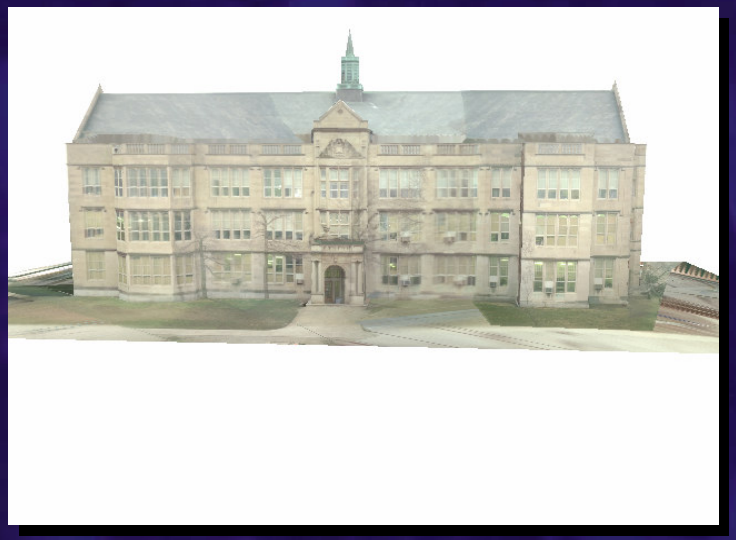


Rendering with Projective Texture Mapping

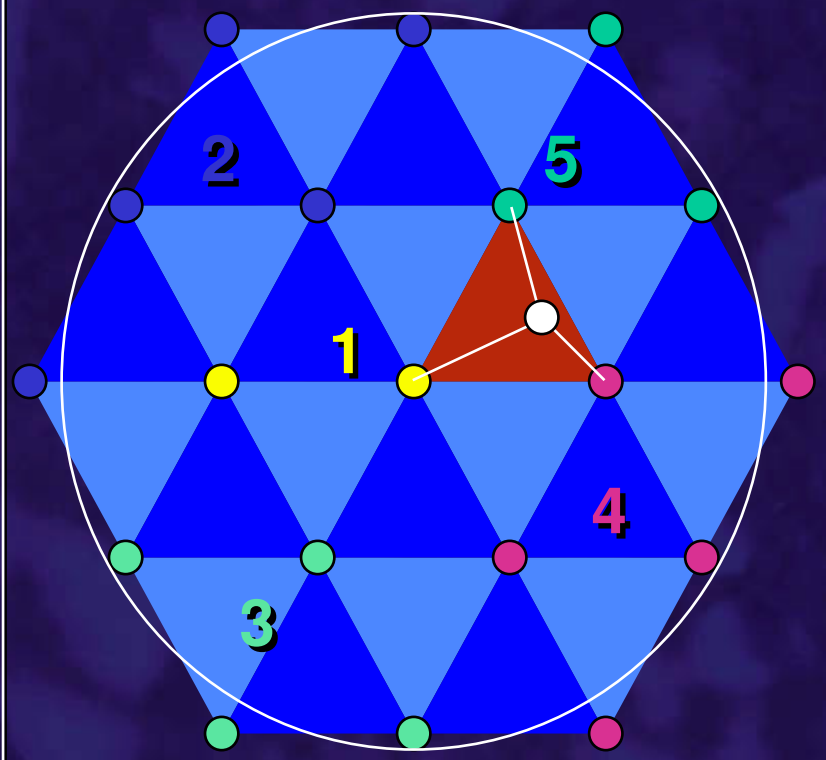








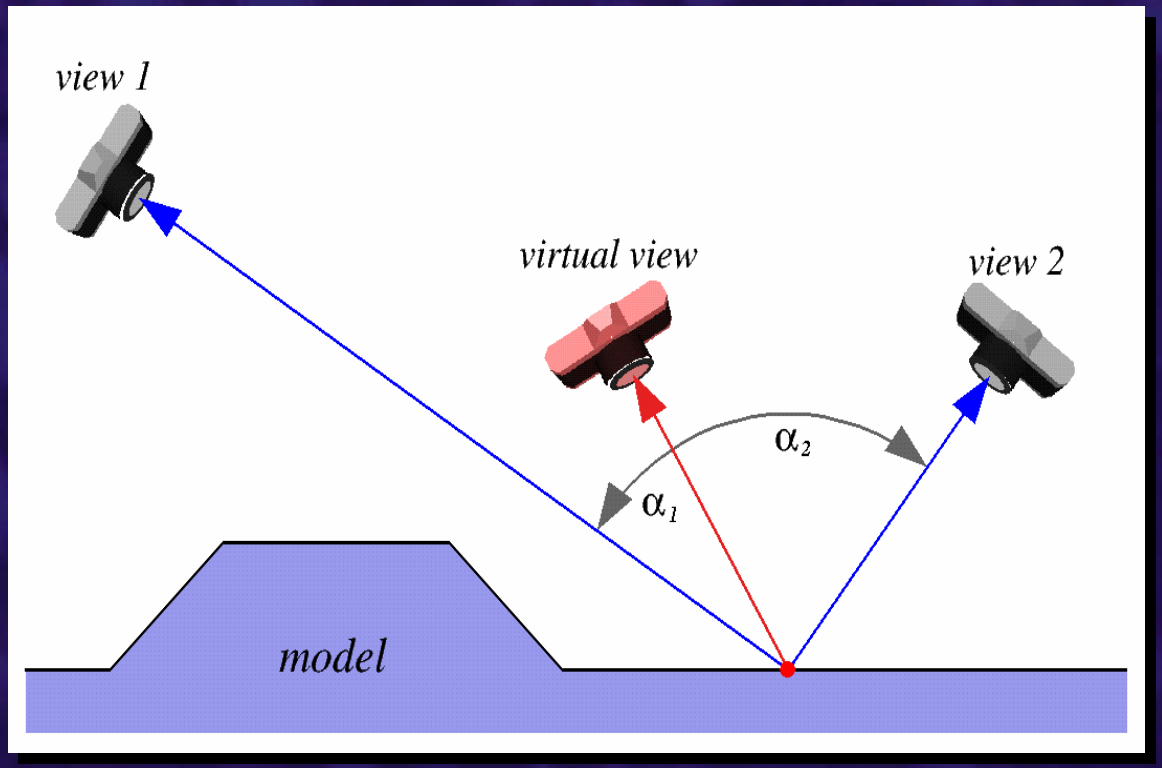
Rendering with View-Dependent Texture Mapping



- To render, determine to which triangle the viewpoint belongs
- Compute Barycentric weights for the triangle vertices
- Render the polygon with a weighted average of the three vertex images

Debevec, Borshukov, and Yu. Eurographics Rendering Workshop 1998.

View-Dependent Texture Mapping



View-Dependent Weighting Function

Image-Based Modeling, Rendering, and Lighting

SIGGRAPH 2000 Course #35

Tuesday, July 25, 2000

Room 243-245, Ernest N. Morial Convention Center

8:30am - 5:00pm

Paul Debevec
UC Berkeley

Leonard McMillan
MIT

Richard Szeliski
Microsoft Research

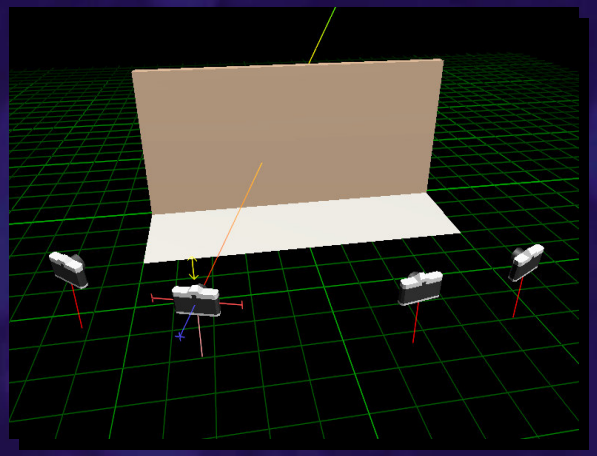
Michael Cohen
Microsoft Research

Chris Bregler
Stanford University

François Sillion
iMAGIS - GRAVIR/IMAG

Scene with Geometric Detail

Model-Based Stereo



Approximate Block Model

Model-Based Stereo

Given a key and an offset image,

- Project the offset image onto the model
- View the model through the key camera
  → Warped offset image

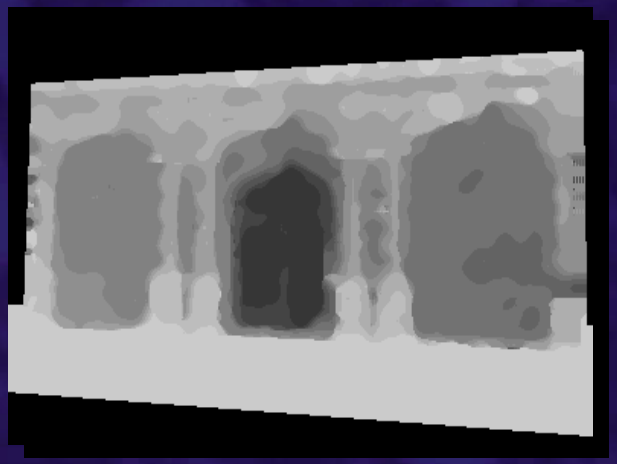
Stereo becomes feasible between key and warped offset images because:

- Disparities are small
- Foreshortening is greatly reduced

Key Image

Warped Offset Image

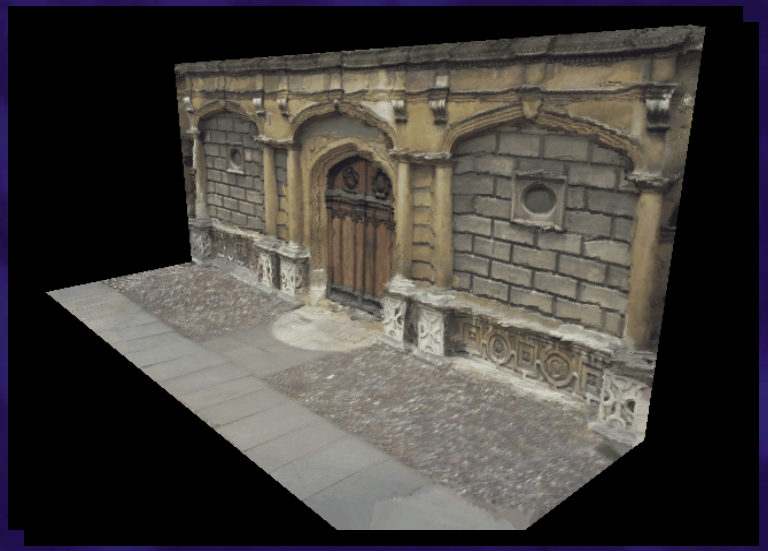
Offset Image



Disparity Map

Synthetic Views of Refined Model

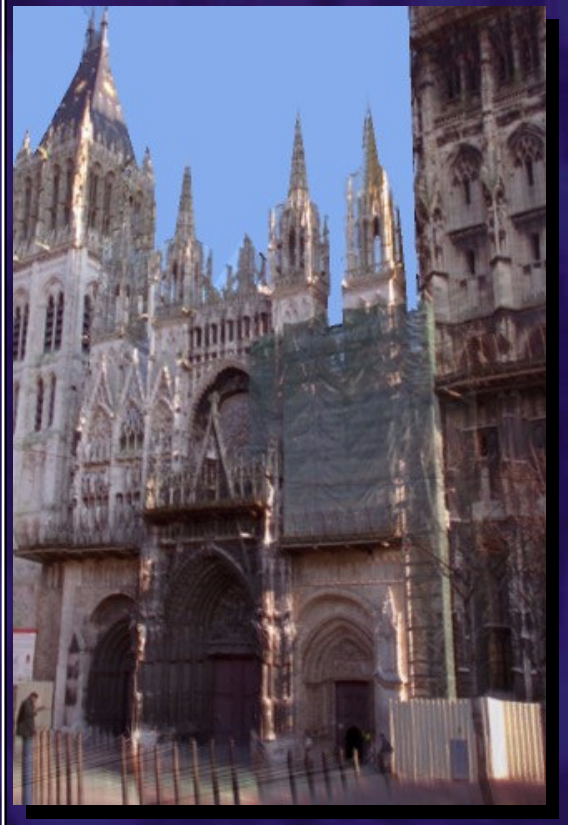
Four images composited with Model-Based Stereo and VDTM



Application: Rouen Revisited

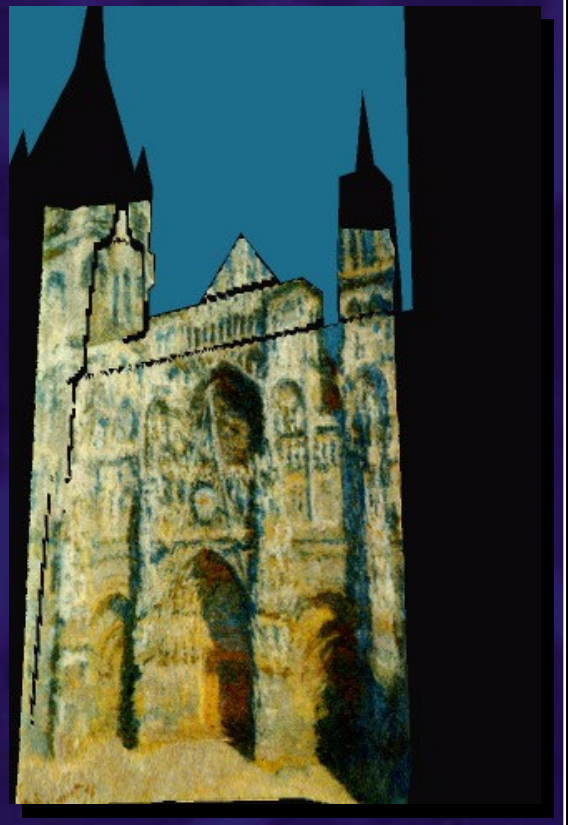
(Golan Levin and Paul Debevec)

www.debevec.org/Rouen



Synthetic View:
1996

Synthetic View:
1896



Synthetic View:
Monet Painting

(Uncalibrated Views)

Video

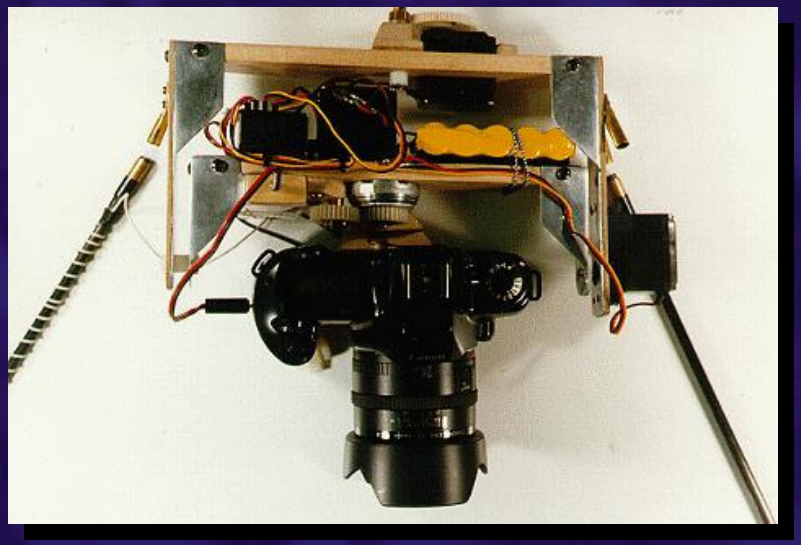
Application: The Campanile Movie

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

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.

Cris Benton: Kite Aerial Photography



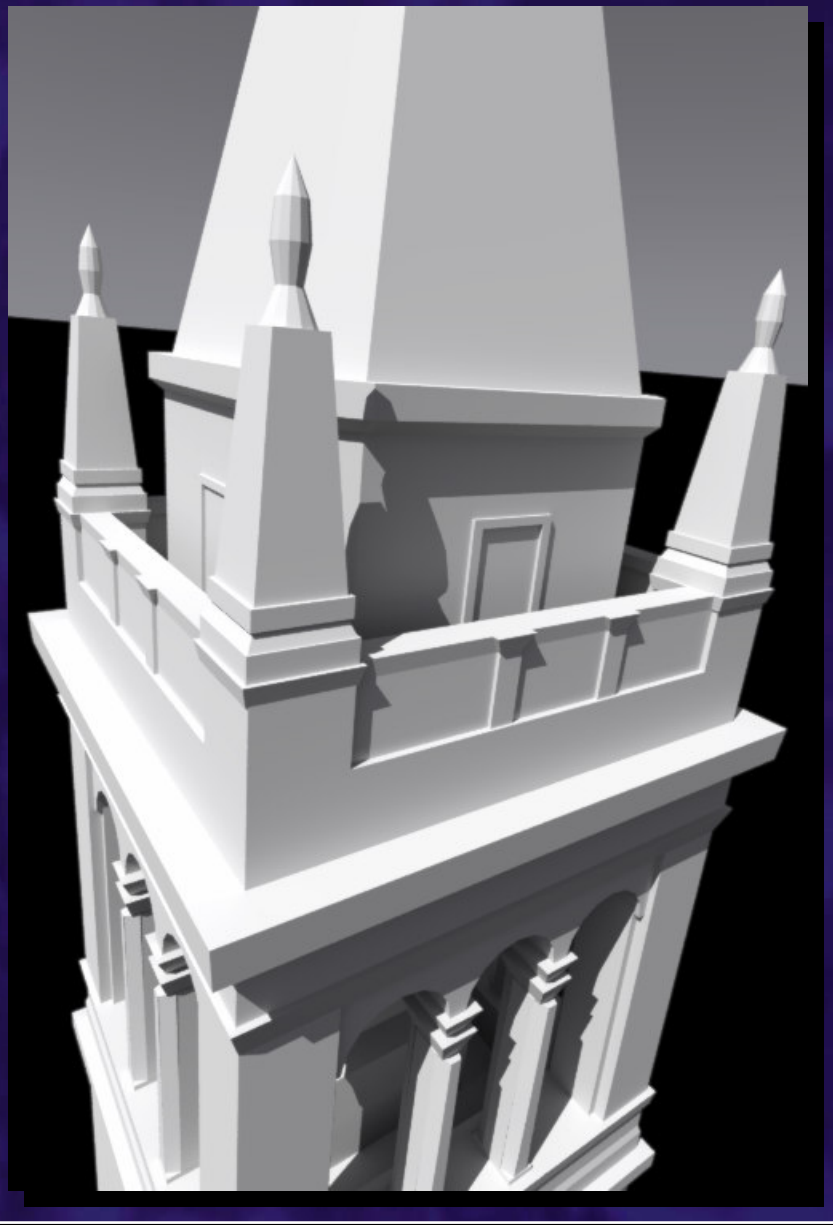
http://www-archfp.ced.berkeley.edu/kap/

Cris Benton: Kite Aerial Photography

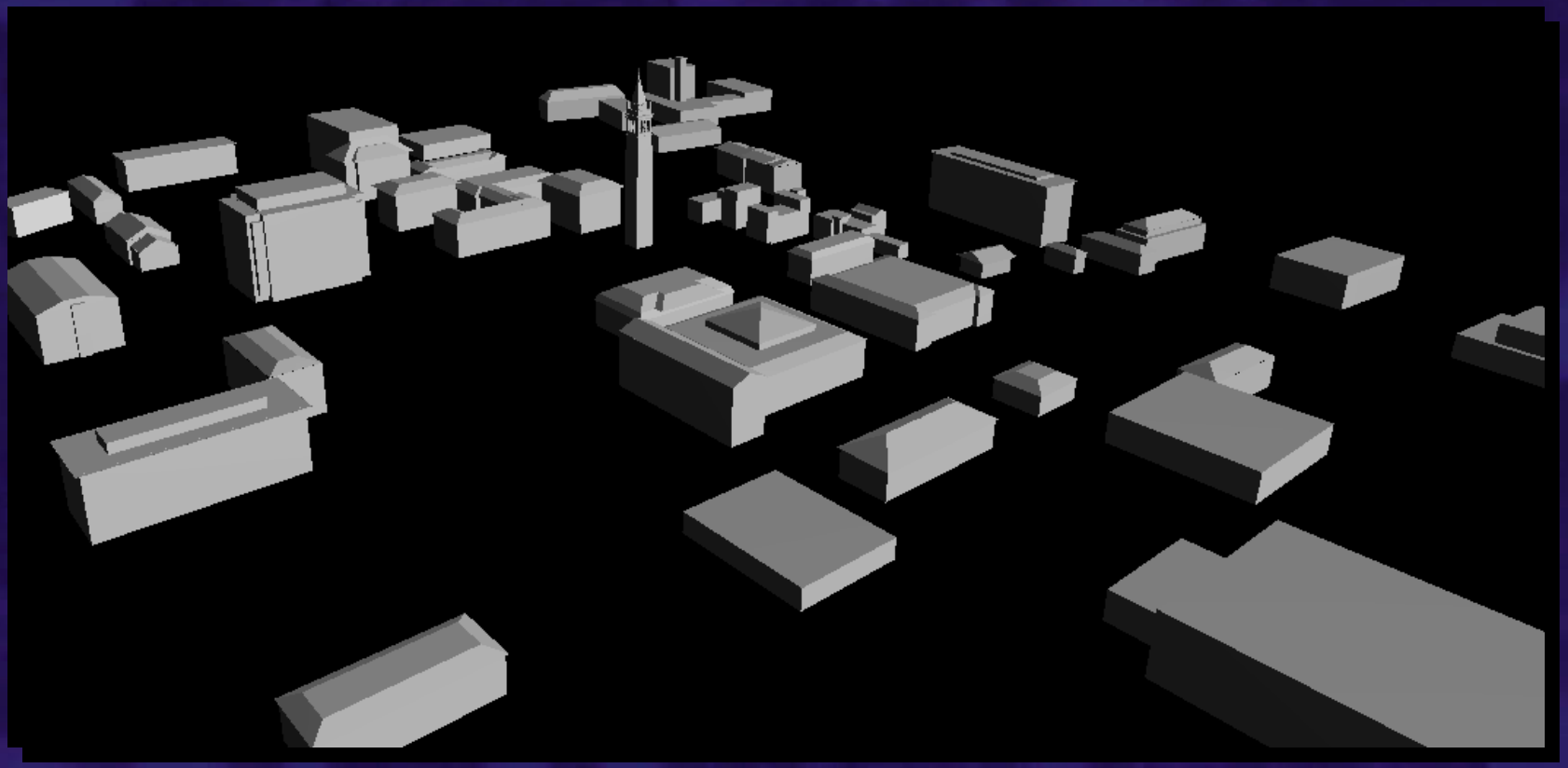
http://www-archfp.ced.berkeley.edu/kap/

Tower Photographs

Campanile Model



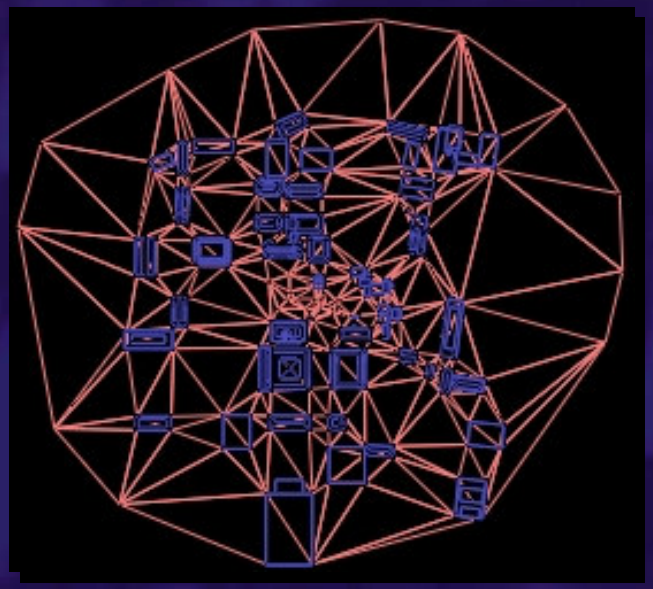
Environment Photographs

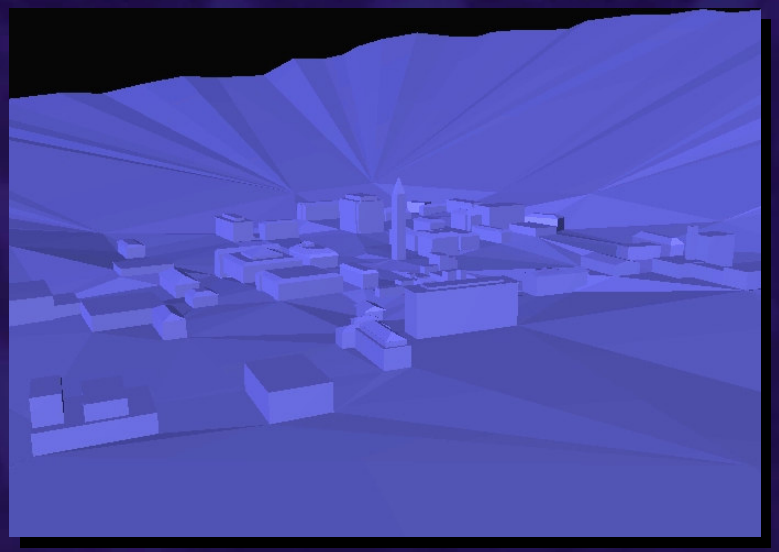


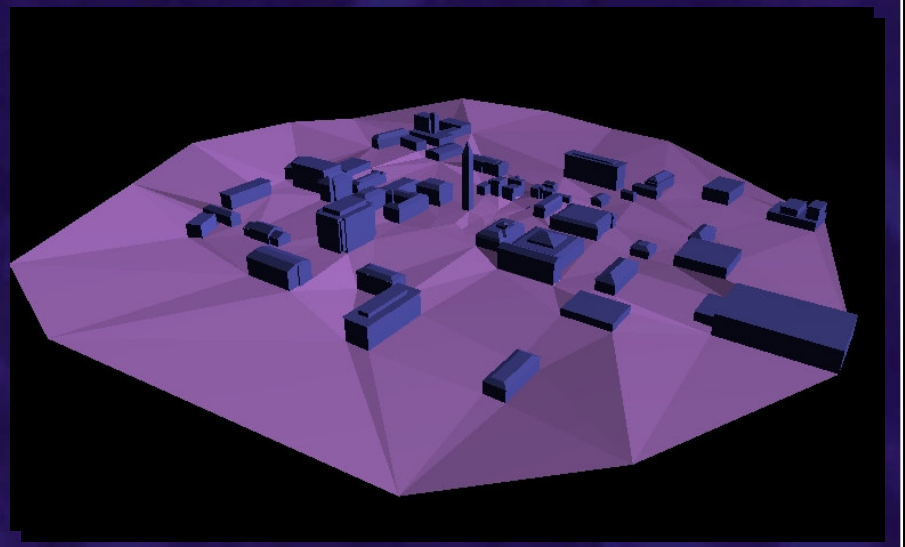
Campus Model (Campanile + 40 buildings)

Terrain Modeling

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





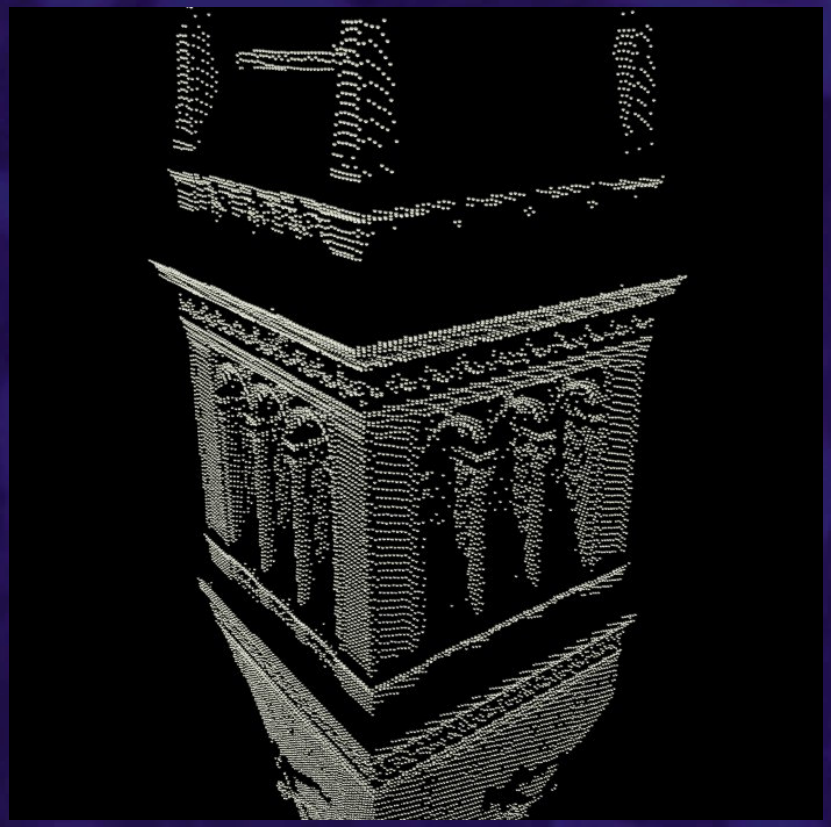


Video

A view from too far away

Comparison: Time-of-flight Laser Scanning

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

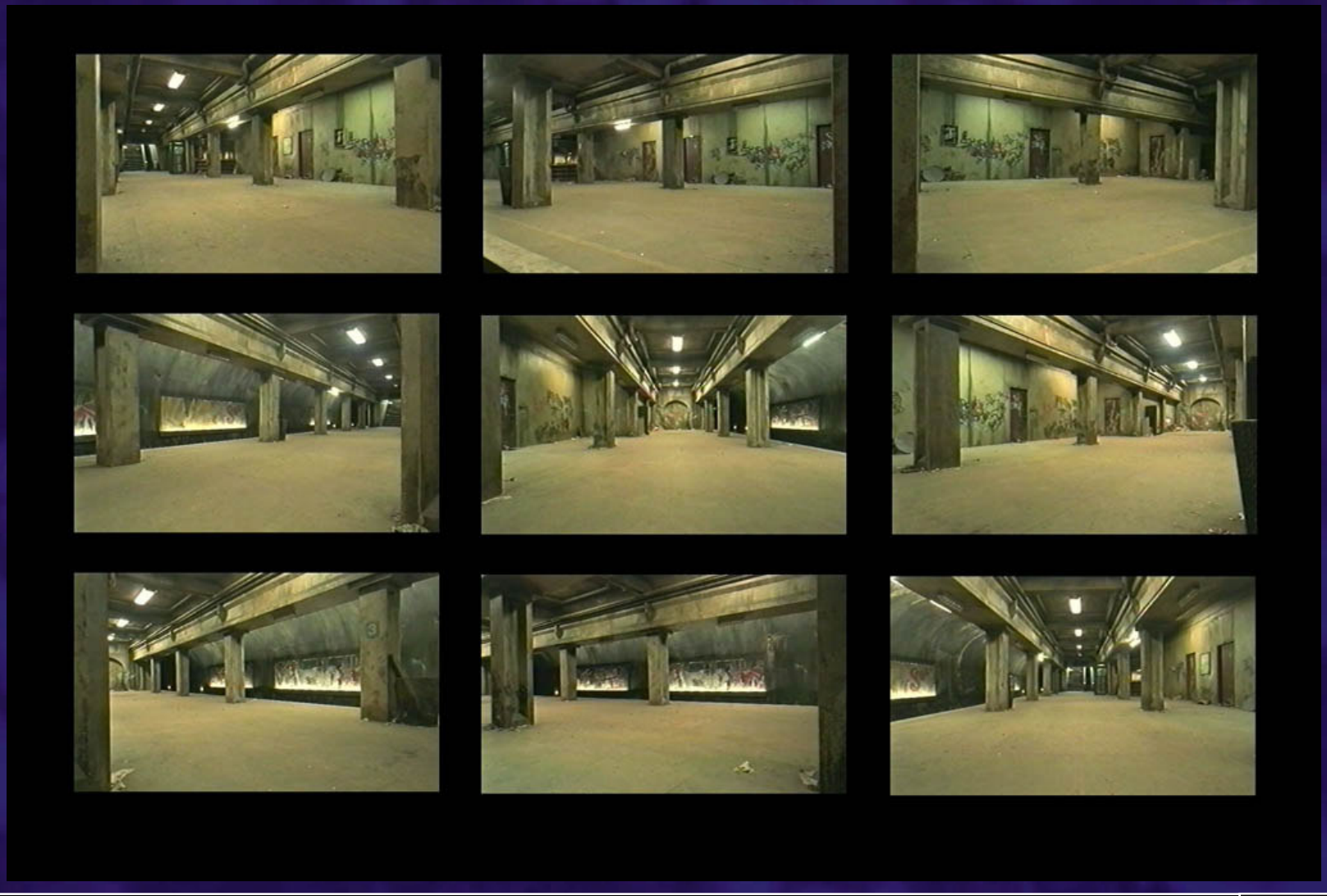


Application: The Matrix

www.mvfx.com

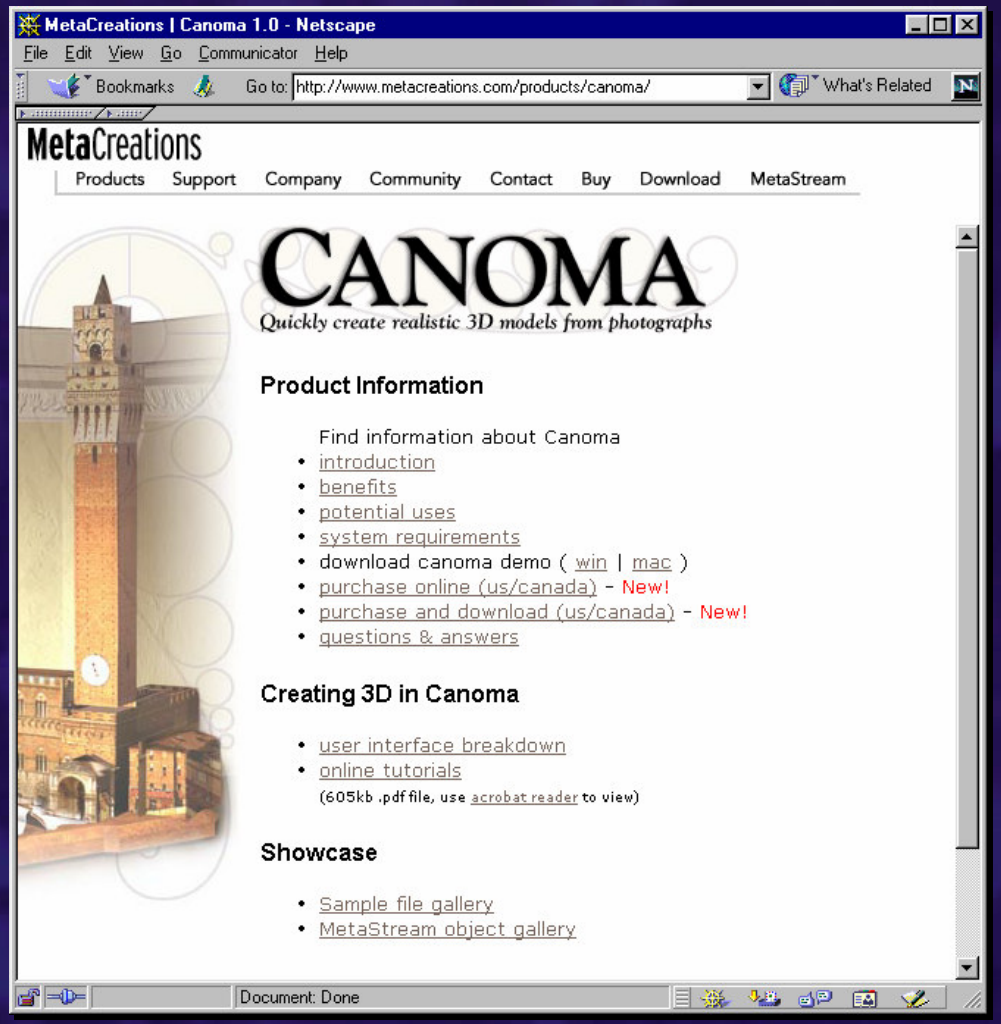
George Borshukov, Dan Piponi, Kim Libreri, and John Gaeta, MANEX Entertainment

The Matrix – Reconstruction Stills – EF9



Video

Commercial Product: Metacreations (now Adobe) Canoma



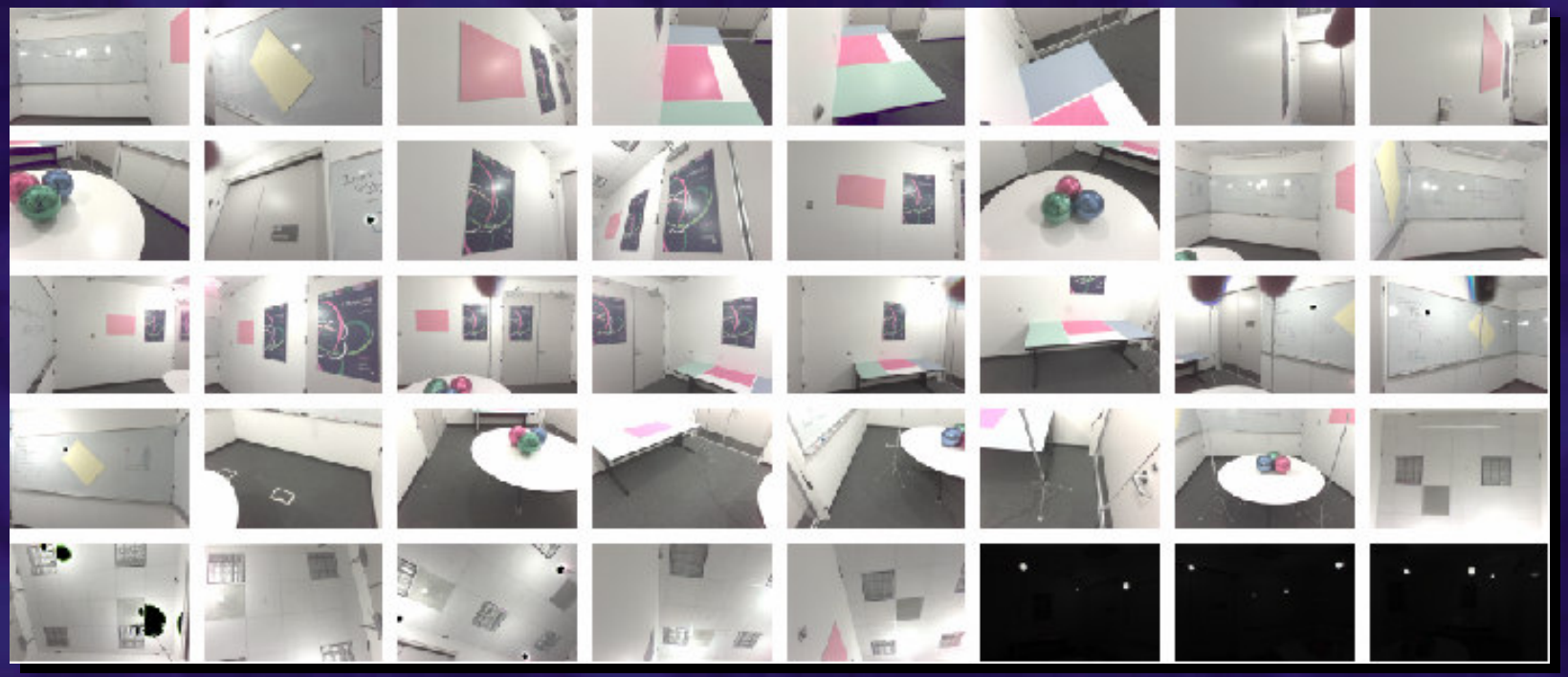
www.metacreations.com/canoma

www.canoma.com

Application: Inverse Global Illumination

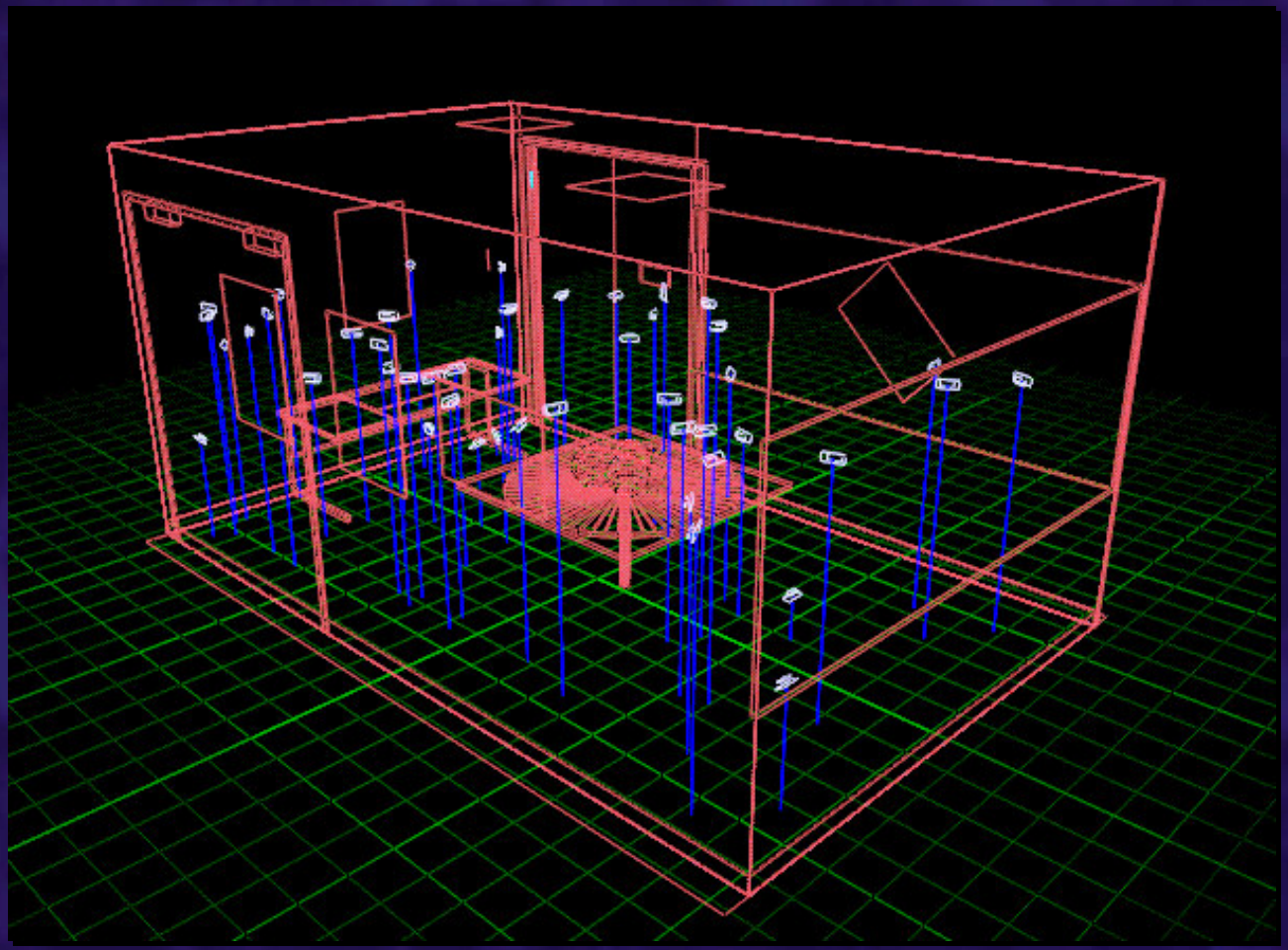
Yizhou Yu, Paul Debevec, Jitendra Malik, Tim Hawkins

SIGGRAPH 99



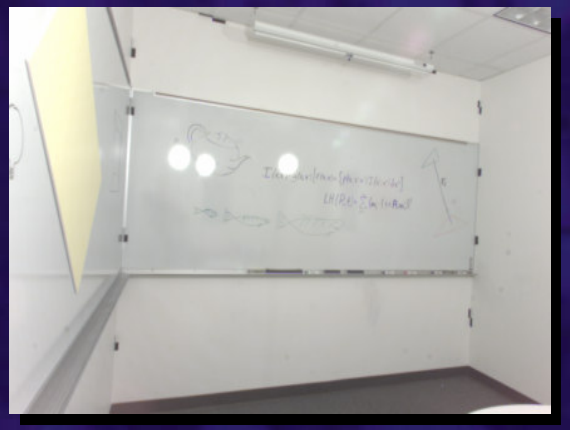
40 radiance maps of a room

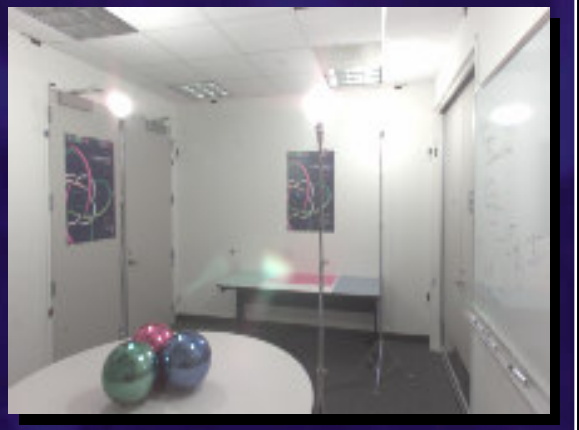
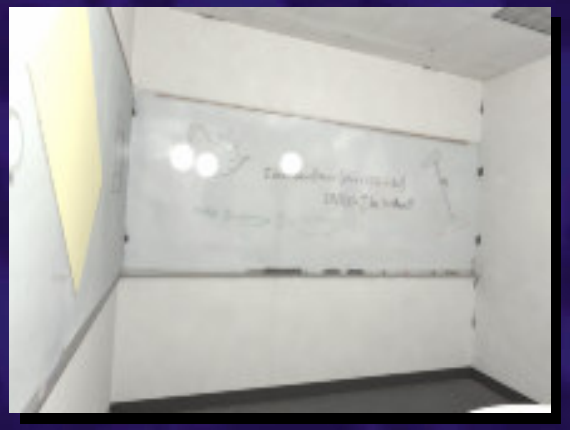
Recovered Geometry and Viewpoints

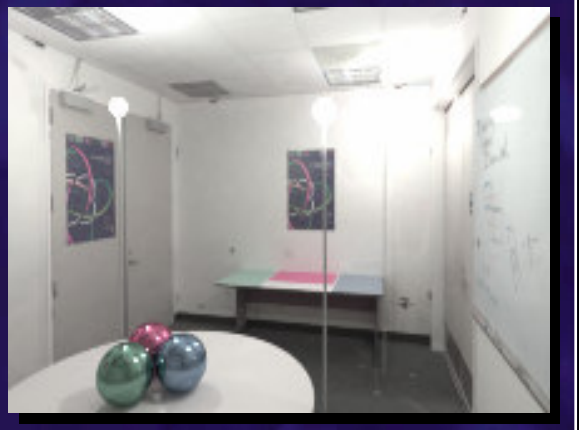


Real/Synthetic Comparison

Same viewpoints, Same lighting, Same objects

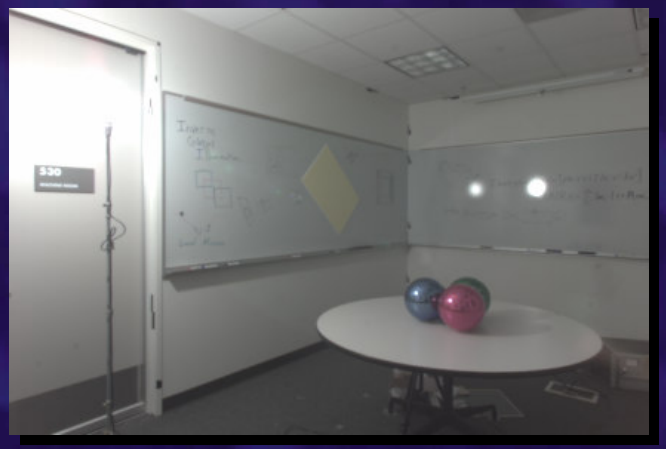




Real/Synthetic Comparison

New viewpoint, New lighting, New object



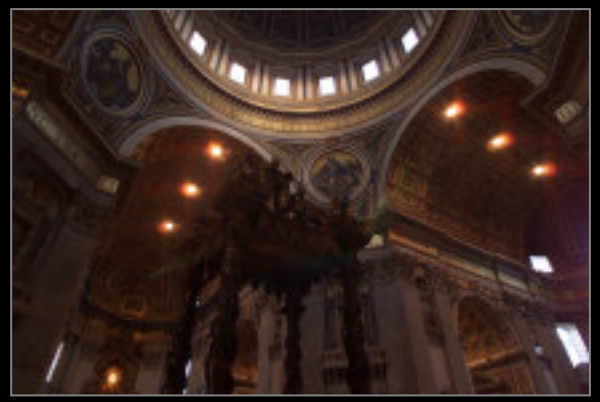
MODELING IN *FIAT LUX*

Paul Debevec, Tim Hawkins, Westley Sarokin, H. P. Duiker, Christine Cheng, Tal Garfinkel, Jenny Huang

Radiance Image Data

Debevec and Malik. Recovering High Dynamic Range Radiance Maps from Photographs. SIGGRAPH 1997.

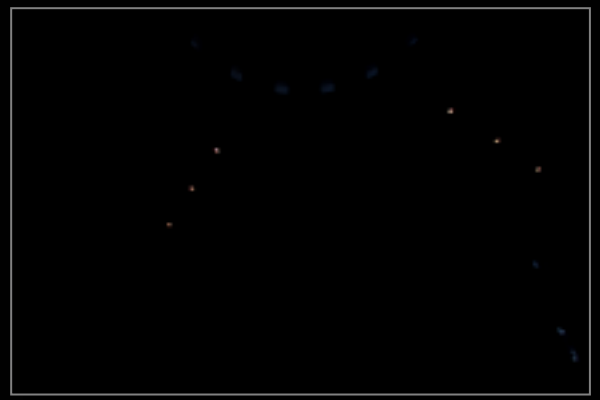
2 sec



1/4 sec

1/30 sec

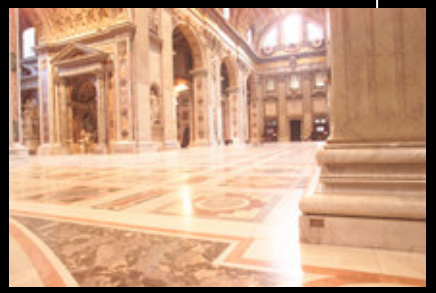
1/250 sec



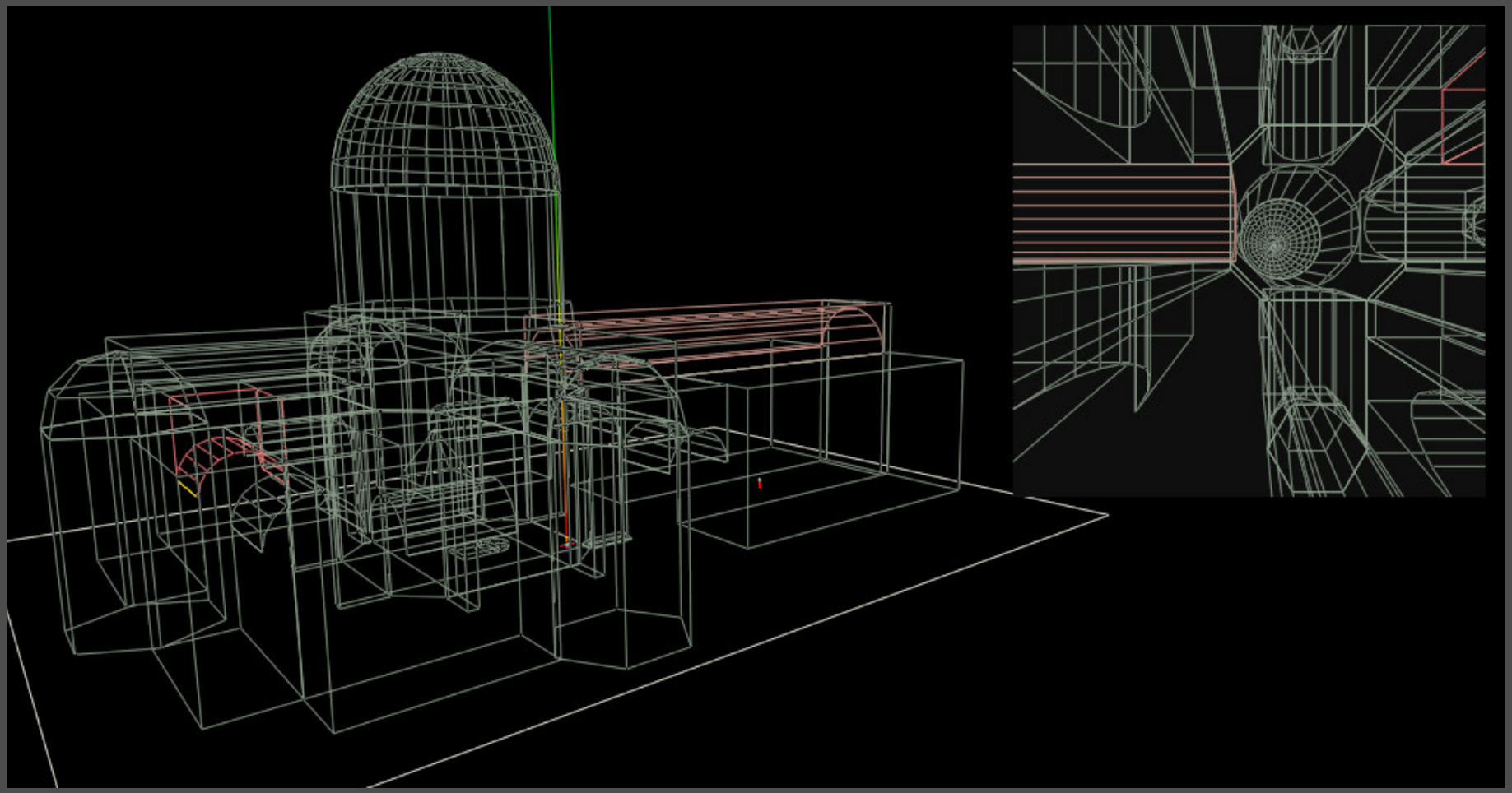
1/2000 sec

1/8000 sec

Stp1 Panorama



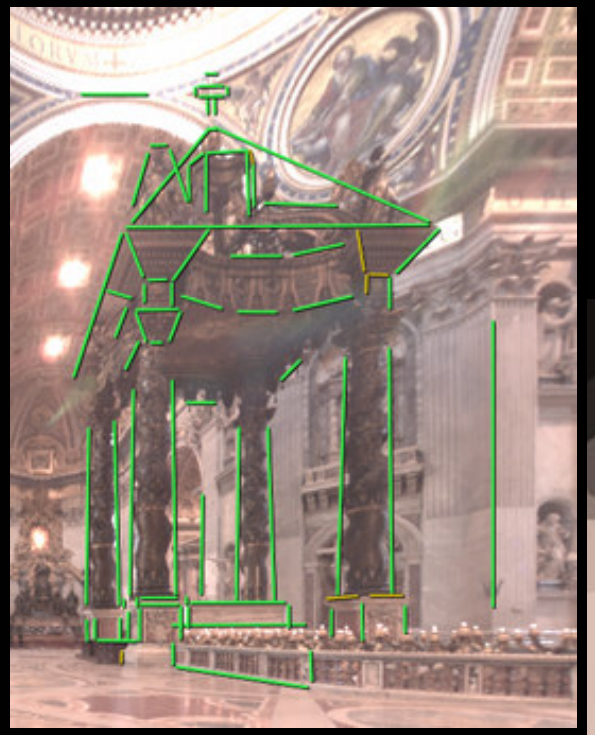
Assembled Panorama

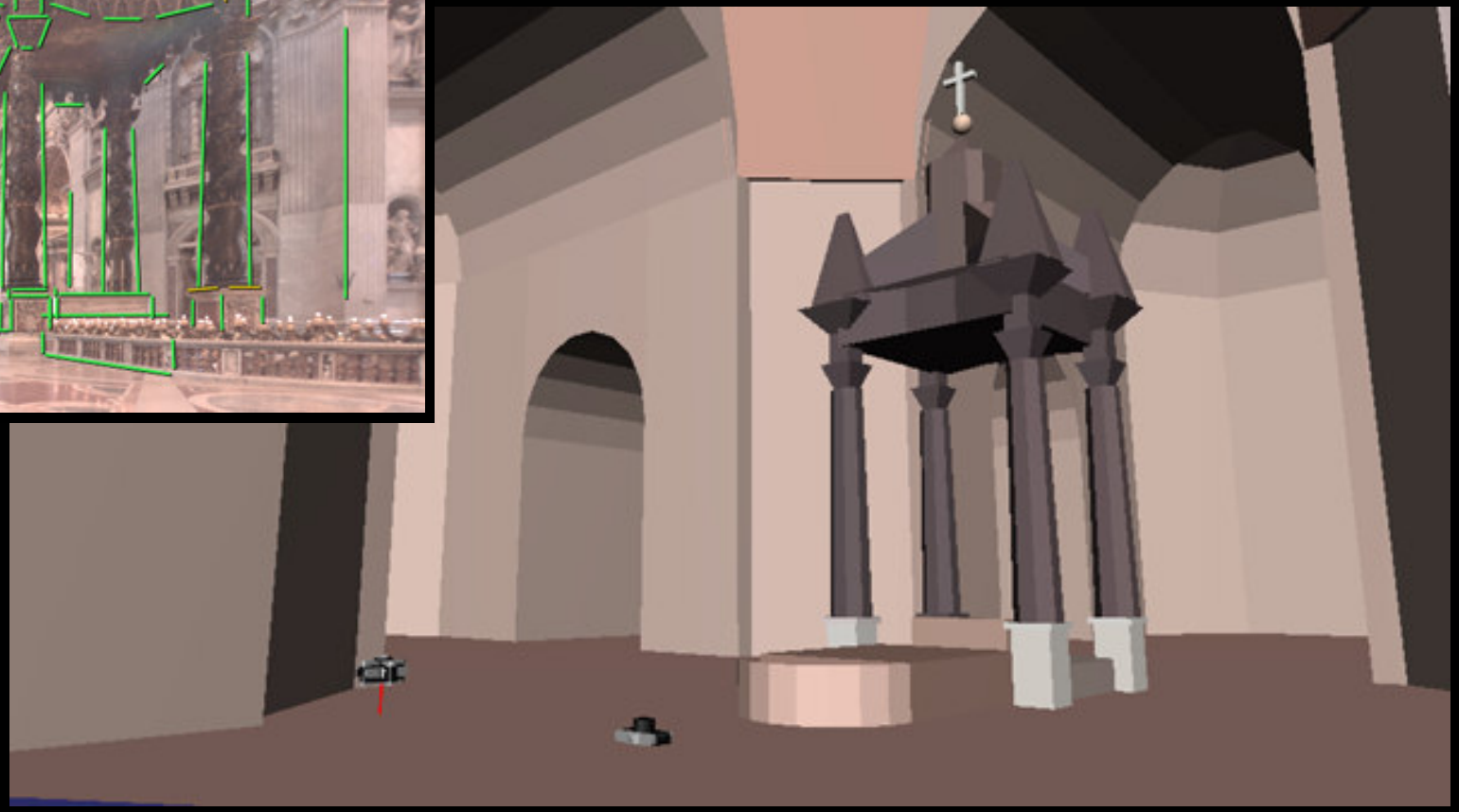


Interior model recovered from panorama

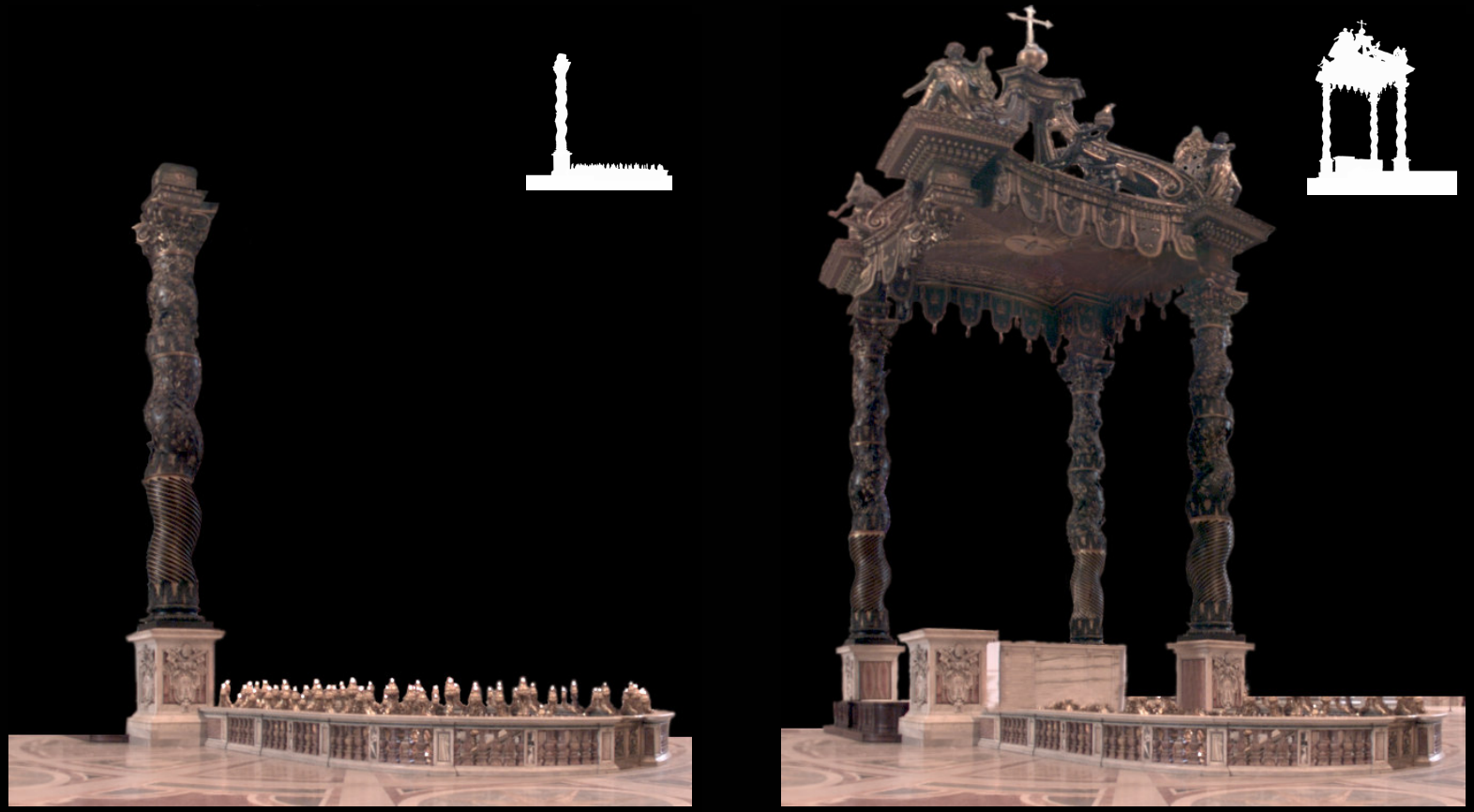
(35 parameters)

Baldacchino Model



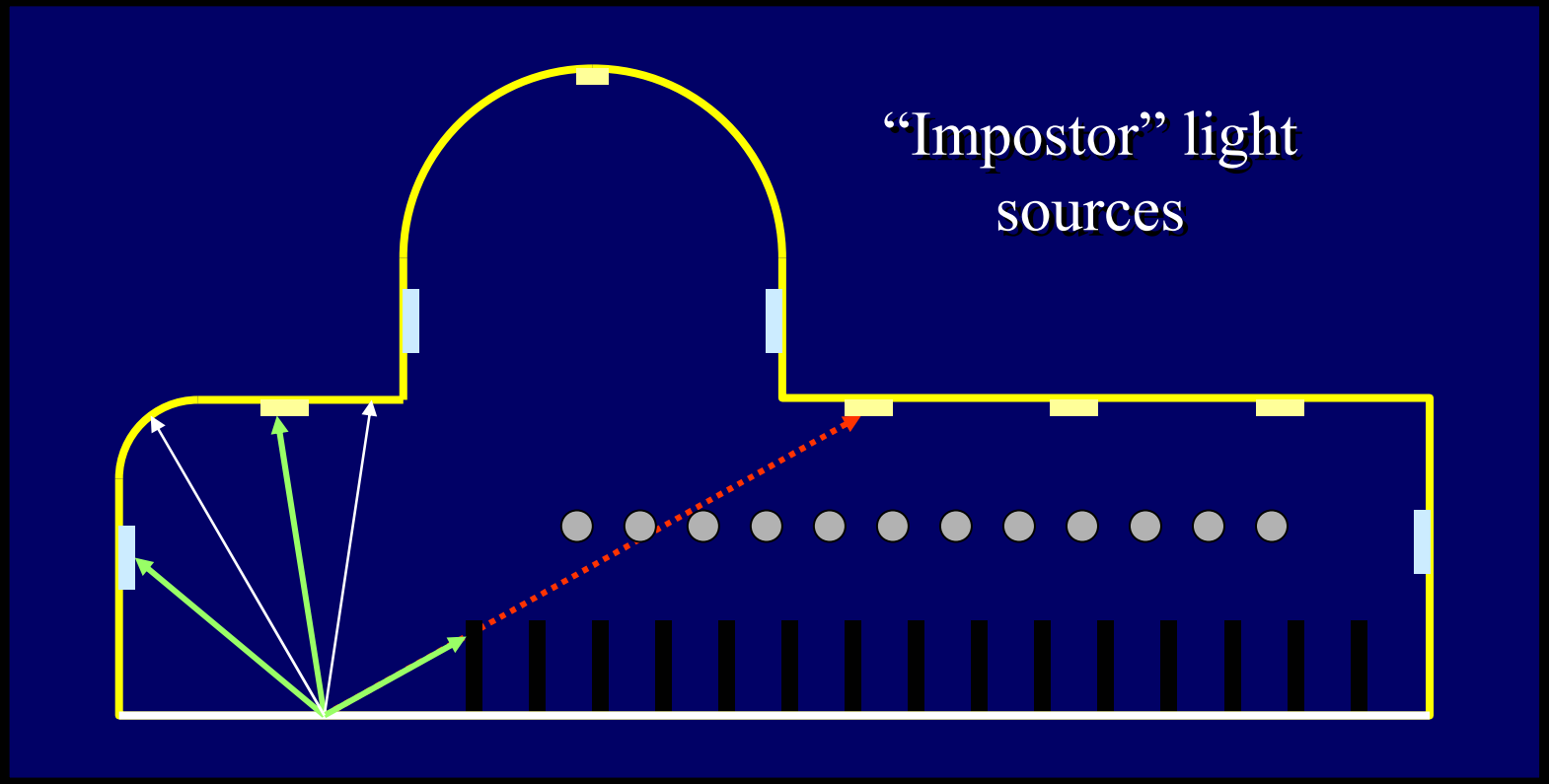


Baldacchino Layers



Light Probe Images

Lighting Calculation



Renderings made with Radiance: http://radsite.lbl.gov/radiance/

Synthetic Objects

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