Modeling and Rendering Architecture from Photographs

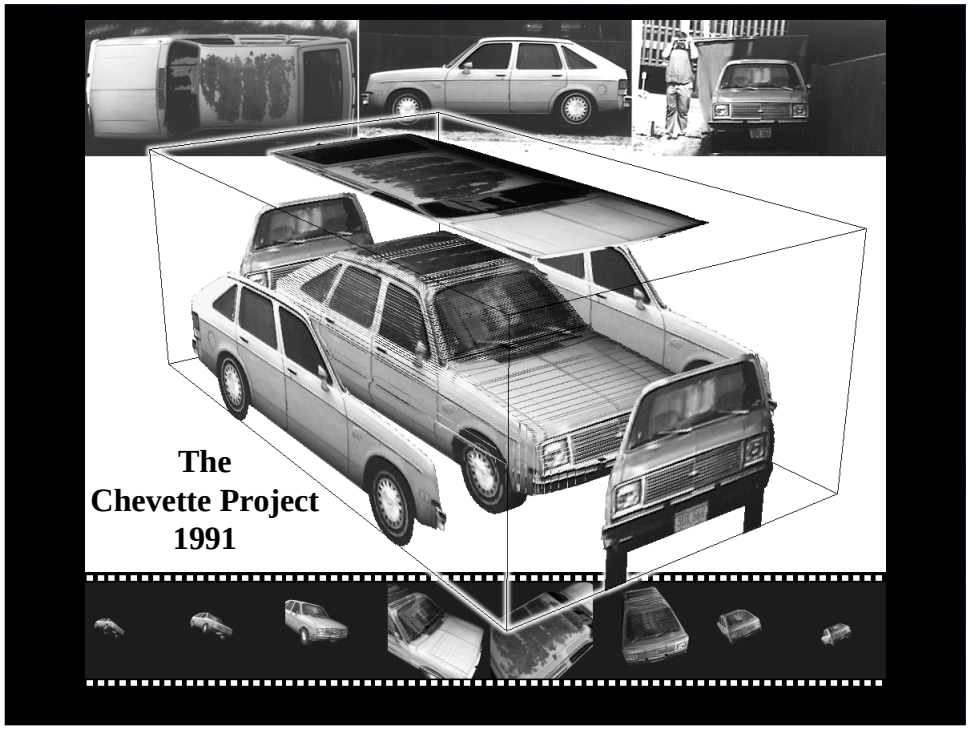
Paul Debevec

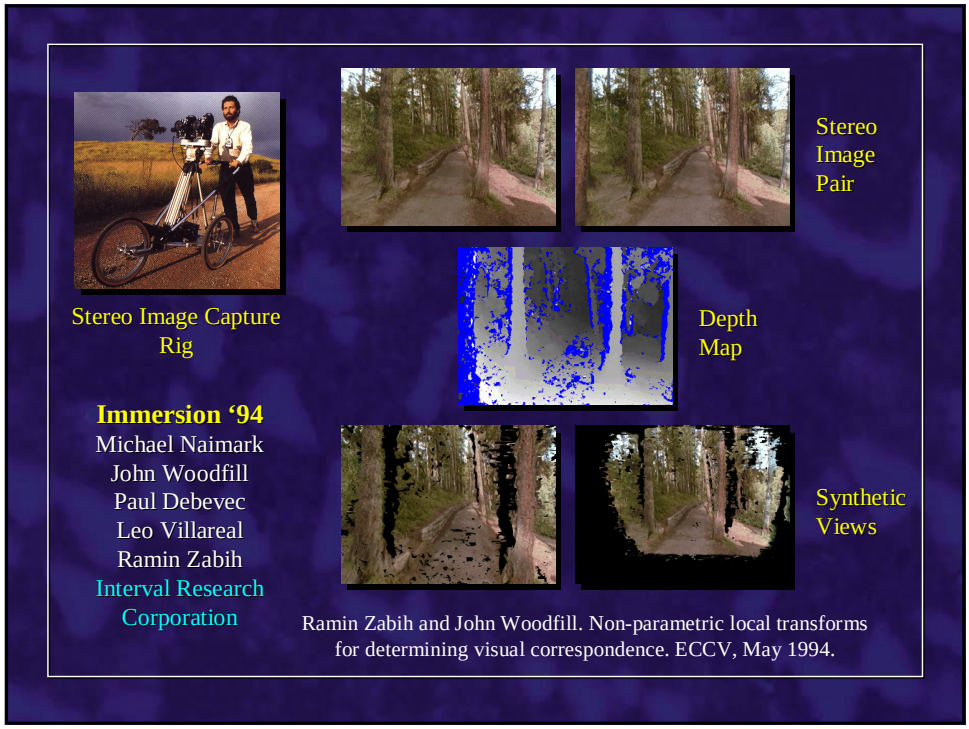
University of Southern California
Institute for Creative Technologies

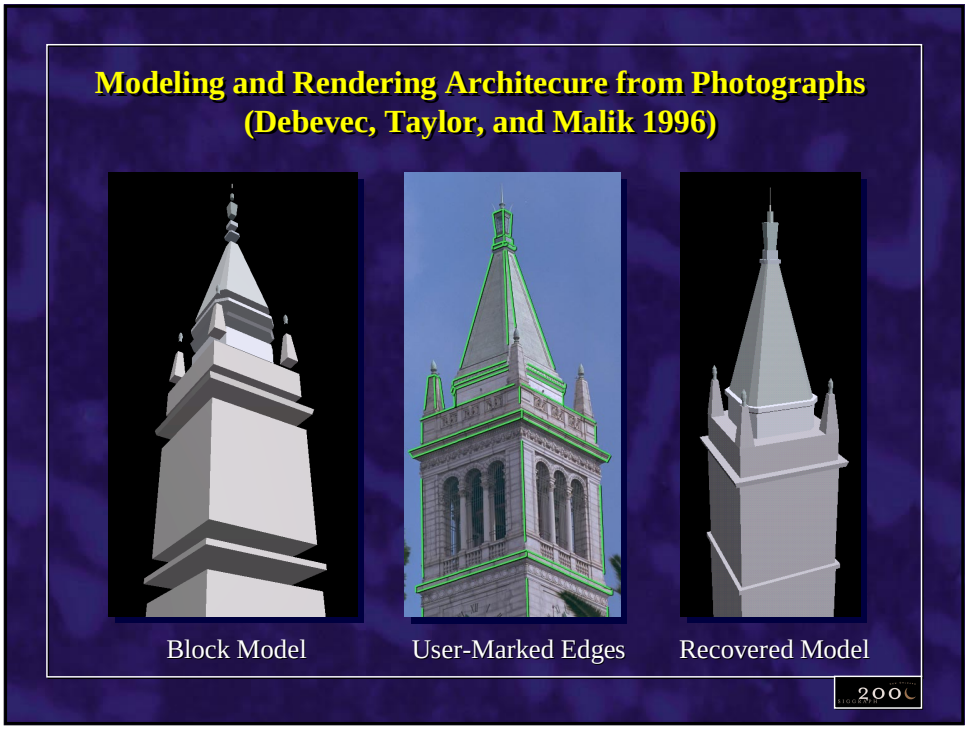
SIGGRAPH 2000 Course #19, 3D Photography
Brian Curless and Steve Seitz, organizers

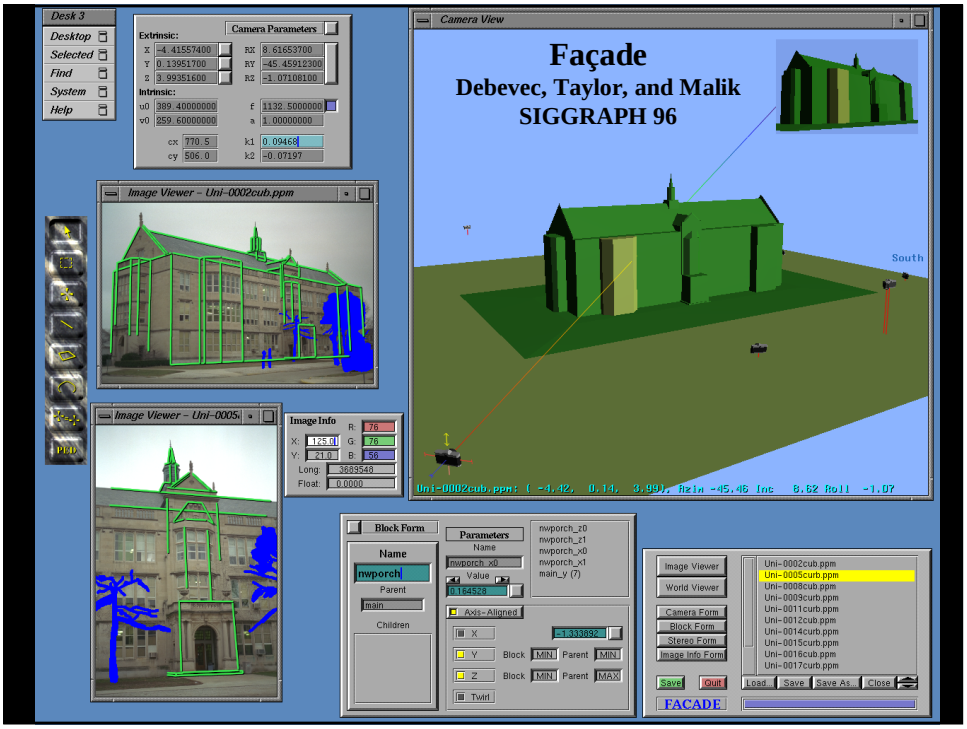
July 24, 2000

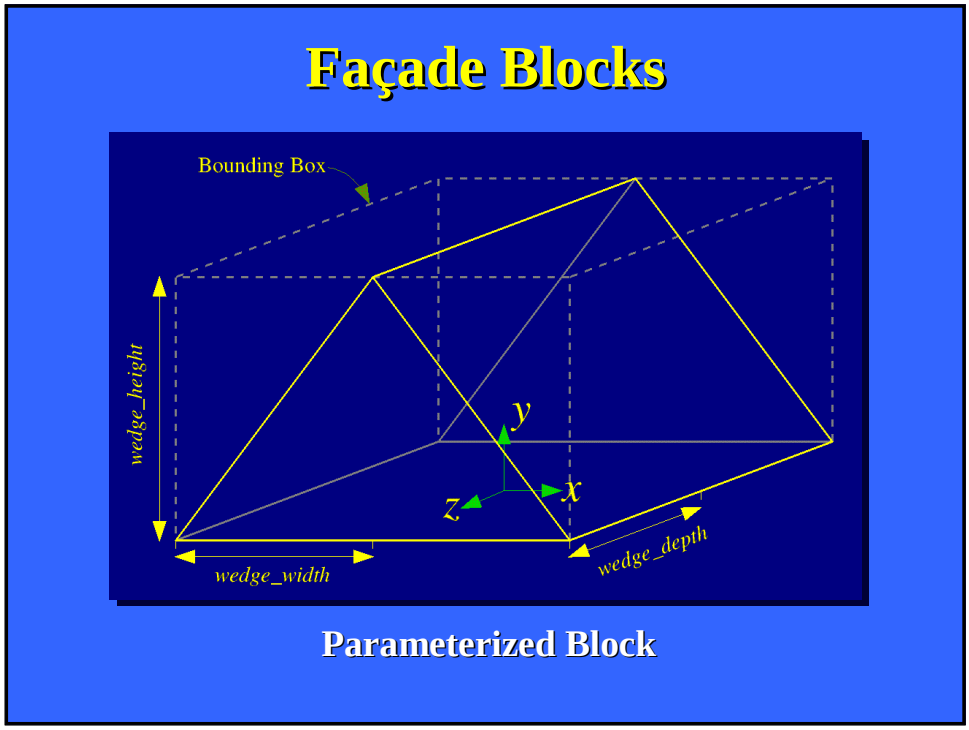
www.debevec.org

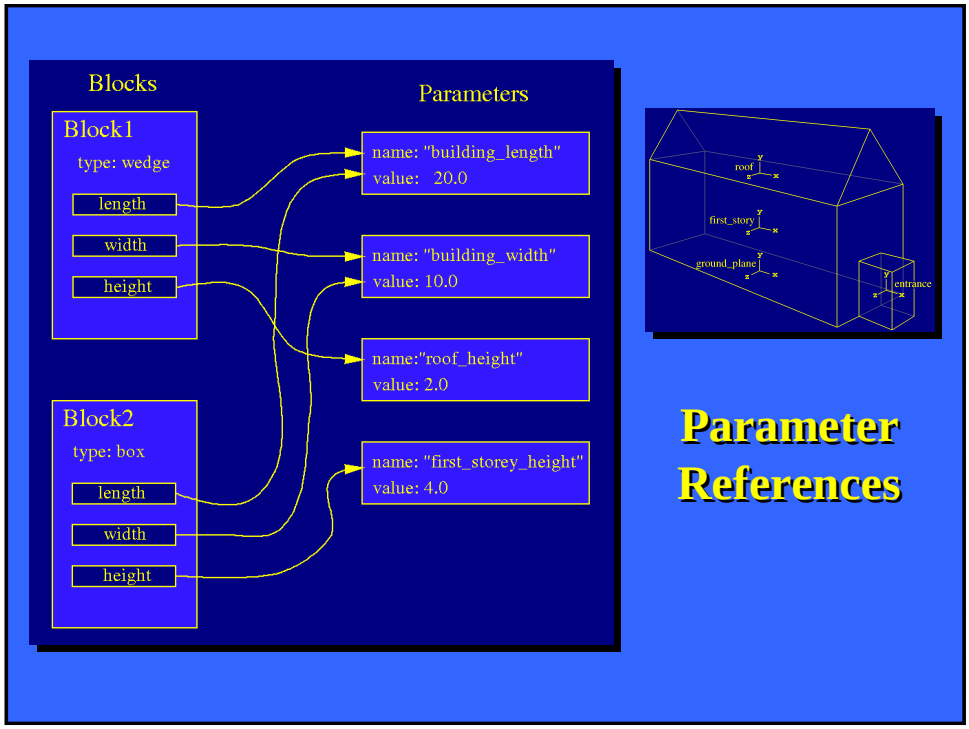

The
Chevette Project
1991

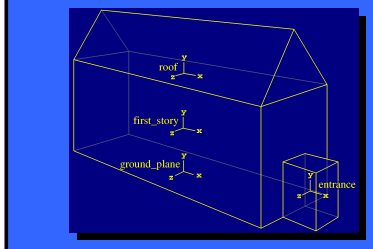

Stereo Image Capture Rig
Immersion '94
Michael Naimark
John Woodfill
Paul Debevec
Leo Villareal
Ramin Zabih
Interval Research Corporation
Stereo Image Pair
Depth Map
Synthetic Views
Ramin Zabih and John Woodfill. Non-parametric local transforms for determining visual correspondence. ECCV, May 1994.


Modeling and Rendering Architecure from Photographs
(Debevec, Taylor, and Malik 1996)
Block Model
User-Marked Edges
Recovered Model

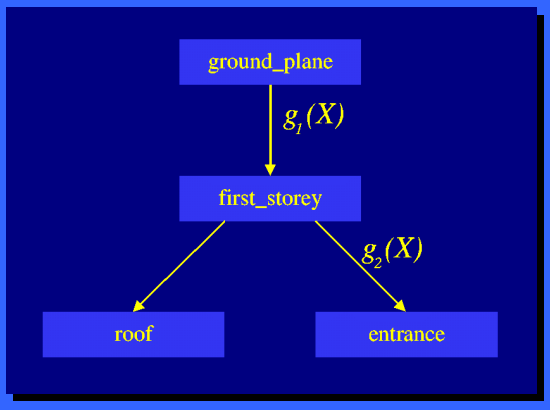

Façade
Debevec, Taylor, and Malik
SIGGRAPH 96
Desk 3
Desktop
Selected
Find
System
Help
Camera Parameters
Extrinsic:
Intrinsic:
Camera View
Image Viewer - Uni-0002cub.ppm
Image Viewer - Uni-0005
Image Info
South
Block Form
Name
nwporch
Parent
main
Children
Parameters
Image Viewer
World Viewer
Camera Form
Block Form
Stereo Form
Image Info Form
Save
Quit
FACADE
Load
Save
Save As
Close


Façade Blocks
Bounding Box
wedge_height
y
x
z
wedge_width
wedge_depth
Parameterized Block


Blocks
Parameters
Block1
type: wedge
length
width
height
name: "building_length"
value: 20.0
name: "building_width"
value: 10.0
name:"roof_height"
value: 2.0
Block2
type: box
length
width
height
name: "first_storey_height"
value: 4.0
roof
first_story
ground_plane
entrance
Parameter References



Model Hierarchy



Relation can be:

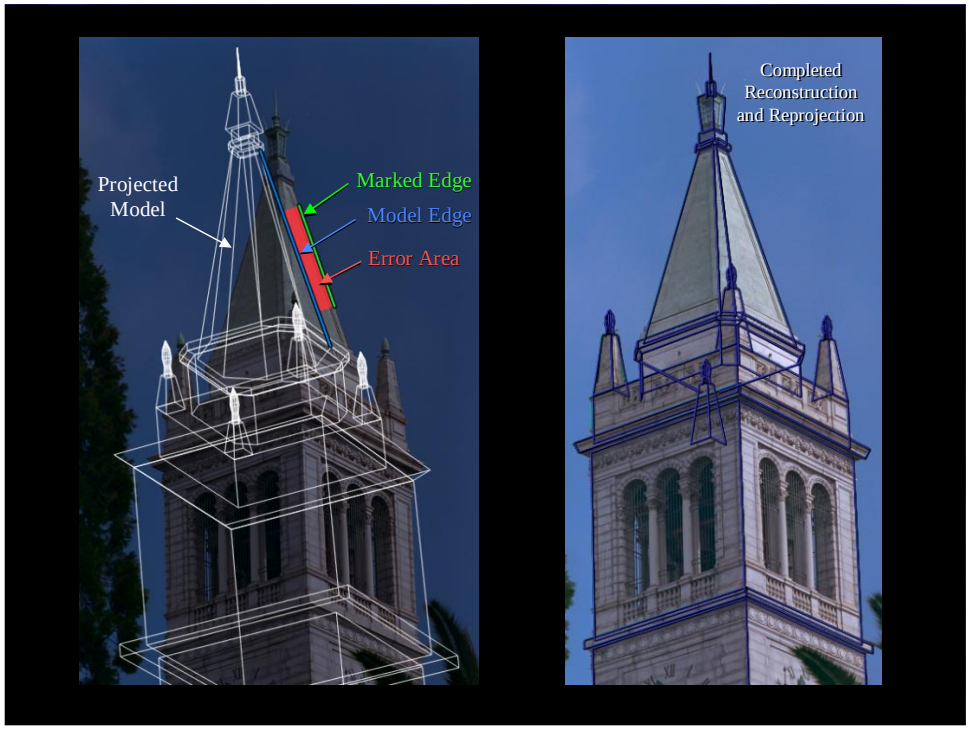
* Arbitrary 6 DOF
* Fixed Rotation
* Fixed Translation
* Geometric Relationship

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



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

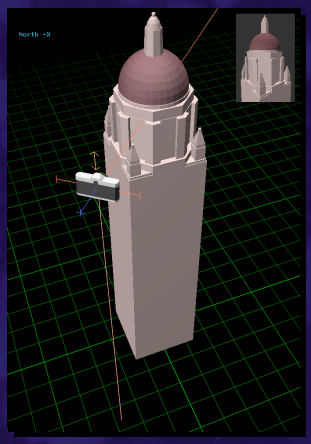
240 parameters as independent blocks

33 parameters as constrained blocks

- → Few marked features required
- → Easier to solve

Surfaces of Revolution

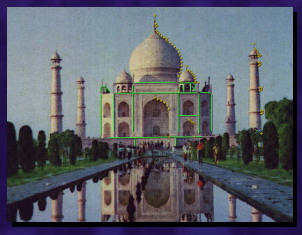
Photograph

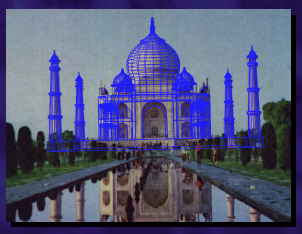


Recovered Model

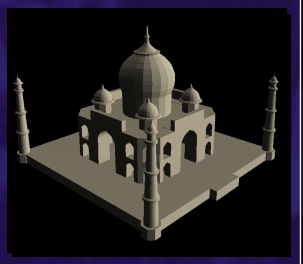
Synthetic View

Arches and Surfaces of Revolution

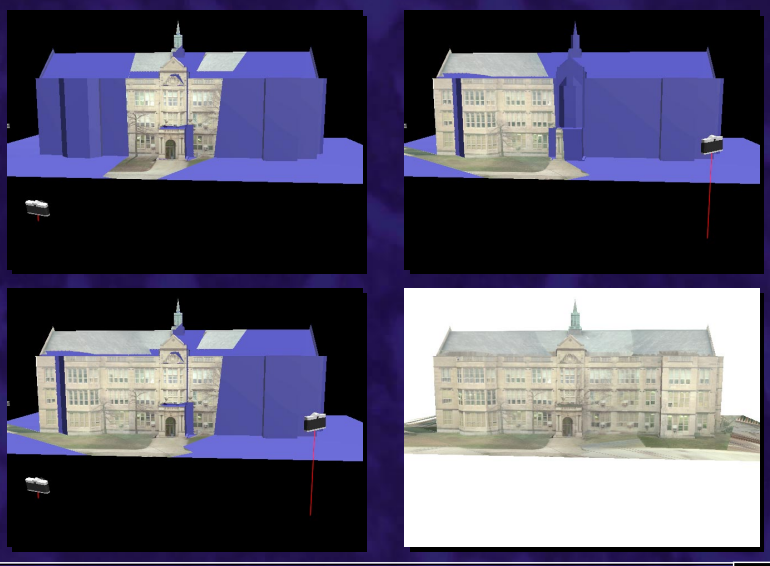




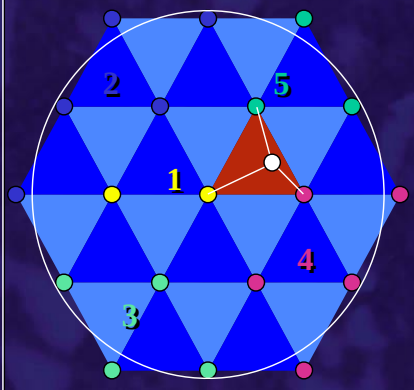
Taj Mahal modeled from one photograph



Rendering with Projective Texture Mapping



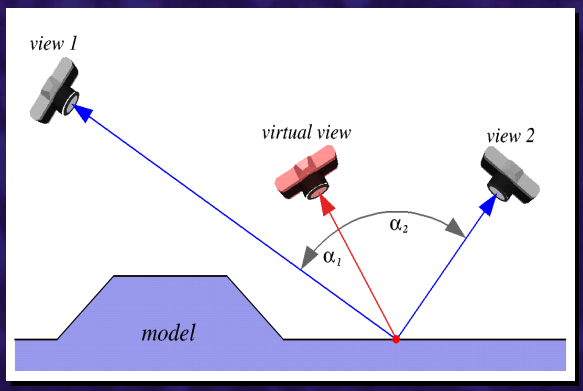
Rendering with View-Dependent Texture Mapping



- 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

Michael Cohen
Microsoft Research

Leonard McMillan
MIT

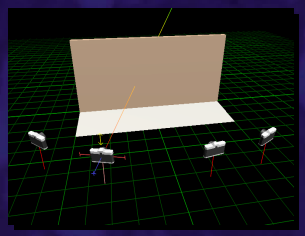
Chris Bregler
Stanford University

Richard Szeliski
Microsoft Research

François Sillion
iMAGIS - GRAVIR/IMAG

Scene with Geometric Detail

Model-Based Stereo



Approximate Block Model

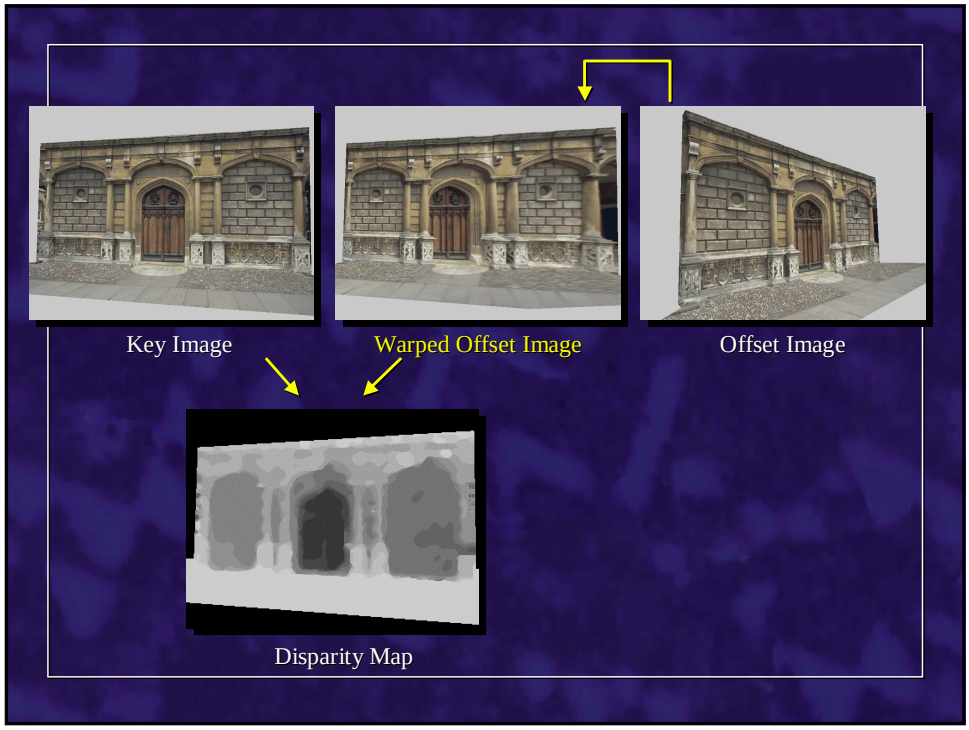
Model-Based Stereo

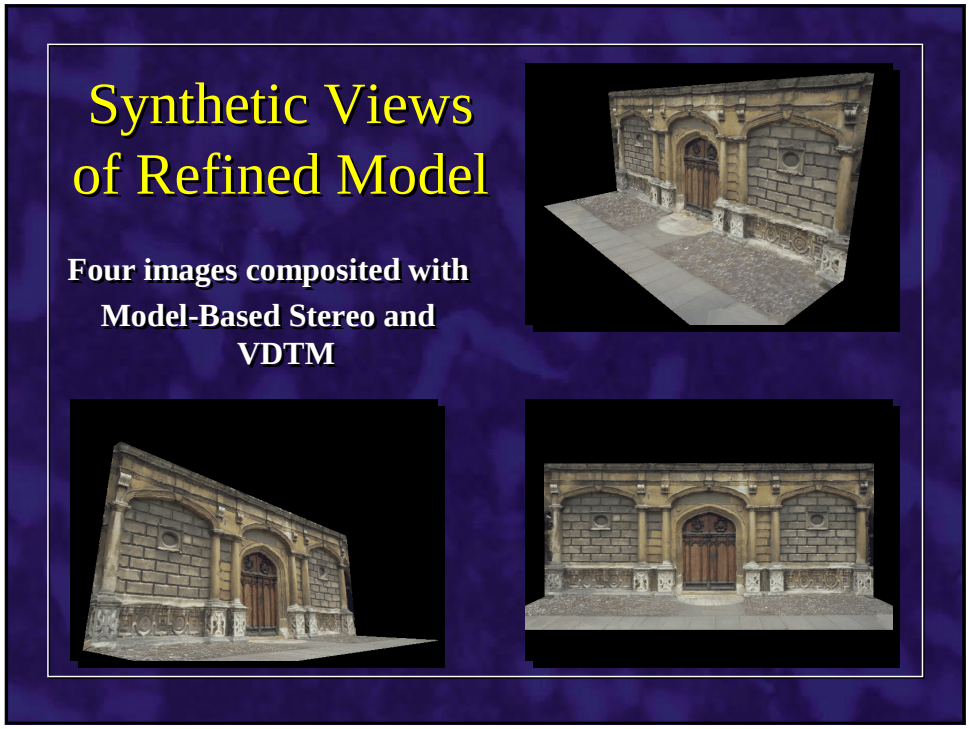
Given a key and an offset image,

- 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

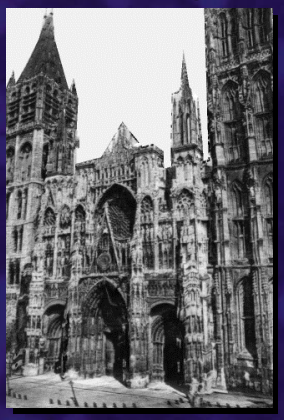

Synthetic Views of Refined Model
Four images composited with Model-Based Stereo and VDTM

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

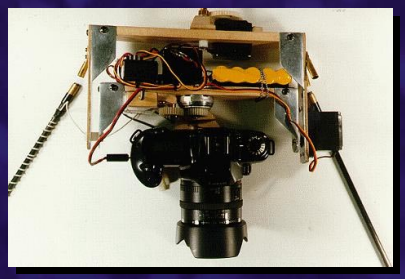
Application: The Campanile Movie

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/

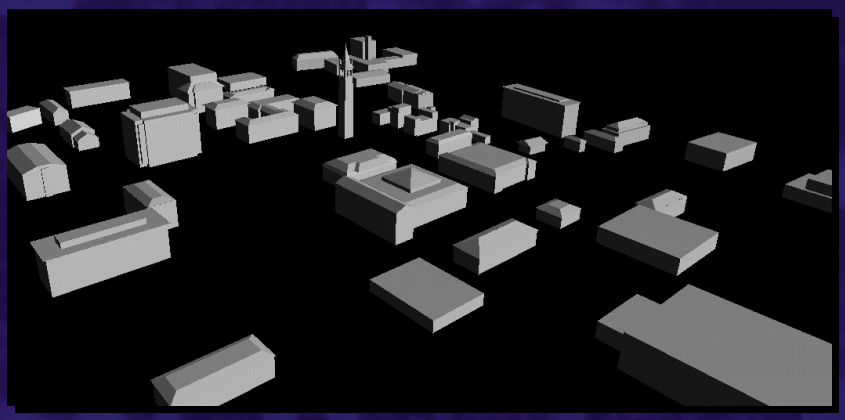
Cris Benton: Kite Aerial Photography

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

Tower Photographs

Campanile Model

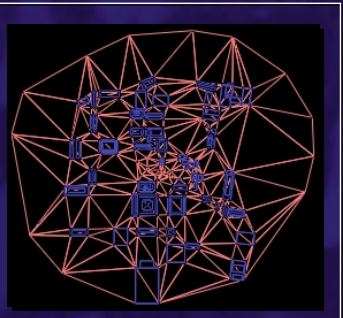
Environment Photographs

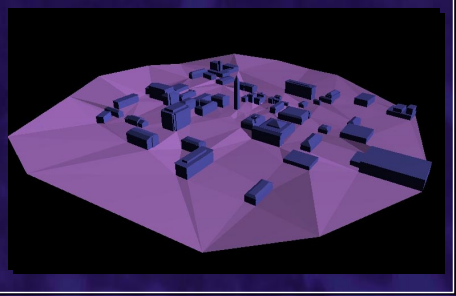


Campus Model (Campanile + 40 buildings)

Terrain Modeling

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

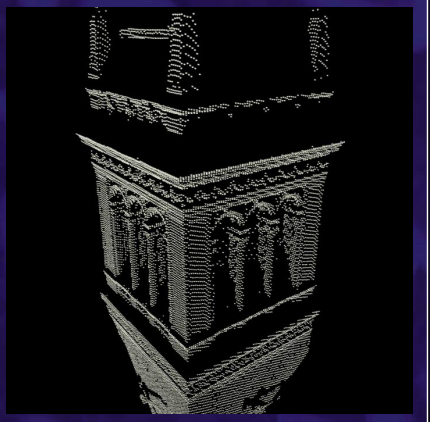




Video

Comparison: Time-of-flight Laser Scanning

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



Application: The Matrix

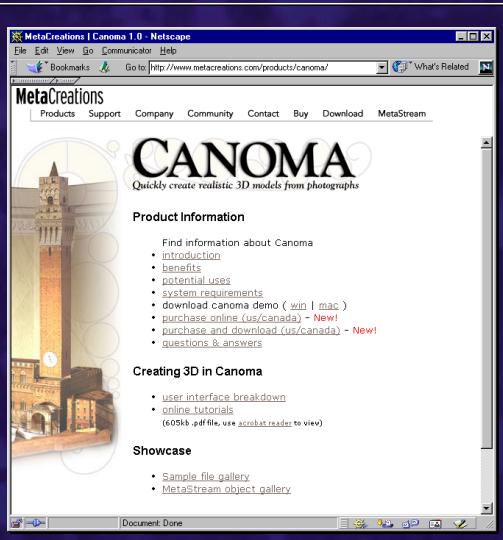
www.mvfx.com

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

The Matrix – Reconstruction Stills – EF9

Video

Commercial Product: Metacreations (now Adobe) Canoma

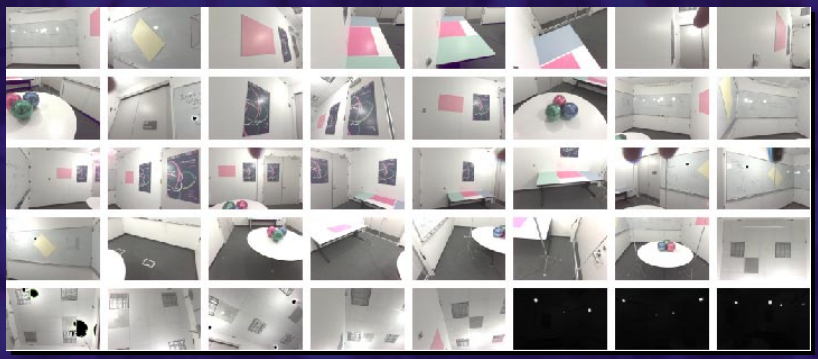


www.metacreations.com/canoma
www.canoma.com

Application: Inverse Global Illumination

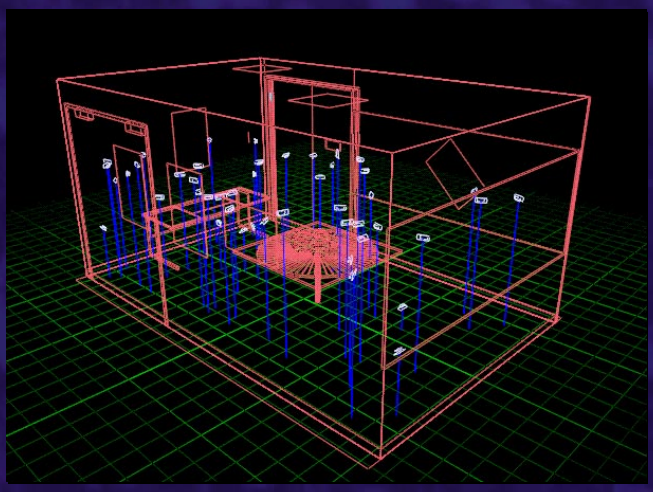
Yizhou Yu, Paul Debevec, Jitendra Malik, Tim Hawkins

SIGGRAPH 99



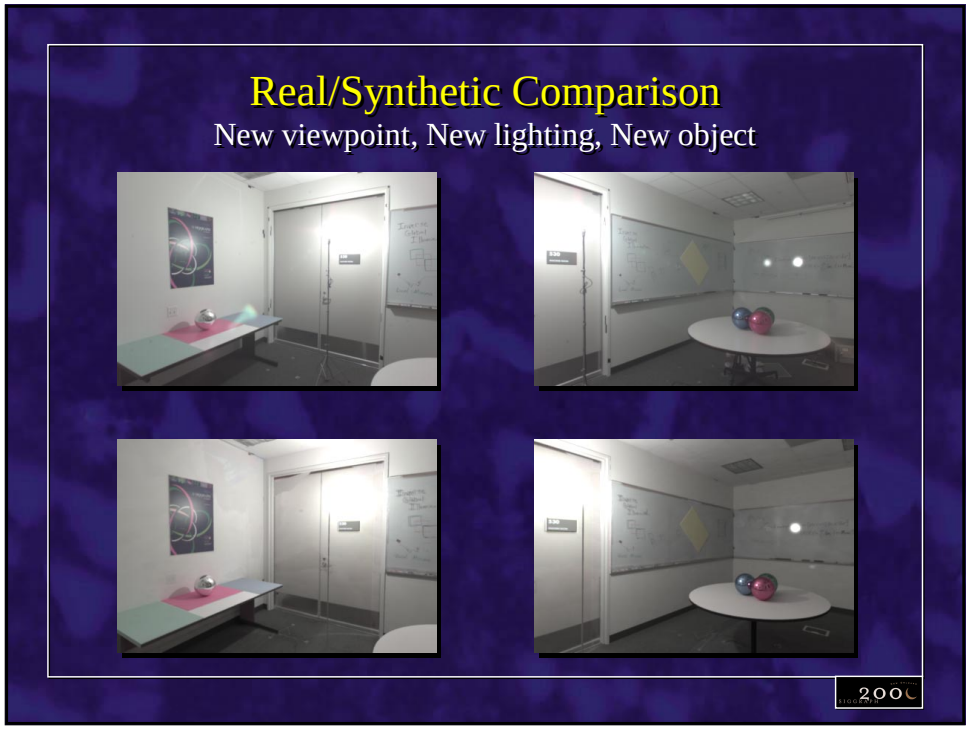
40 radiance maps of a room

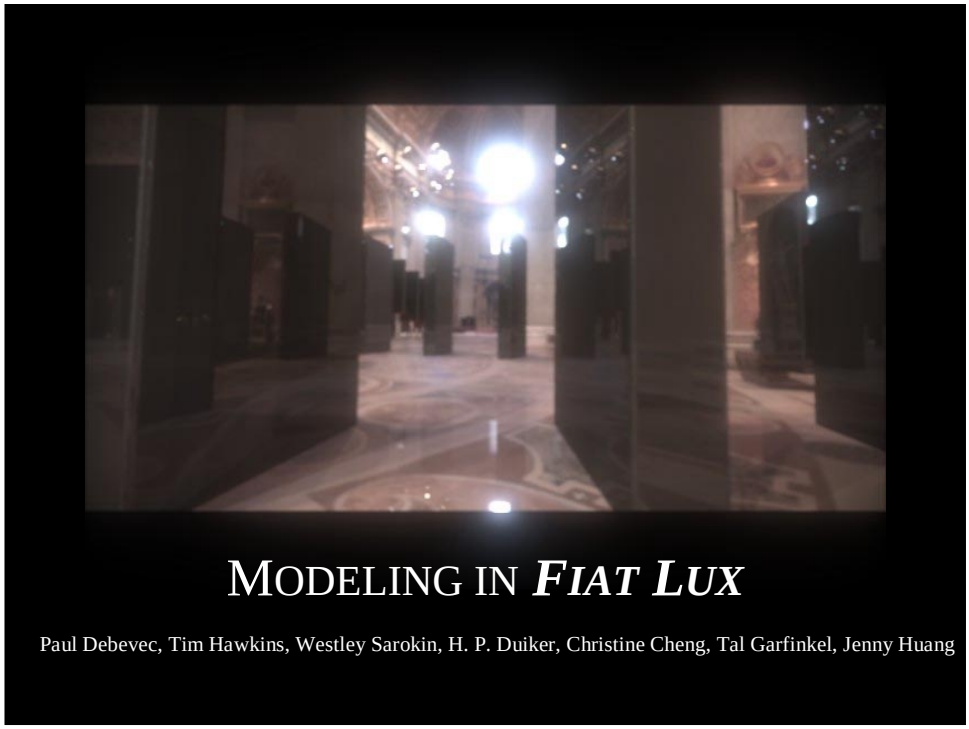
Recovered Geometry and Viewpoints

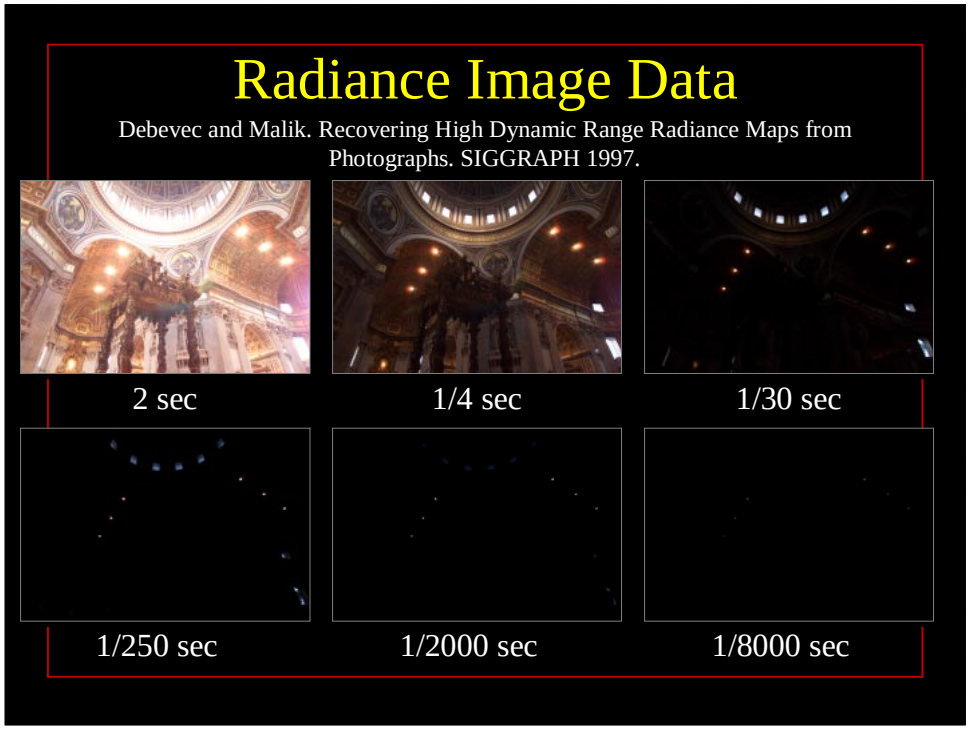


Real/Synthetic Comparison

Same viewpoints, Same lighting, Same objects

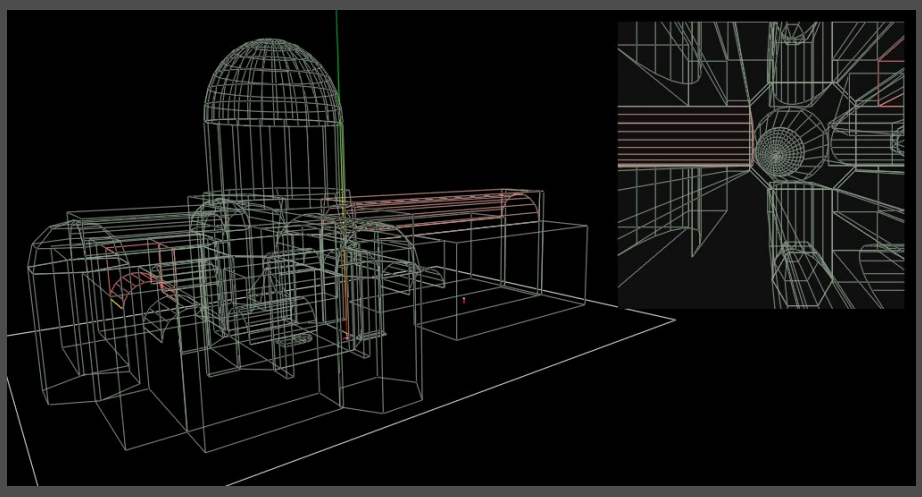

Real/Synthetic Comparison
New viewpoint, New lighting, New object


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

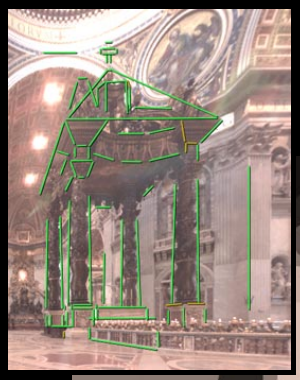
Assembled Panorama

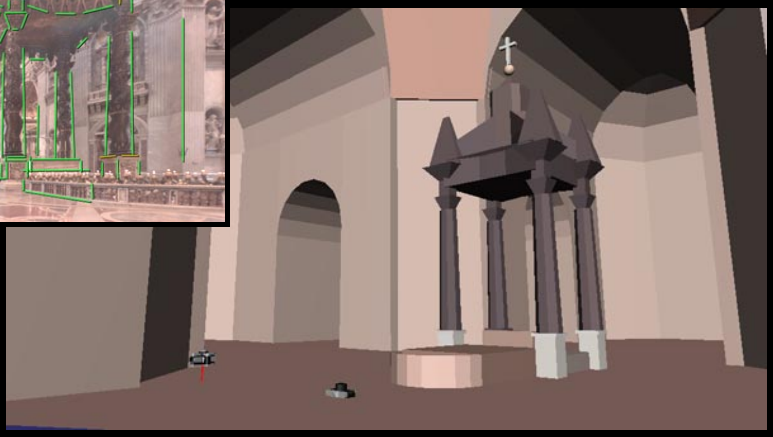


Interior model recovered from panorama

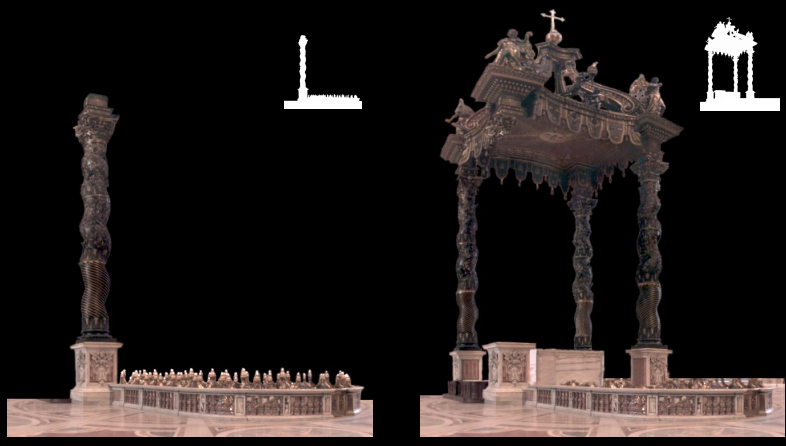
(35 parameters)

Baldacchino Model

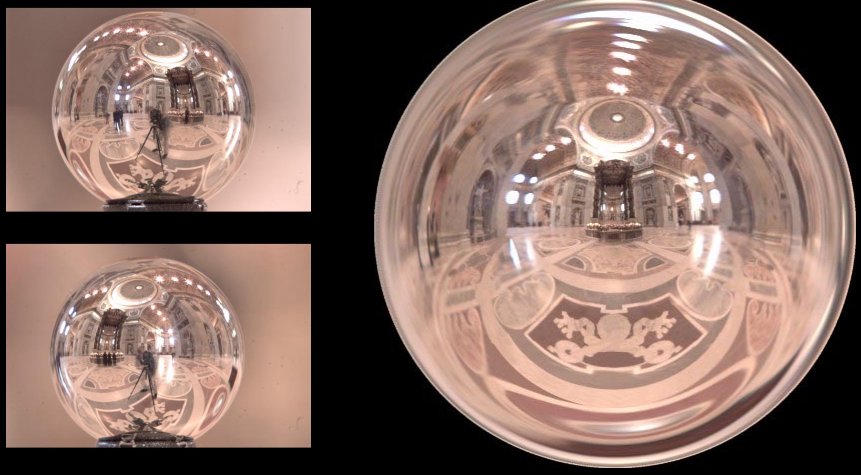




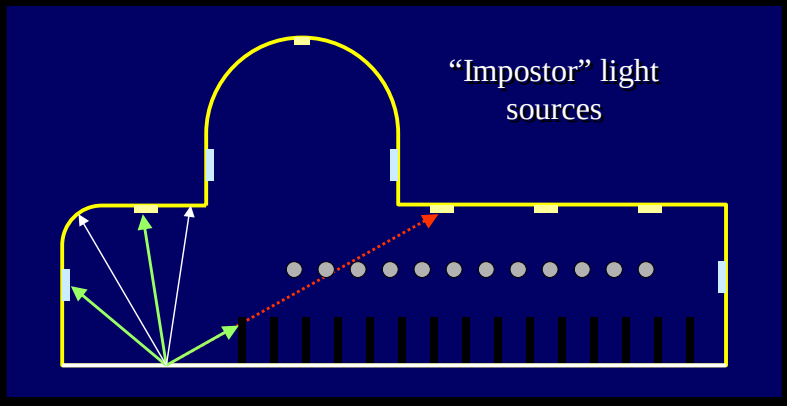
Baldacchino Layers



Light Probe Images



Lighting Calculation



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

Synthetic Objects

Thanks

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