

Image-Based Rendering

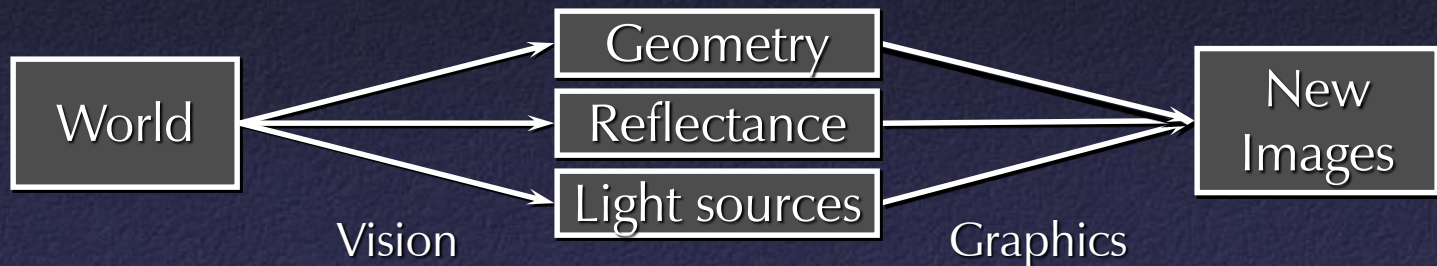
COS 526, Fall 2014

Thomas Funkhouser

Acknowledgments: Dan Aliaga, Marc Levoy, Szymon Rusinkiewicz

Image-Based Modeling and Rendering

- For many applications, re-rendering is goal
- Traditional vision / graphics pipelines:



- Image-based pipeline:

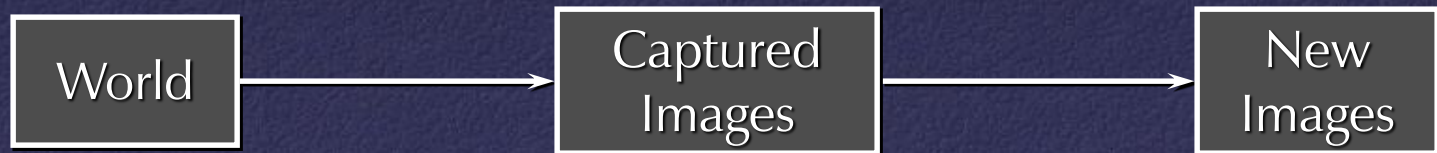


Image-Based Modeling and Rendering

- Generate new views of a scene directly from existing views
- “Pure” IBR (such as lightfields): no geometric model of scene
- Other IBR techniques try to obtain higher quality with less storage by building a model

Plenoptic Function

- $L(x, y, z, \theta, \phi, t, \lambda)$
- Captures all light flow in a scene
 - to/from any point (x, y, z) ,
 - in any direction (θ, ϕ) ,
 - at any time (t) ,
 - at any frequency (λ)
- Enough information to construct any image of the scene at any time

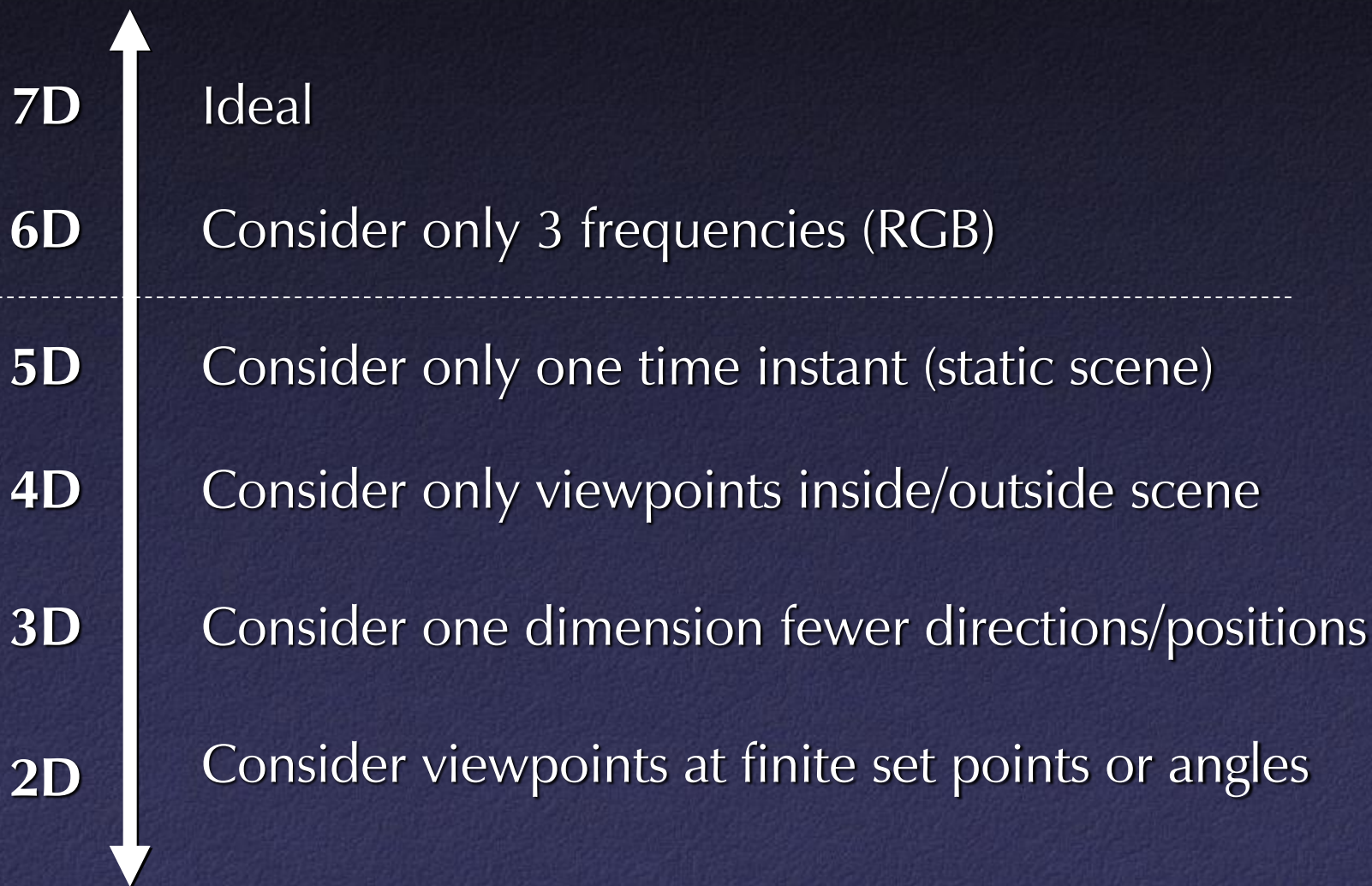


Plenoptic Function Simplifications

- Simplification from 7D to $3 \times 5D$
 - Represent color as RGB: eliminate λ
 - Static scenes: eliminate t
- Other simplifications?



Image-Based Representations



IBR Representations

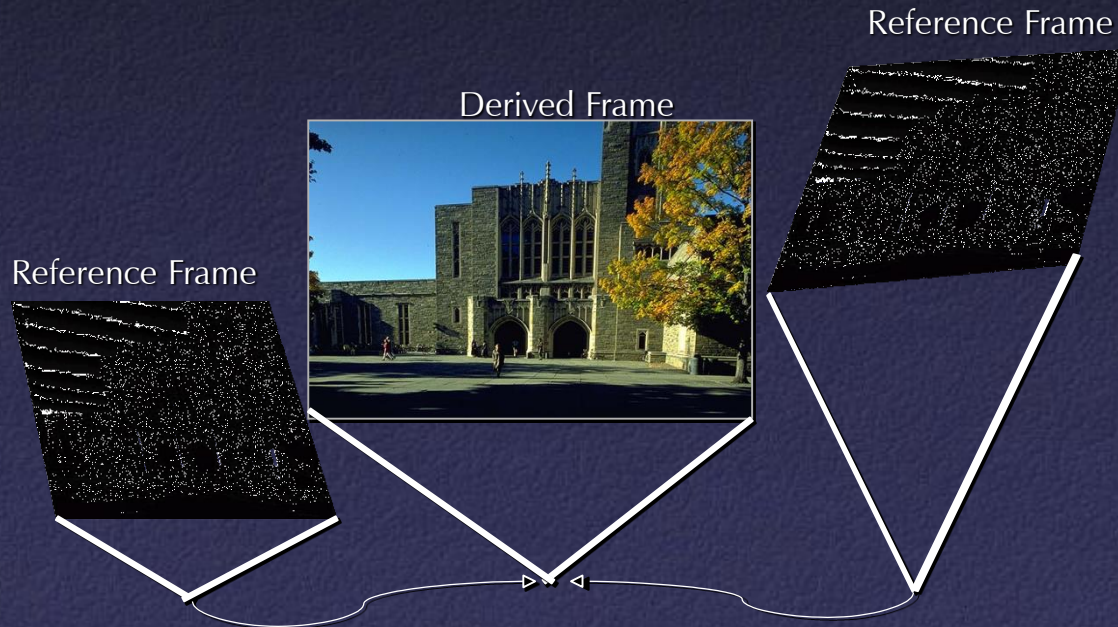
- Image pairs
- Sea of Images
- Lightfields / Lumigraphs

IBR Representations

- Image pairs ←
- Sea of Images
- Lightfields / Lumigraphs

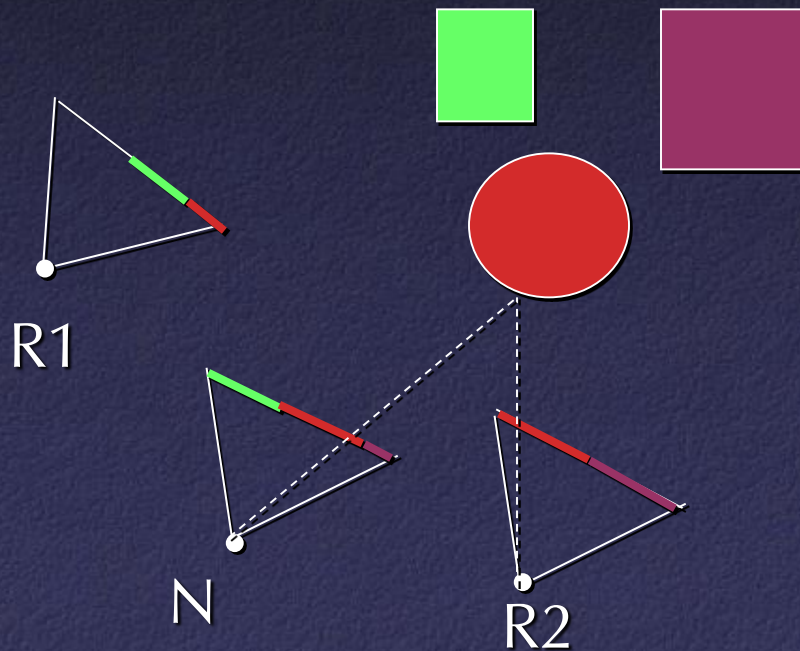
View Interpolation

- Create novel images by resampling photographs
 - Reference images sample 5D plenoptic function



View Interpolation

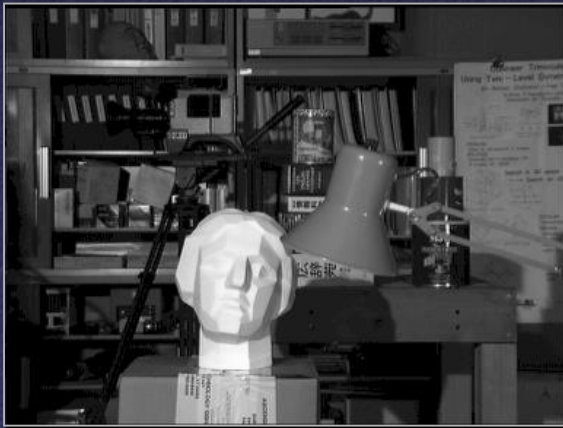
- Method:
 - Warp nearby reference images to novel viewpoint
 - Blend warped images



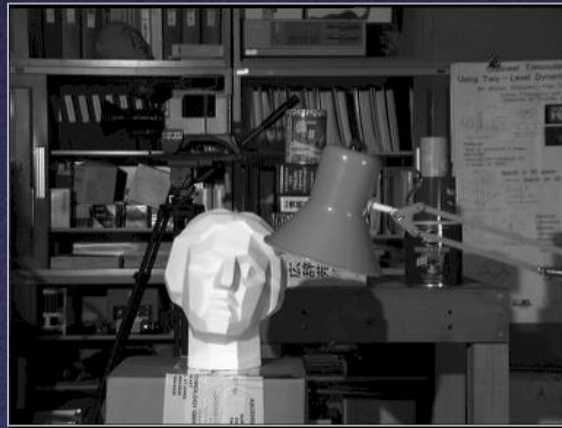
Morph with warp
defined by
pixel correspondences

Pixel Correspondences

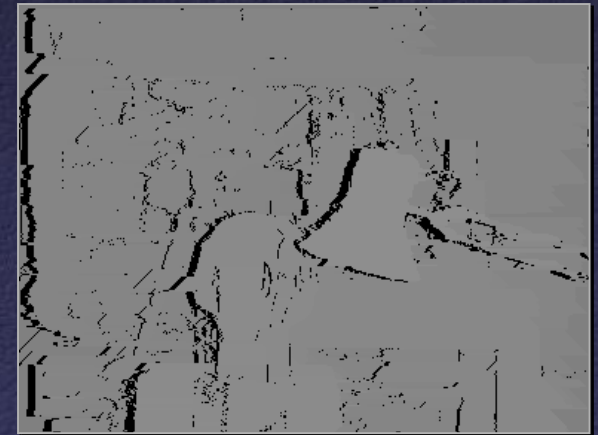
- Vision (e.g. stereo): disparity
- Feature matching: sparse
- 3D model: possibly coarse



Left



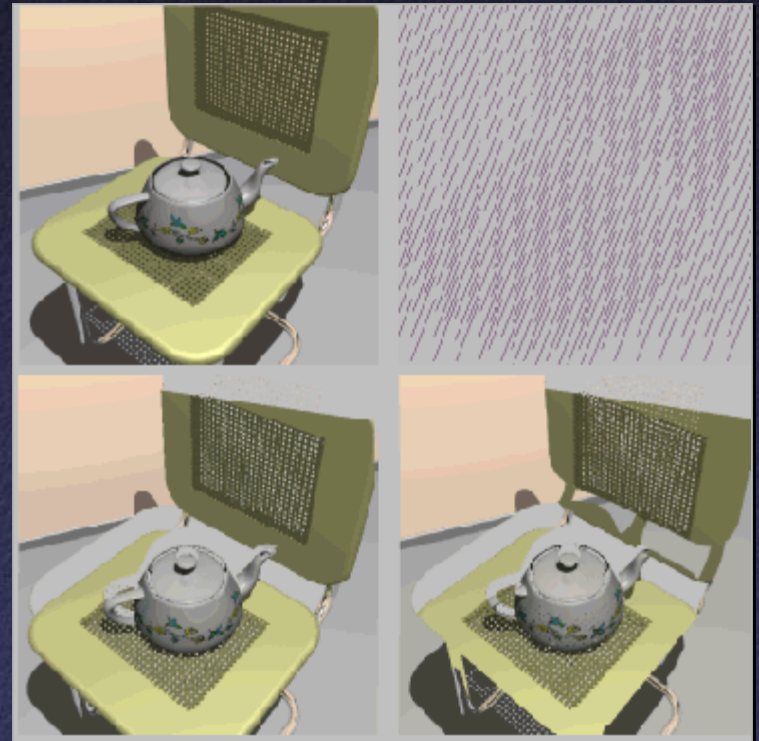
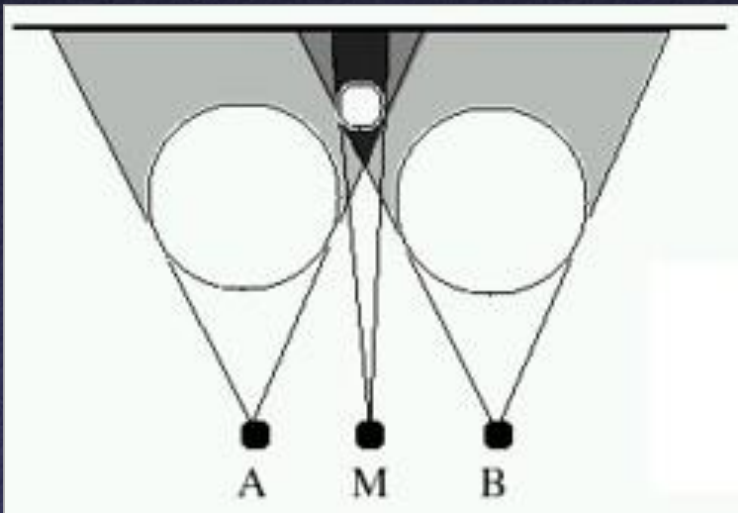
Right



Disparity

View Interpolation

- Problem: changes in visibility
 - Disocclusions



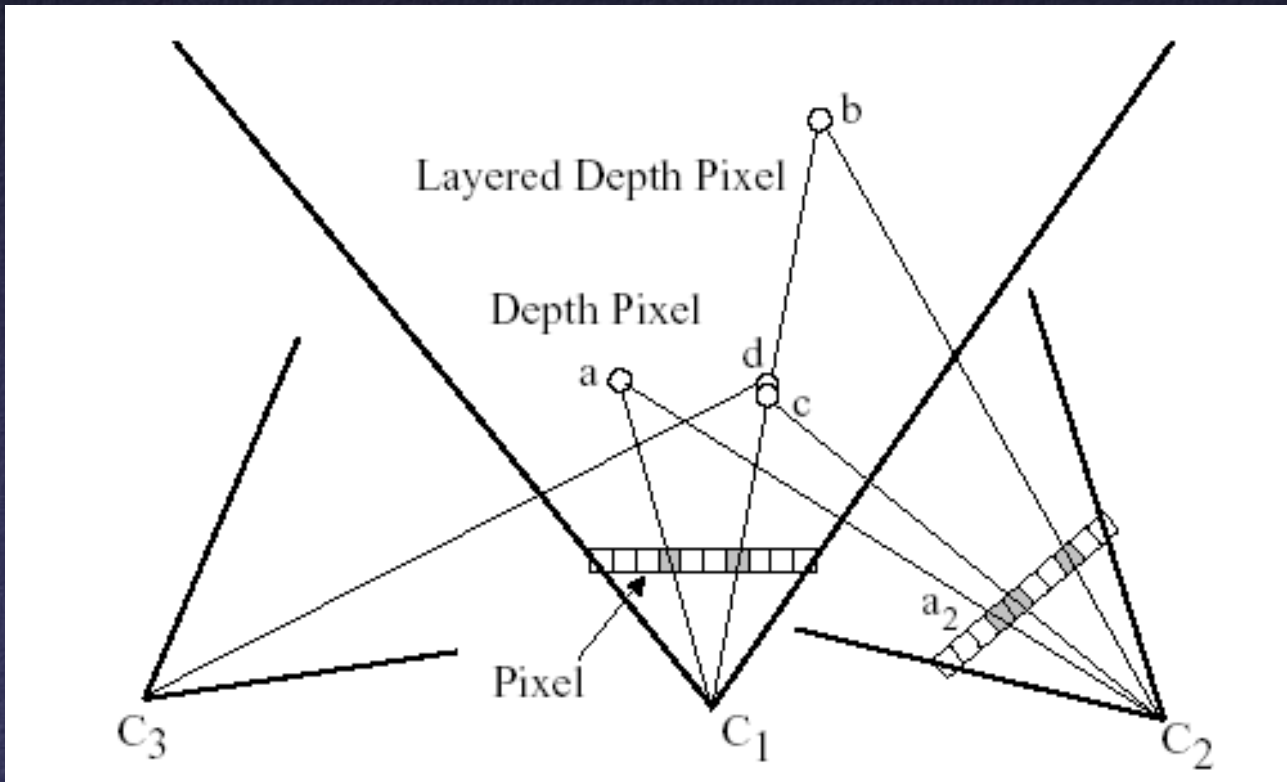
Disocclusions

- Partial solutions:
 - Use more photographs
 - Fill holes by interpolating nearby pixels



Disocclusions

- Better solutions (when possible):
 - Multiple samples per pixel at different depths

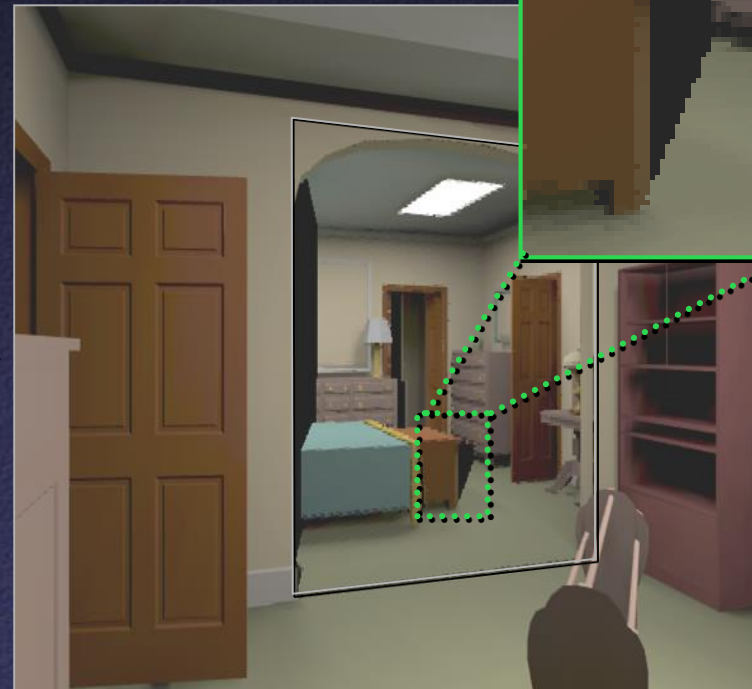


Disocclusions

- Better solutions (when possible):
 - Multiple samples per pixel at different depths



Reference Image



Warped Depth Image

Disocclusions

- Better solutions (when possible):
 - Multiple samples per pixel at different depths



Reference Image



Warped Layered Depth Image

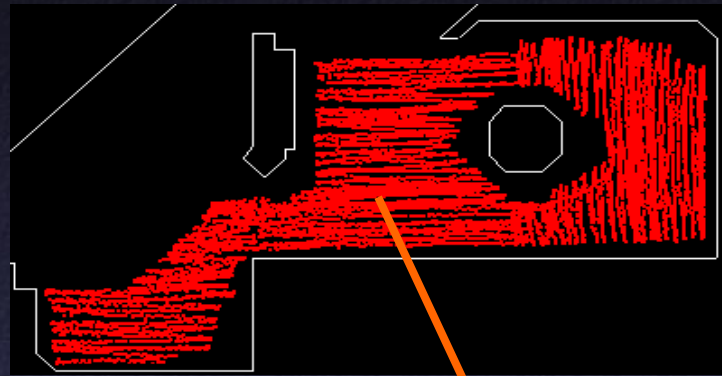
View Interpolation Challenges

- Capture
 - How do we obtain a dense set of calibrated images over a large area in a practical manner?
- Data Management
 - How do we store and access the large amount of data?
- Rendering
 - How do we create novel views from a dense sampling of images in real-time?

IBR Representations

- Image pairs
- Sea of Images ←
- Lightfields / Lumigraphs

Sea of Images



Large-scale Dense Capture



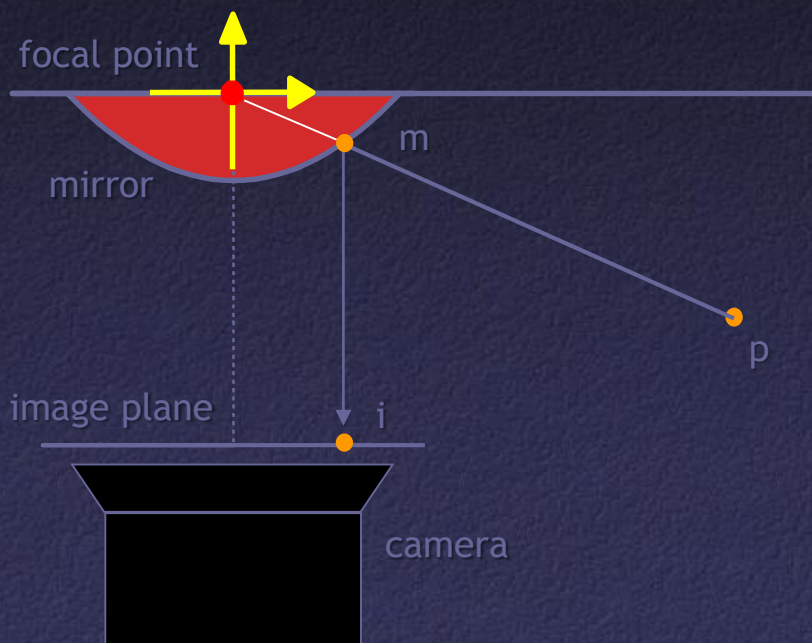
Data Management
and
Rendering Algorithms



Interactive

Sea of Images Capture

- Use a hemispherical FOV camera driven on cart



Paraboloidal Catadioptric Camera
[Nayar97]



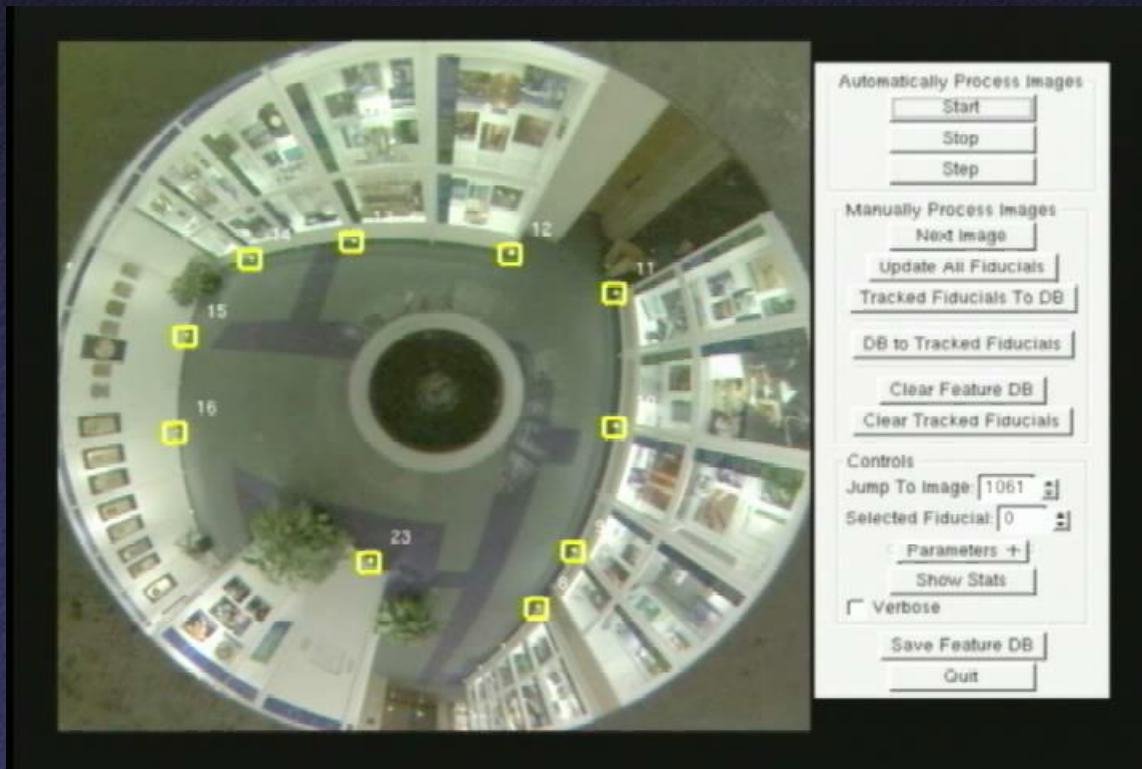
Sea of Images Capture

- Use a hemispherical FOV camera driven on cart



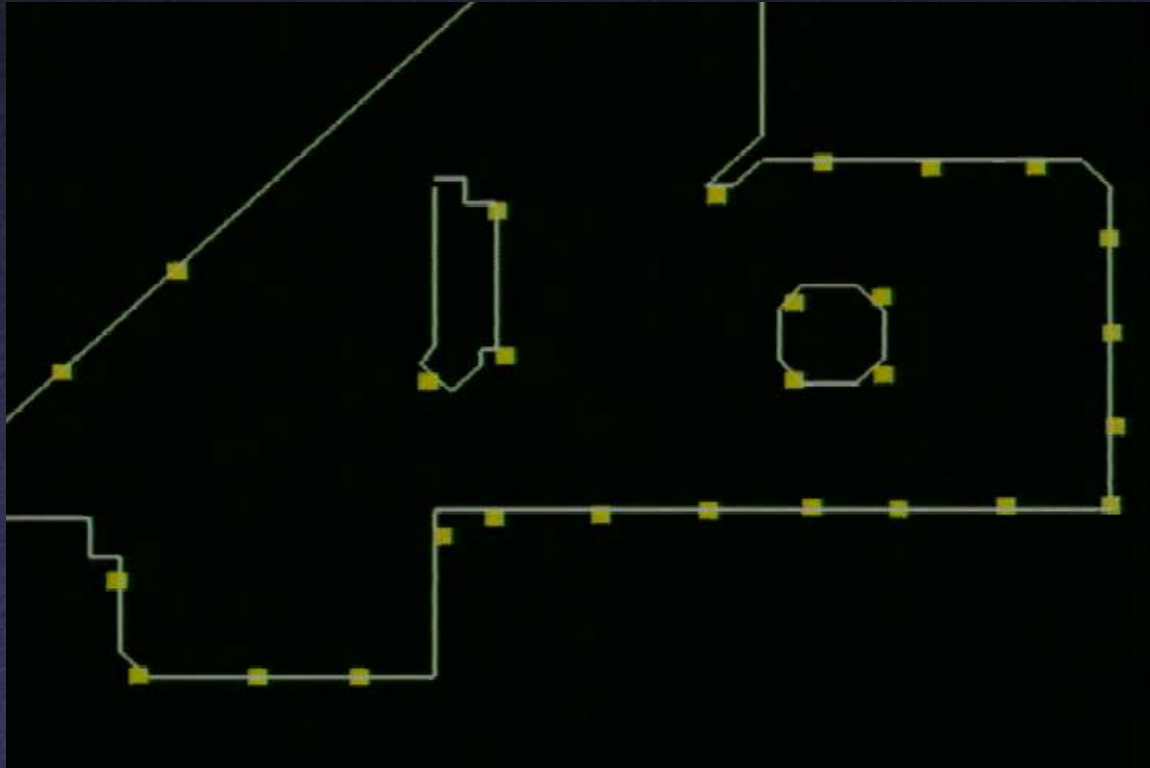
Sea of Images Capture

- Locate camera by tracking fiducials



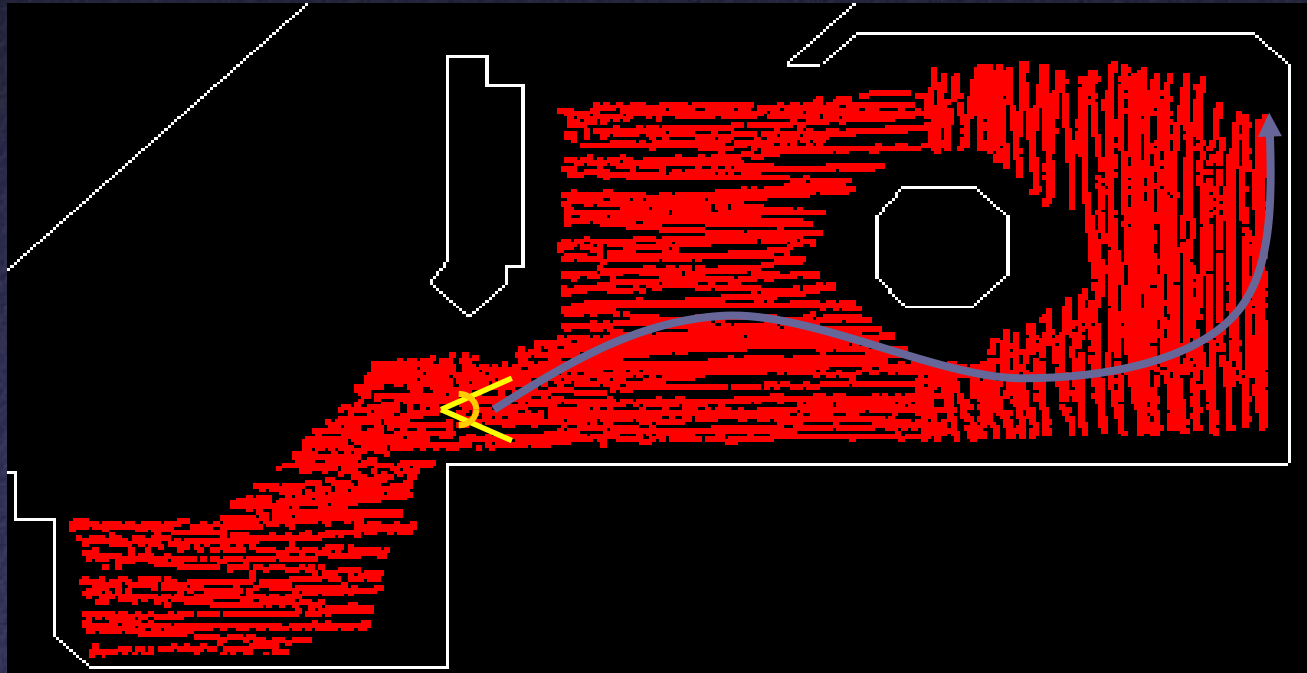
Sea of Images Capture

- Result is a “sea of images” spaced a few inches apart



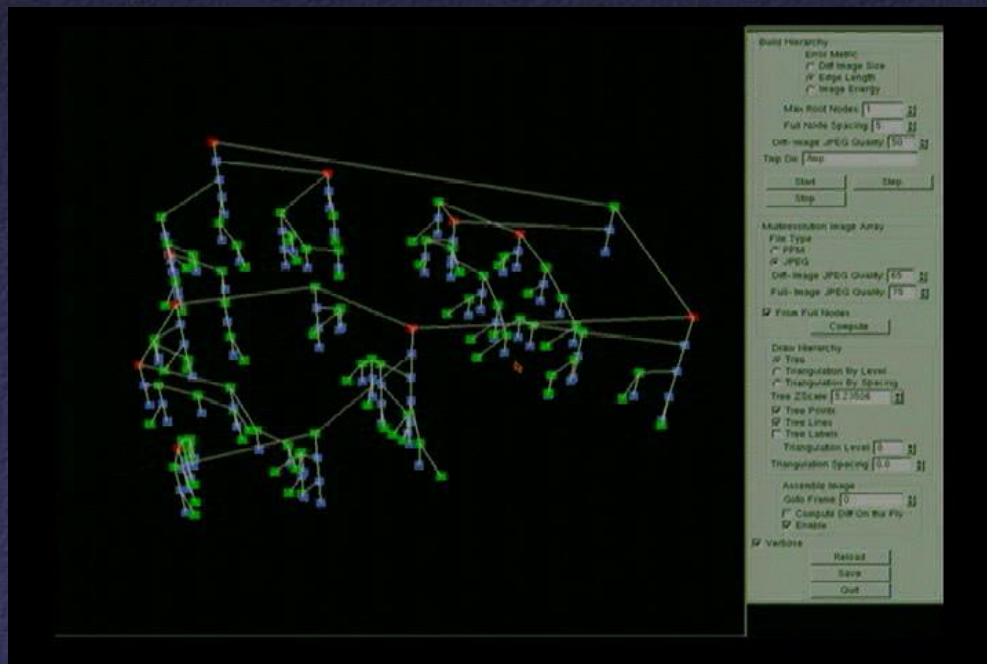
Sea of Images Compression

- Goal: provide access to images along arbitrary viewpoint paths in real-time



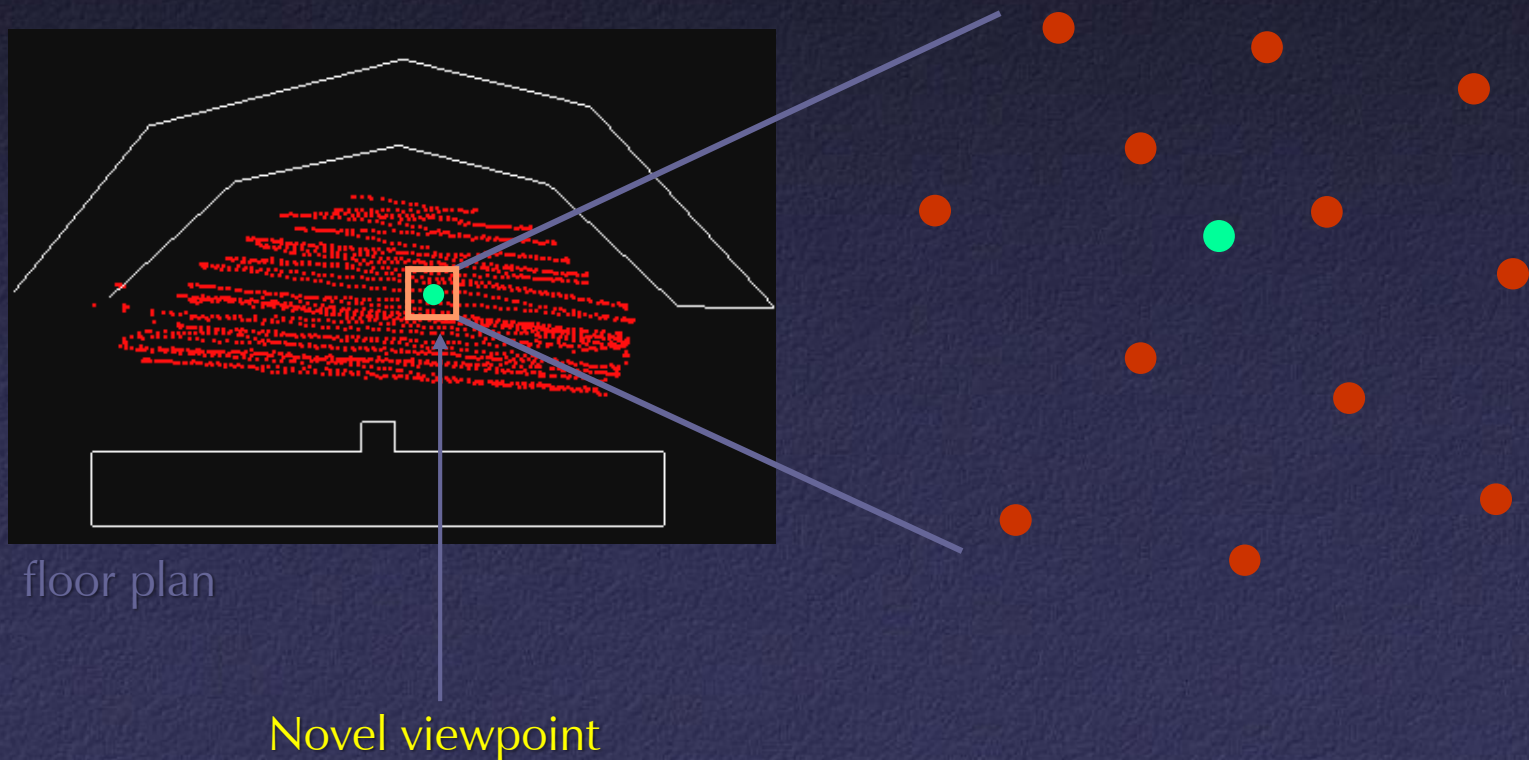
Sea of Images Compression

- Approach: create a multiresolution spatial hierarchy of compressed original images and compressed difference images



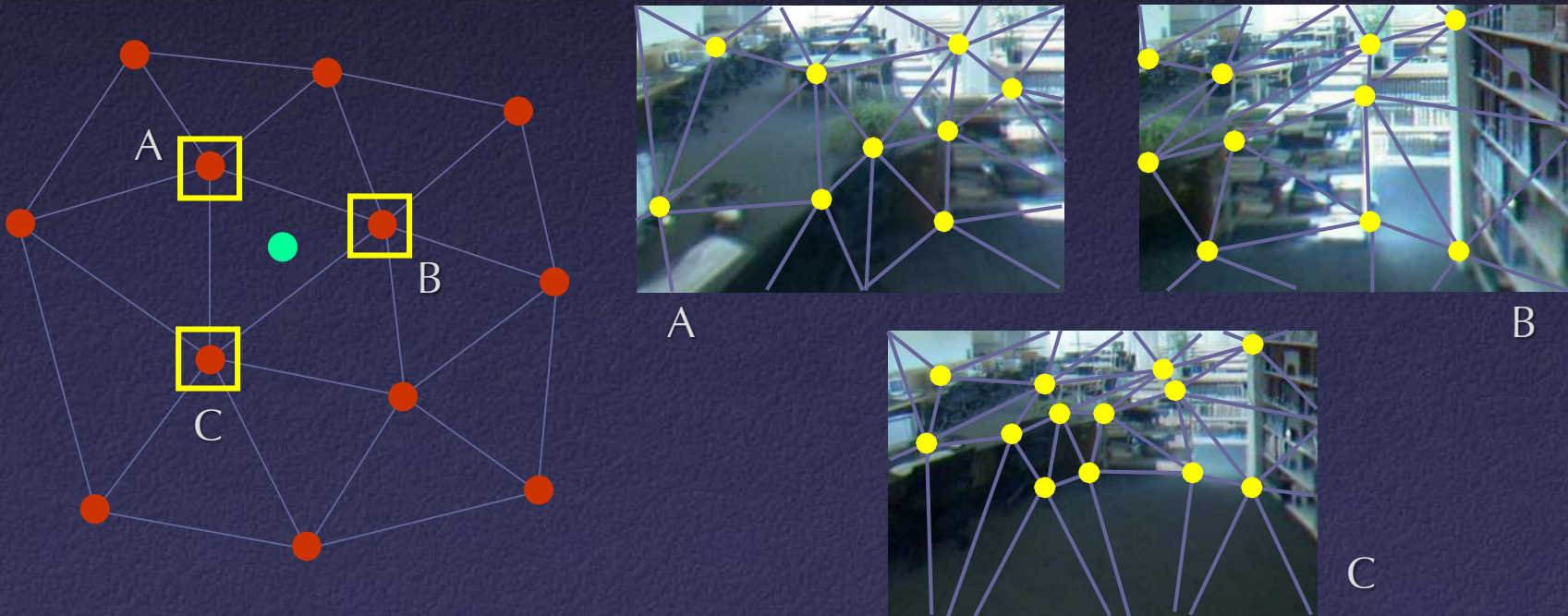
Sea of Images Rendering

- Use captured images near the novel viewpoint to create new views



Sea of Images Rendering

- Interpolate three nearest views using detected feature correspondences



Sea of Images Results

- Bell Labs Museum
 - 900 square ft
 - 9832 images
 - 2.2 inch spacing
- Princeton Library
 - 120 square ft
 - 1947 images
 - 1.6 inches
- Personal Office
 - 30 square feet
 - 3475 images
 - 0.7 inches



Sea of Images Results

- Times
 - Setup: ~15 minutes
 - Capture: ~30-60 minutes
 - Preprocessing time: 4 to 17 hours
- Frame rate
 - 1024x1024 @ 20Hz, 512x512 @ 30Hz

Sea of Images Results



1/2

Sea of Images Results



Sea of Images Results



Sea of Images Results

- Render complex light effects (specular highlights)

cylindrical
projection



Sea of Images Results

- Multiresolution pre-filtering: far-to-near image sequence



Sea of Images Results

captured
omnidirectional
image



reconstructed
omnidirectional
image

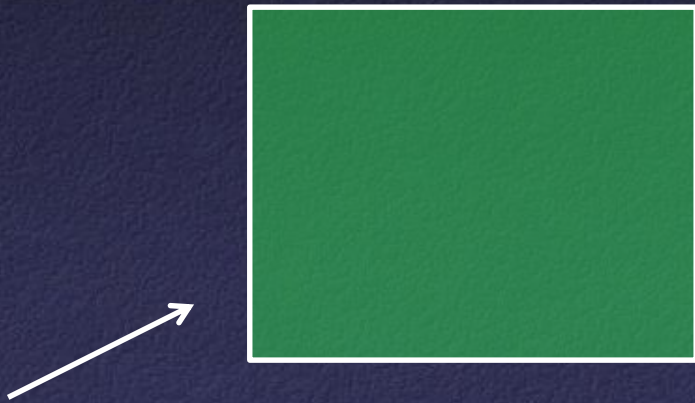


IBR Representations

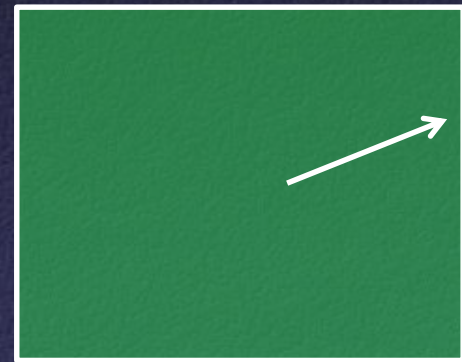
- Image pairs
- Sea of Images
- Lightfields / Lumigraphs ←

Lightfields

- In unoccluded space, can reduce plenoptic function to 4D



Outside looking in



Inside looking out

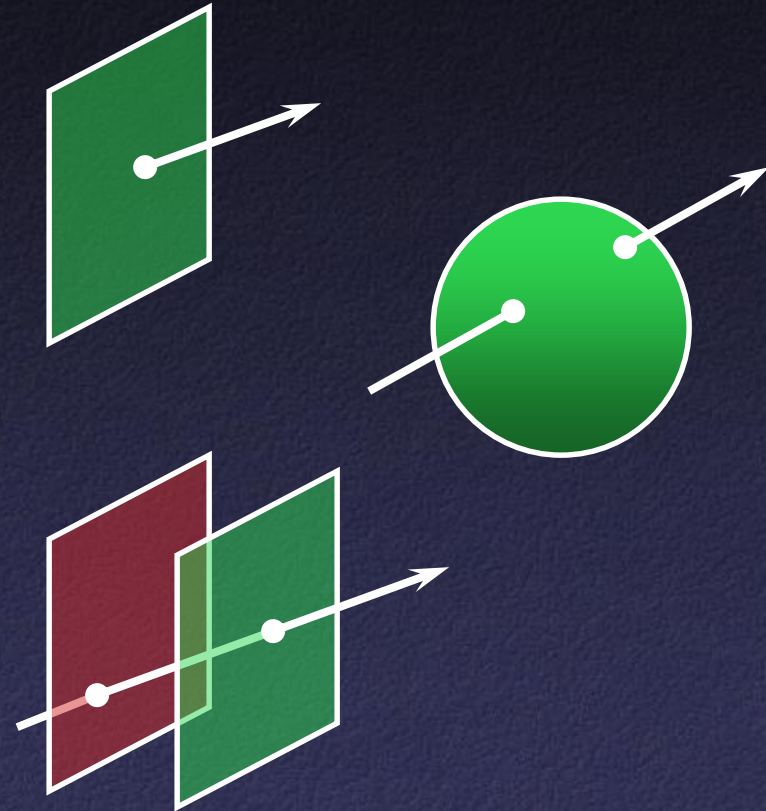
Using Lightfields

- Obtain 2D slices of 4D data set
- Arbitrary views: take other 2D slices
- Challenges:
 - Parameterization
 - Capture
 - Compression
 - Rendering



Lightfield Parameterization

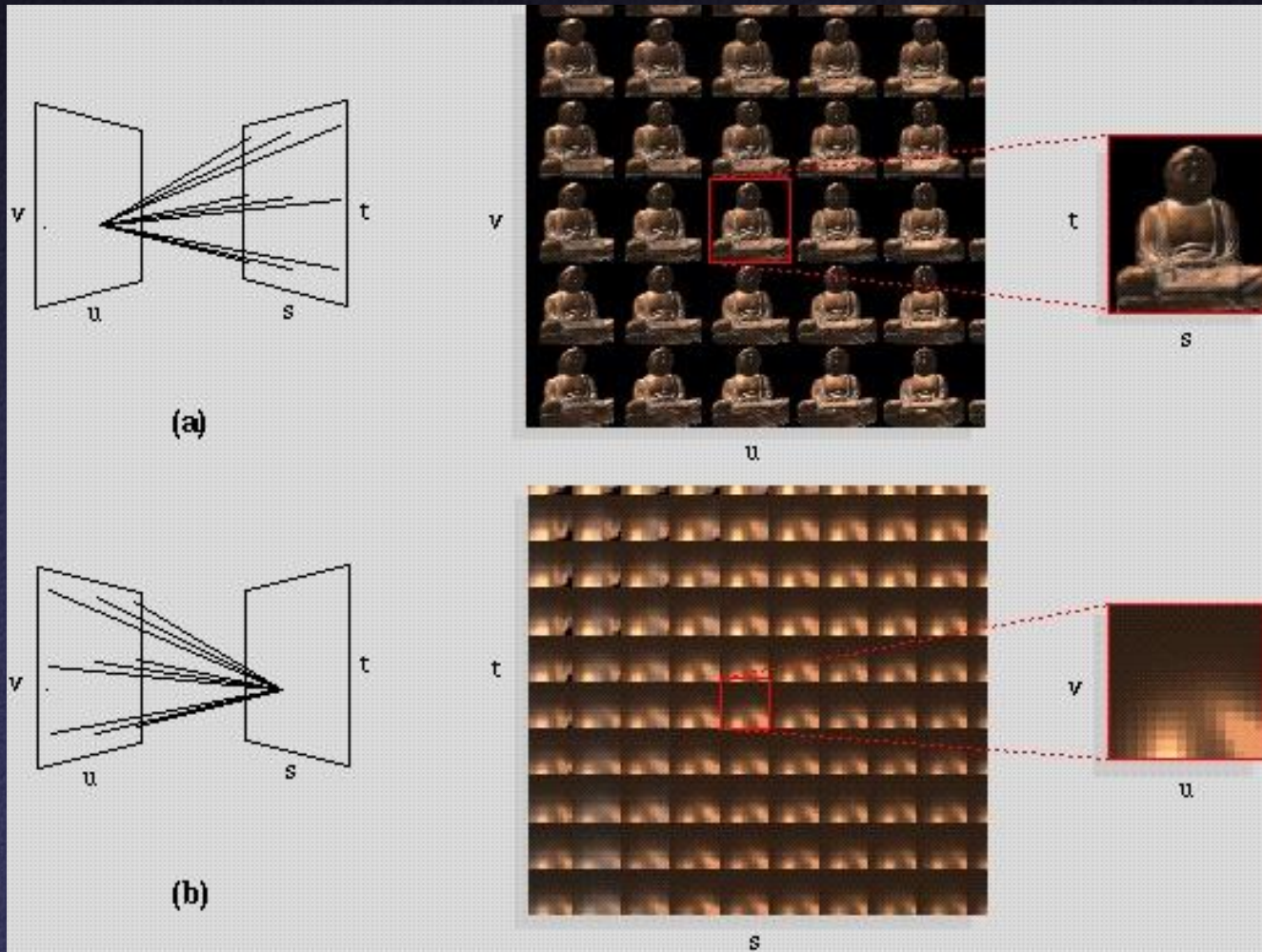
- Point / angle
- Two points on a sphere
- Points on two planes
- Original images and camera positions



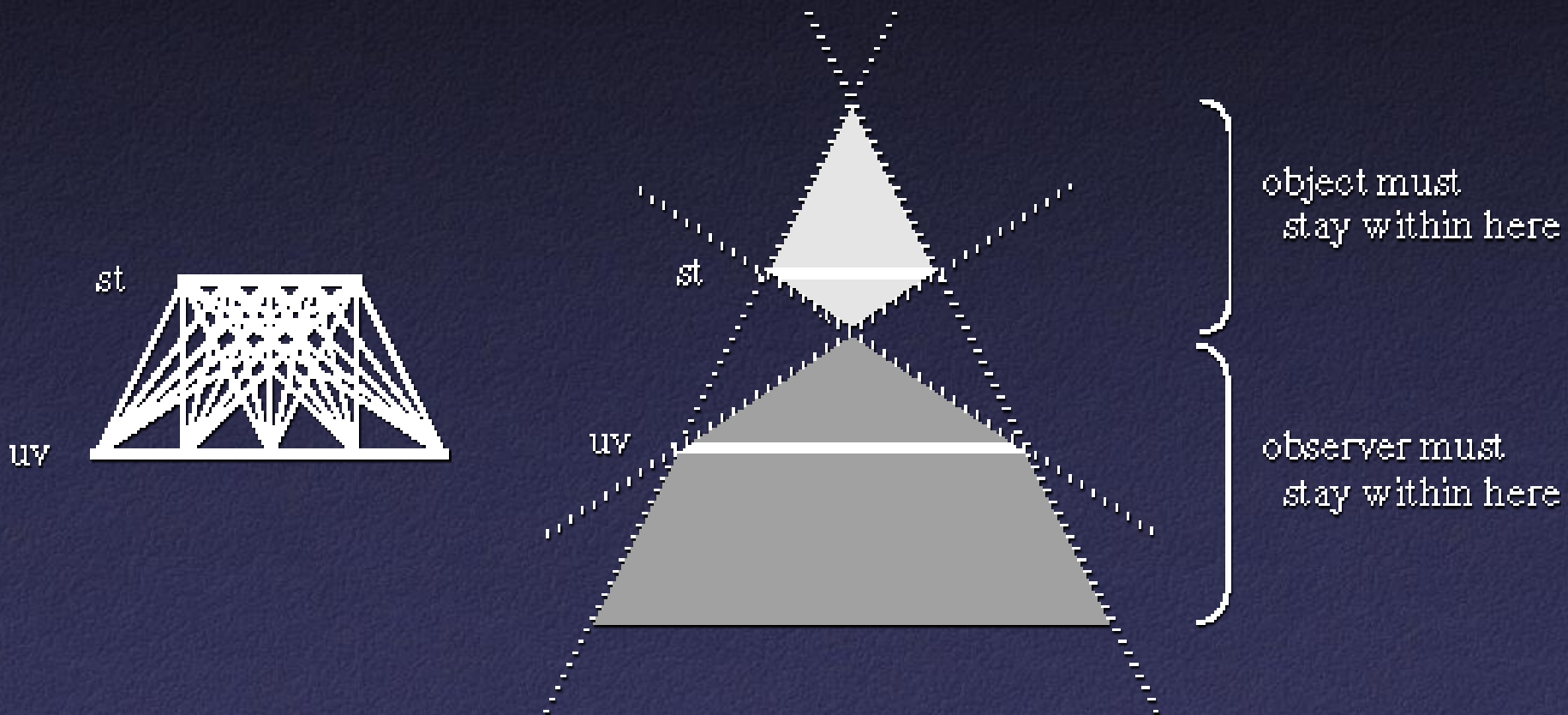
Light Field Two-Plane Parameterization

- Two planes, evenly sampled: “light slab”
- In general, planes in arbitrary orientations
- In practice, one plane = camera locations
 - Minimizes resampling

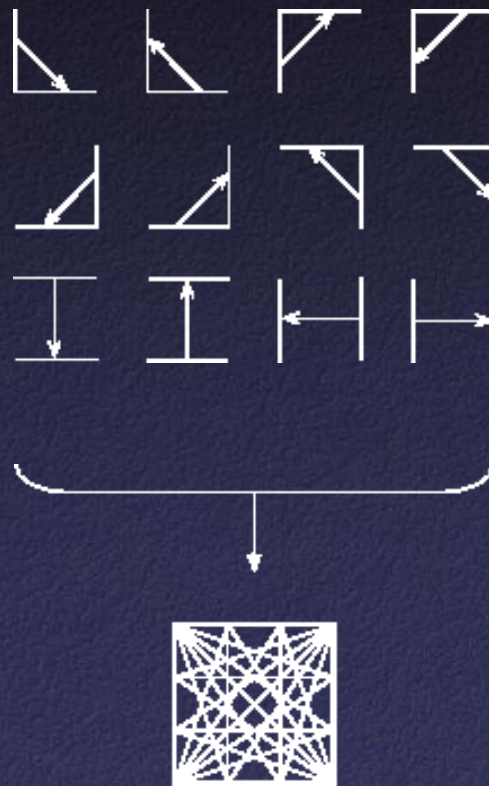
Light Field Two-Plane Parameterization



Light Field Coverage



Multi-Slab Light Fields

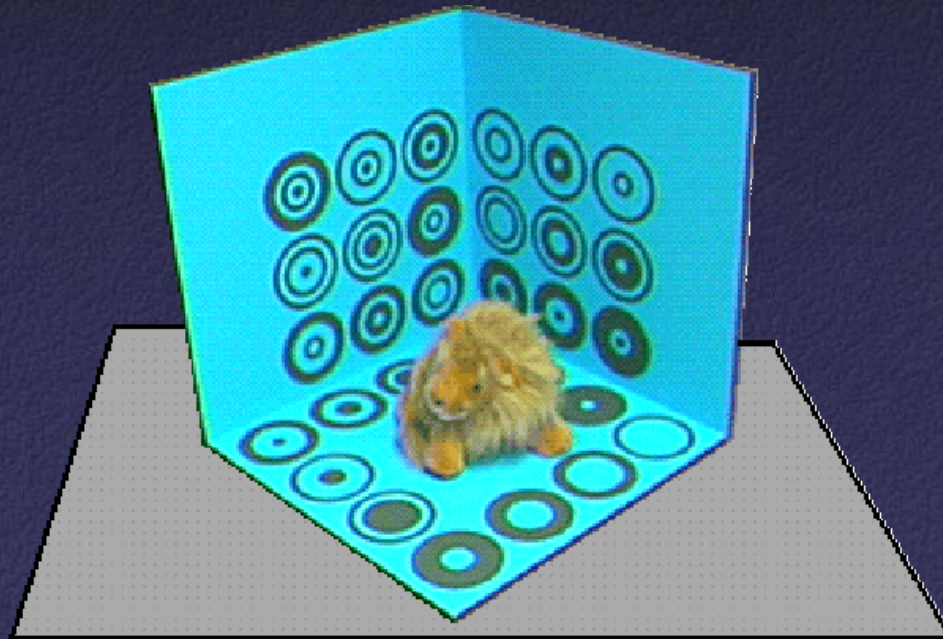


Lightfield Capture

- Capture a 2D set of (2D) images
- Choices:
 - Camera motion: human vs. computer
 - Constraints on camera motion
 - Coverage and sampling uniformity
 - Aliasing

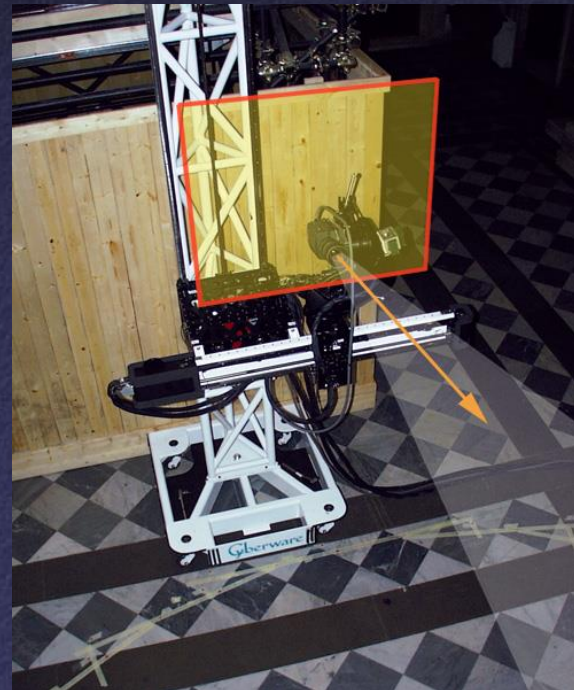
Lumigraph Capture

- Capture: move camera by hand
- Camera intrinsics assumed calibrated
- Camera pose recovered from markers



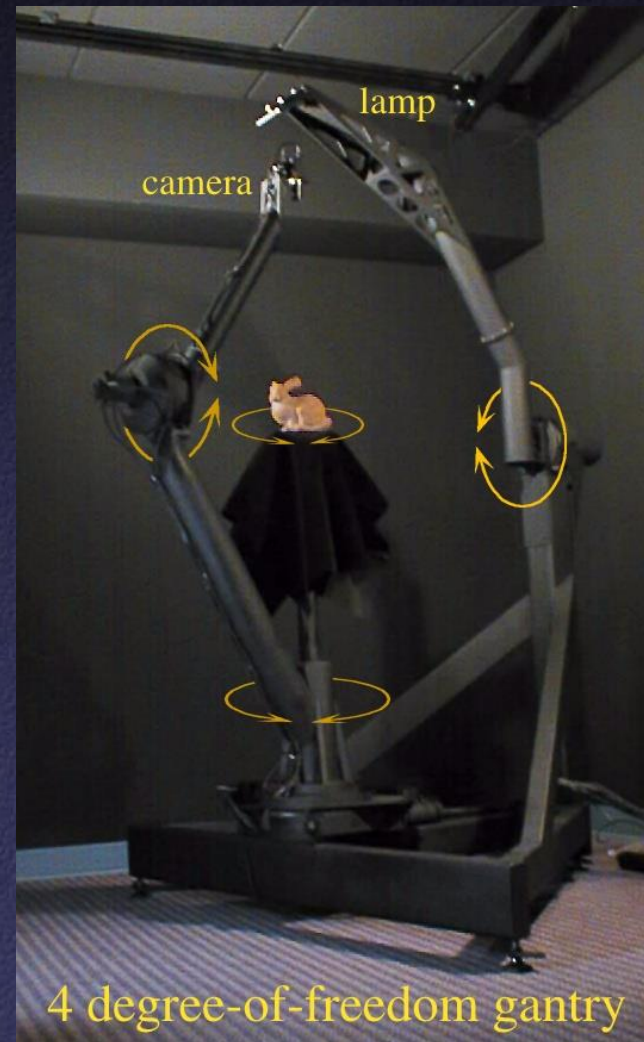
Lightfield Capture

- Levoy 06:
 - Computer-controlled camera rig
 - Move camera to grid of locations on a plane



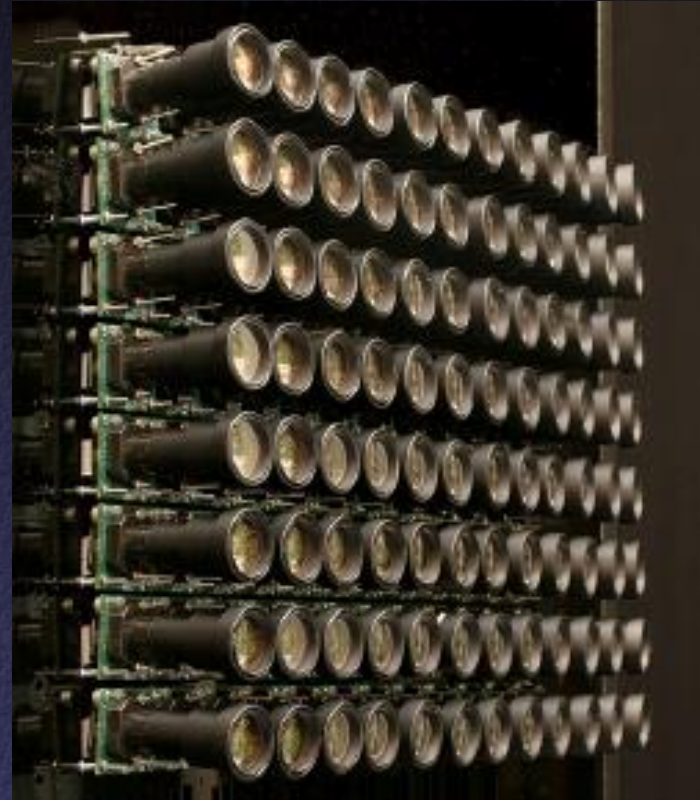
Lightfield Capture

- Spherical motion of camera around an object
- Samples space of directions uniformly
- Second arm to move light source – measure reflectance



Lightfield Capture

- Acquire an entire light field at once
- Video rates
- Integrated MPEG2 compression for each camera



(Bennett Wilburn, Michal Smulski, Mark Horowitz)

Lightfield Capture



Lytro

Lightfield Compression

- Compress individual images (JPEG, etc.)
- Adapt video compression to 2D arrays
- Decomposition into basis functions
- Vector quantization

Lightfield Rendering

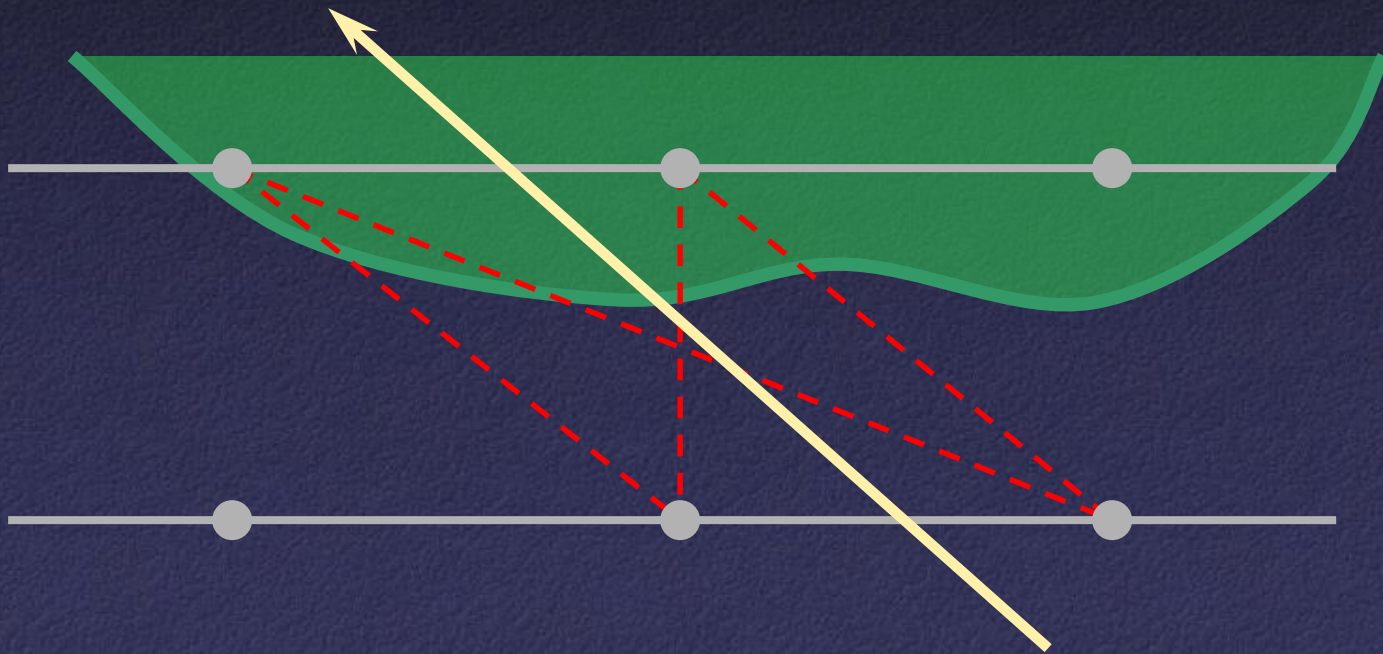
- How to select rays?
- How to interpolate

Lightfield Rendering

- For each desired ray:
 - Compute intersection with (u,v) and (s,t) planes
 - Take closest ray
- Variants: interpolation
 - Bilinear in (u,v) only
 - Bilinear in (s,t) only
 - Quadrilinear in (u,v,s,t)

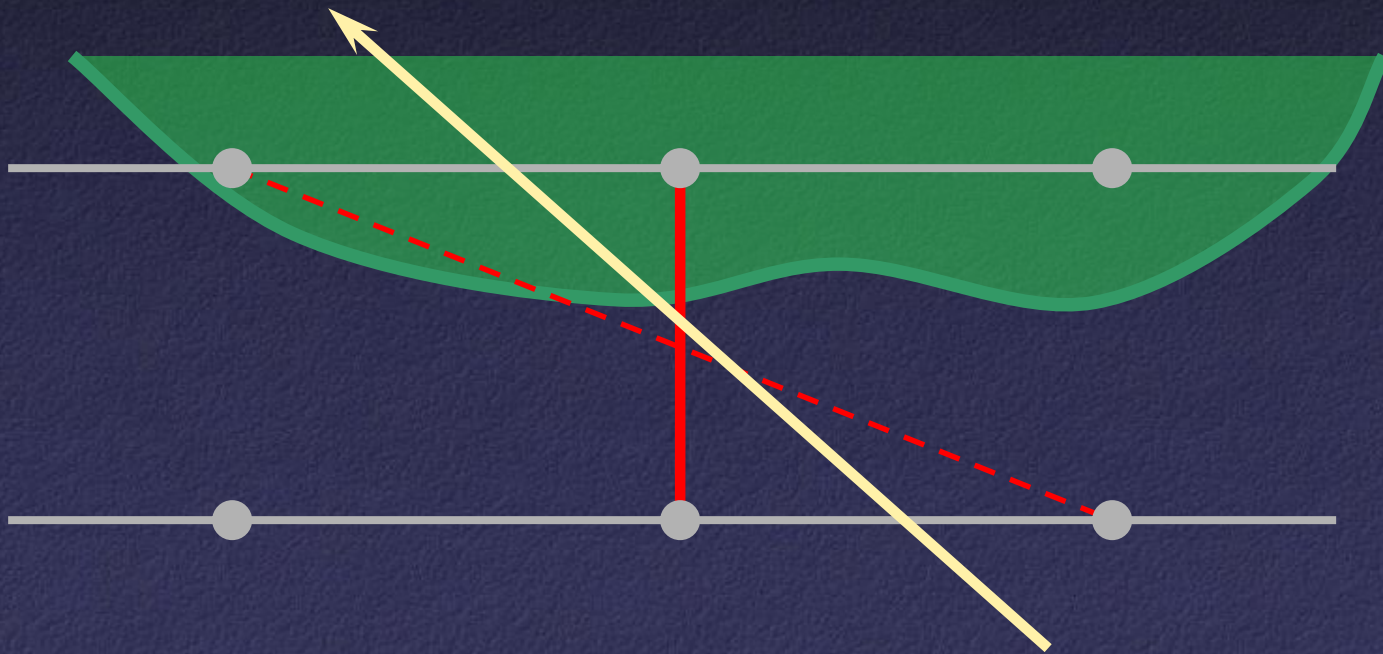
Lumigraph Rendering

- Use rough depth information to improve rendering quality



Lumigraph Rendering

- Use rough depth information to improve rendering quality



Lumigraph Rendering



Without using
geometry



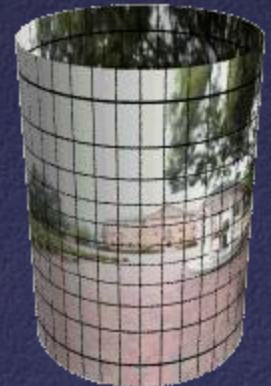
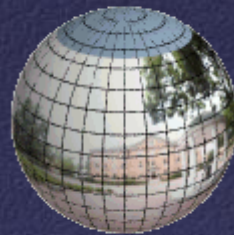
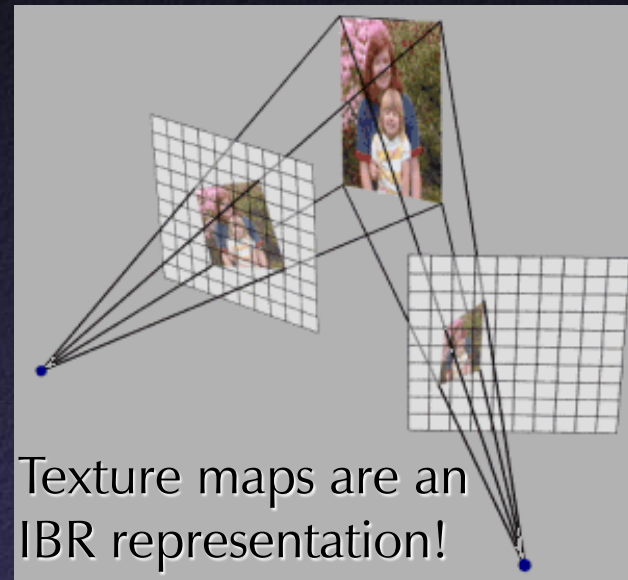
Using approximate
geometry

Lightfields

- Advantages:
 - Simpler computation vs. traditional CG
 - Cost independent of scene complexity
 - Cost independent of material properties and other optical effects
 - Avoid hard vision problems
- Disadvantages:
 - Static geometry
 - Fixed lighting
 - High storage cost

Other IBR Representations

- Texture maps
- VDTMs
- Surface lightfields
- Unstructured lightfields
- Concentric mosaics
- Panorama
- Etc.



IBR Summary

- Advantages
 - Photorealistic - by definition
 - Do not have to create 3D detailed model
 - Do not have to do lighting simulation
 - Performance independent of scene
- Disadvantages
 - Static scenes only
 - Real-world scenes only
 - Difficult for scenes with specularities, etc.
 - Limited range of viewpoints
 - Limited resolution