**Image-Based Rendering**

CSE 274, Lecture 4: IBR and Light Fields

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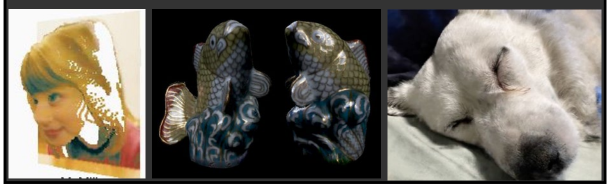

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## To Do

- Project Milestone Reports Due ??
- 1-2 page PDF or weblink with at least one image or video to show current results
- Describe project, progress to date, and final proposal based on results

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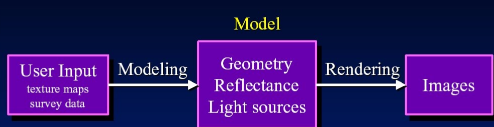
## Traditional Modeling and Rendering




For Photorealism:

**Modeling is Hard** **Rendering is Slow**

Next few slides courtesy Paul Debevec; SIGGRAPH 99 course notes

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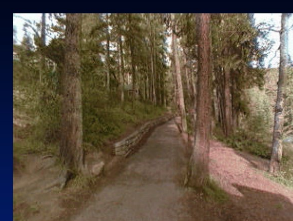

Can we model and render this?

What do we want to do with the model?

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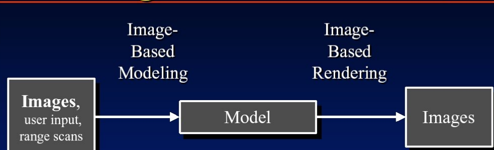
## Image-Based Modeling and Rendering

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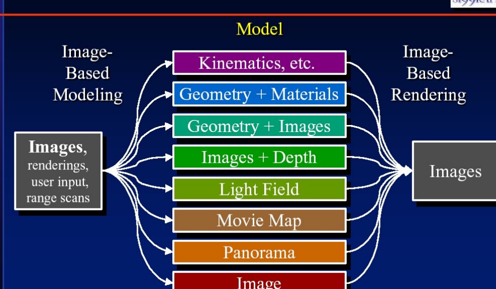
## The Spectrum of IBMR

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## IBR: Pros and Cons

- Advantages
  - Easy to capture images: photorealistic by definition
  - Simple, universal representation
  - Often bypass geometry estimation?
  - Independent of scene complexity?
- Disadvantages
  - WYSIWYG but also WYSIAYG
  - Explosion of data as flexibility increased
  - Often discards intrinsic structure of model?
- Today, IBR-type methods also often used in synthetic rendering (e.g. real-time rendering PRT)
  - General concept of data-driven graphics, appearance
  - Also, data-driven geometry, animation, simulation
  - Spawned light field cameras for image capture

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## Image-Based Models: What do they allow?

SIGGRAPH

| Model | 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 | Rotation | None | Fixed |
| Image | None | None | Fixed |

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## IBR: A brief history

- Texture maps, bump maps, environment maps [70s]
- Poggio MIT 90s: Faces, image-based analysis/synthesis
- Mid-Late 90s
  - Chen and Williams 93, View Interpolation [Images+depth]
  - Chen 95 Quicktime VR [Images from many viewpoints]
  - McMillan and Bishop 95 Plenoptic Modeling [Images w disparity]
  - Gortler et al, Levoy and Hanrahan 96 Light Fields [4D]
  - Shade et al. 98 Layered Depth Images [2.5D]
  - Debevec et al. 00 Reflectance Field [4D]
  - Inverse rendering (Marschner,Sato,Yu,Boivin,…)
- Today: IBR hasn't replaced conventional rendering, but has brought sampled and data-driven representations to graphics

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## Game #1: increase the dimensionality

| | |
| --- | --- |
| 2D rgb | texture |
| 2D rgbz | range image |
| 2.5D rgbαz | layered depth images |
| 4D rgb | light field / Lumigraph |
| 4D rgbz | array of range images |
| 4.5D rgbαz | layered light fields |

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## Game #2: replace the quantity represented

4D rgb — light field / Lumigraph
$\{u, v, s, t\}$

5D rgb — plenoptic function
$\{x, y, z\} \times \{\theta, \varphi\}$

6D ρ — free-space BRDF field
$\{u, v, s, t\} \times \{\theta_i, \varphi_i\}$

7D ρ — BRDF volume
$\{x, y, z\} \times \{\theta_i, \varphi_i, \theta_r, \varphi_r\}$

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## Outline

- Overview of IBR
- Basic approaches
  - *Image Warping*
    - *[2D + depth. Requires correspondence/disparity]*
  - Light Fields [4D]
  - Survey of some early work

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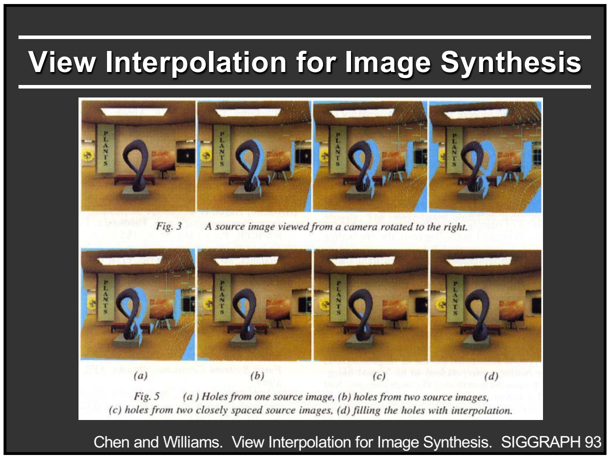


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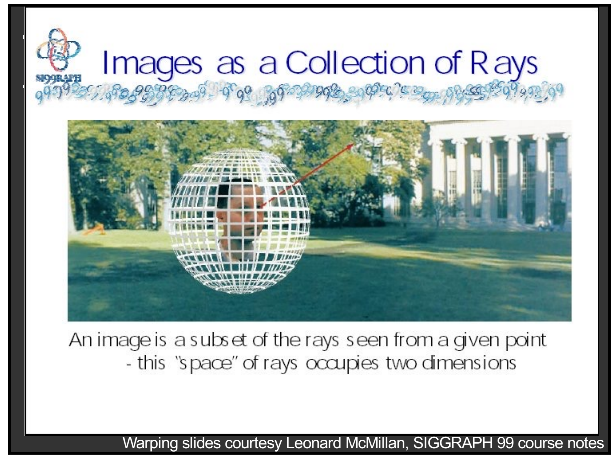


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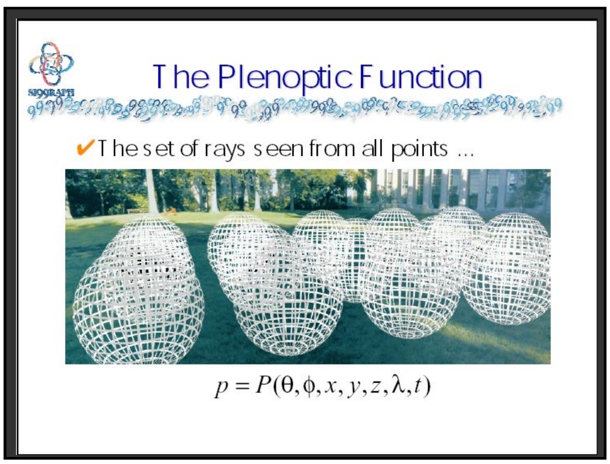


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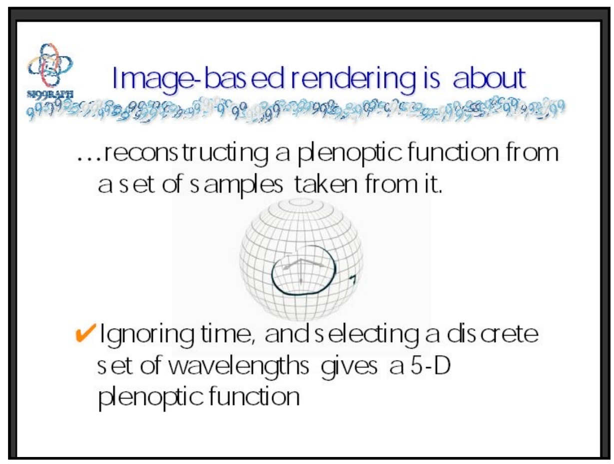


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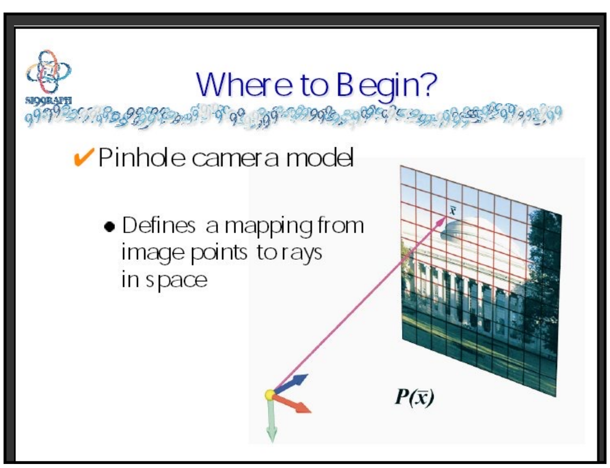


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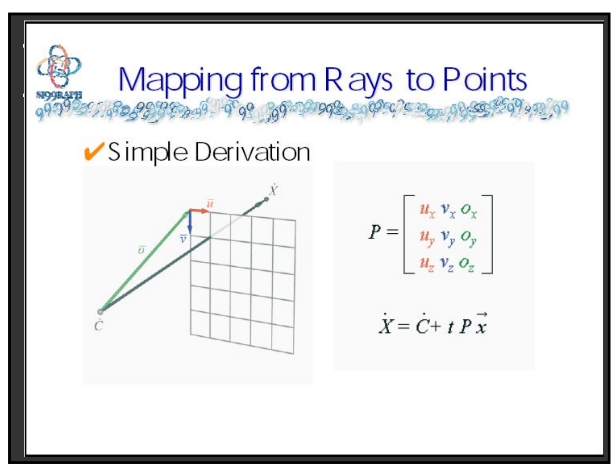


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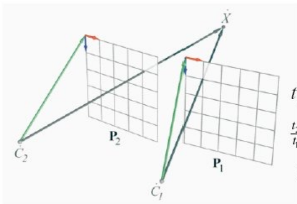
## Correspondence




$$\dot{C}_2 + t_2 P_2 \vec{x}_2 = \dot{C}_1 + t_1 P_1 \vec{x}_1$$

$$t_2 P_2 \vec{x}_2 = \dot{C}_1 - \dot{C}_2 + t_1 P_1 \vec{x}_1$$

$$t_2 \vec{x}_2 = P_2^{-1}\left(\dot{C}_1 - \dot{C}_2\right) + t_1 P_2^{-1} P_1 \vec{x}_1$$

$$\tfrac{t_2}{t_1} \vec{x}_2 = \tfrac{1}{t_1} P_2^{-1}\left(\dot{C}_1 - \dot{C}_2\right) + P_2^{-1} P_1 \vec{x}_1$$

$$\vec{x}_2 \doteq \underbrace{\tfrac{1}{t_1}}_{\delta} \underbrace{P_2^{-1}\left(\dot{C}_1 - \dot{C}_2\right)}_{\vec{e}_{21}} + \underbrace{P_2^{-1} P_1}_{H_{21}} \vec{x}_1$$

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## Warping in Action

✔ A 3D Warp

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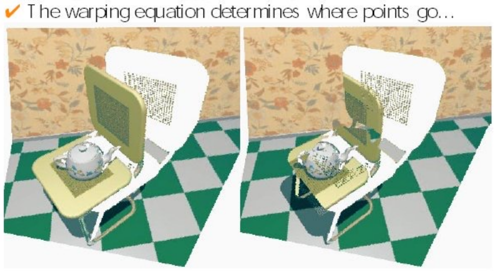
## Visibility

✔ The warping equation determines where points go…



… but that is not sufficient

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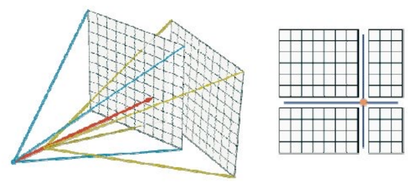
## Partition Reference Image

✔ Project the *desired* center-of-projection onto the reference image



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## Enumeration

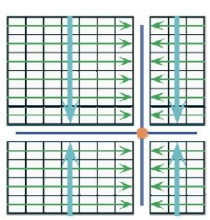
✔ Drawing toward the projected point guarantees an *occlusion compatible* ordering

✔ Ordering is consistent with a painter's algorithm

✔ Independent of the scene's contents

✔ Easily generalized to other viewing surfaces

✔ No auxiliary information required



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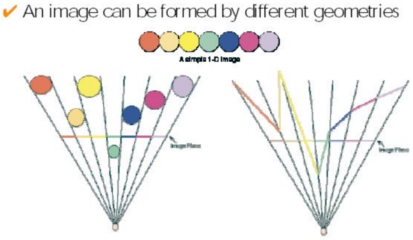
## Reconstruction

✔ Typical images are discrete, not continuous

✔ An image can be formed by different geometries



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  - *Light Fields [4D]*
  - Survey of some early work

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## Light Field Rendering

*Marc Levoy* *Pat Hanrahan*

Computer Science Department
Stanford University

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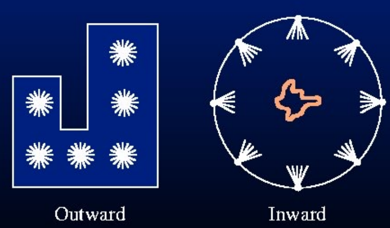
## Apple's QuickTime VR

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## Generating New Views

Problem: fixed vantage point/center

One Solution: view interpolation

- Interpolating between range images (Chen and Willams, 1993)
- Correspondences and epipolar analysis (McMillan and Bishop, 1995)

-> Requires depths or correspondences:

<u>must be extracted from acquired imagery</u>

<u>relatively expensive and error-prone morph</u>

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## Light Fields

Gershun's and Moon's idea of a light field:

*Radiance as a function of a ray or line: $L(x, y, z, \theta, \phi)$*

- In "free space" (no occluders) 5D reduces to 4D
  - Exterior of the convex hull of an object
  - Interior of an environment
- Images are 2D slices
  - Insert acquired imagery
  - Extract image from a given viewpoint

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## 4D Light Field

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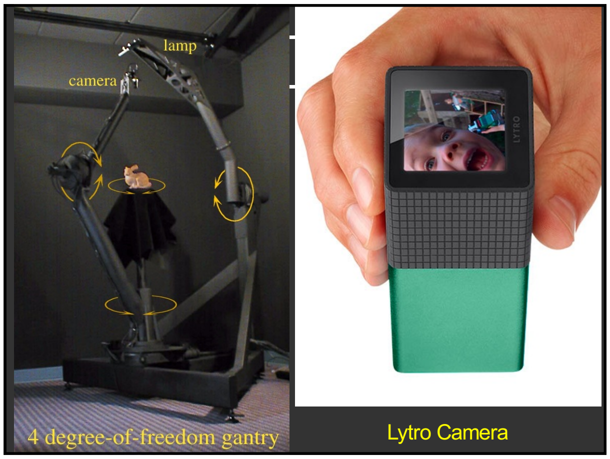


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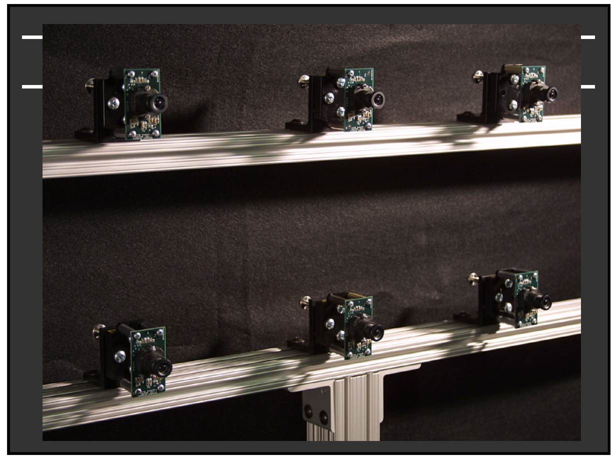

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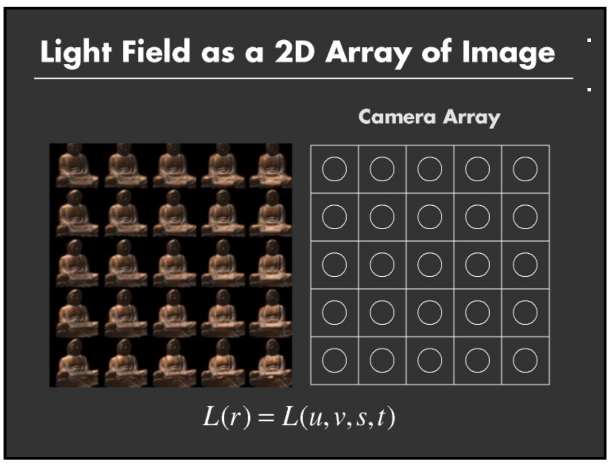


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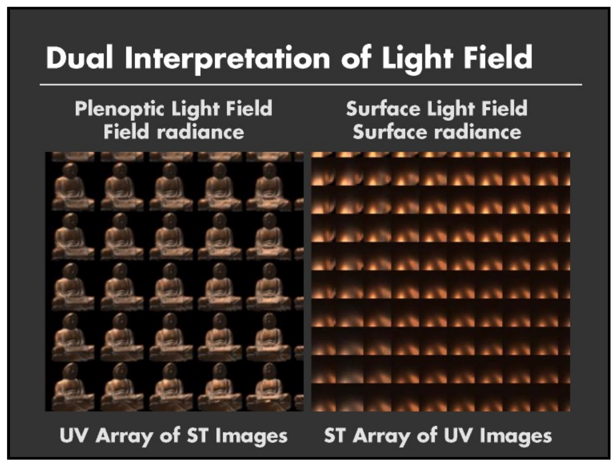


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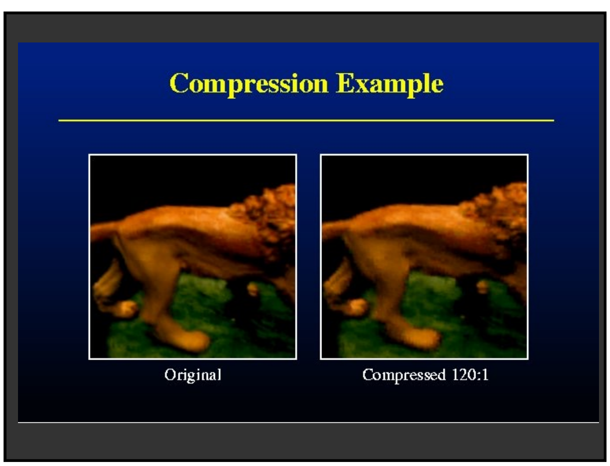


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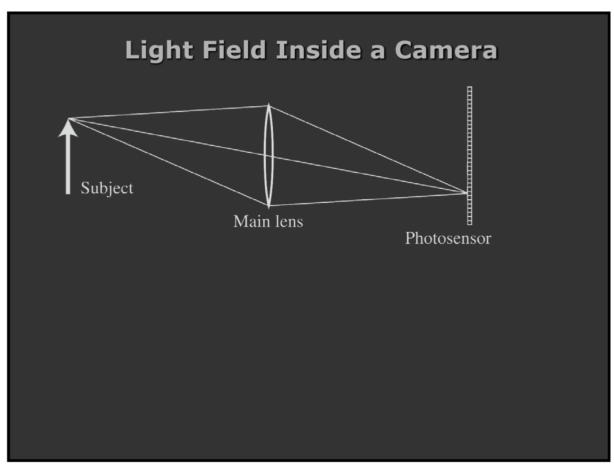


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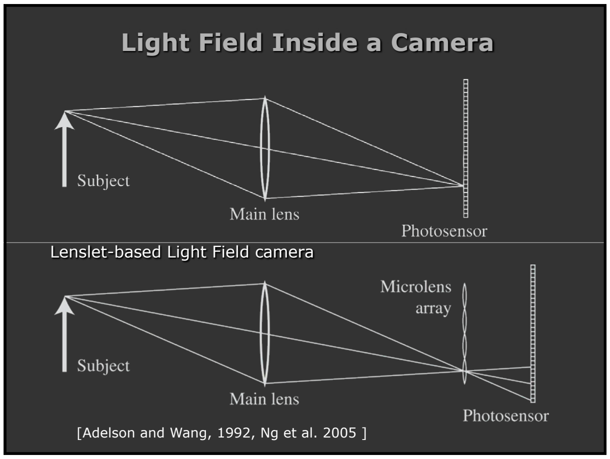


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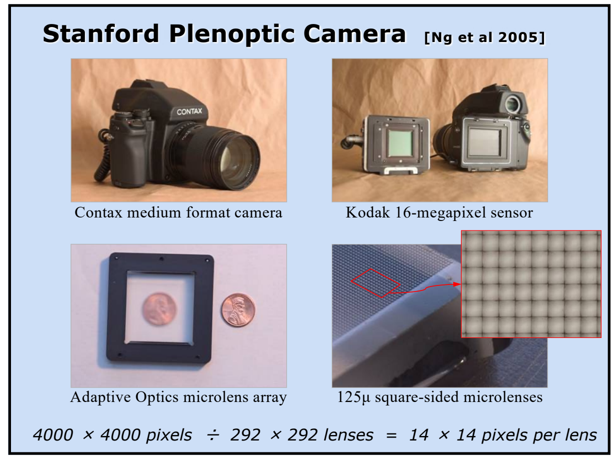


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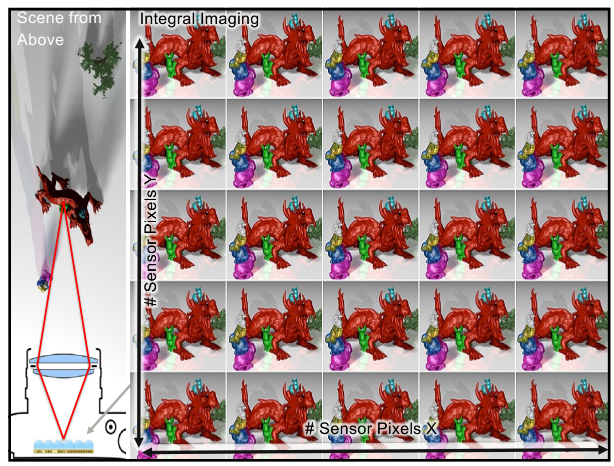


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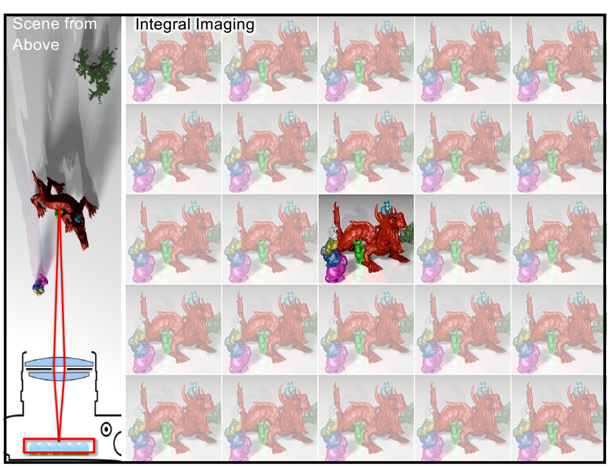


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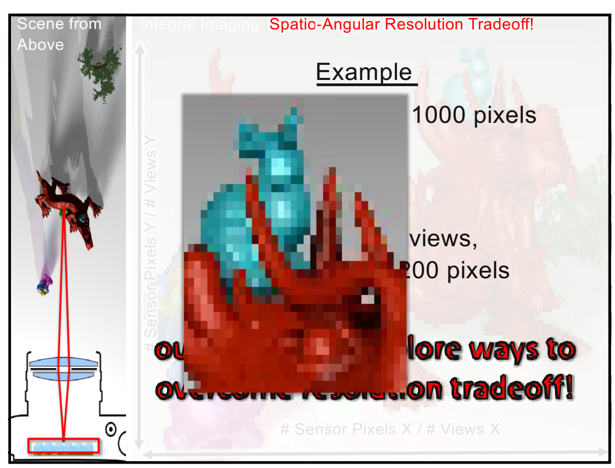


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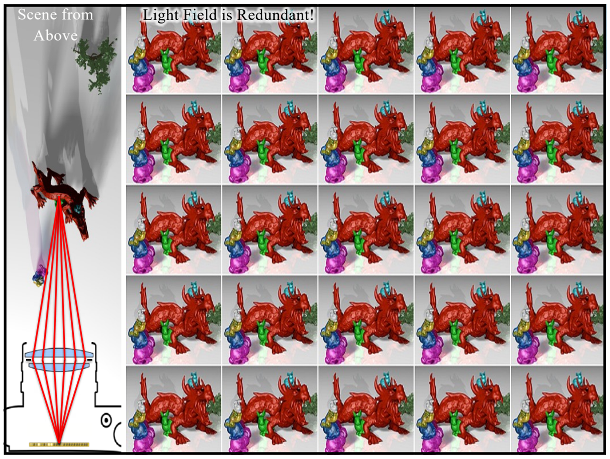


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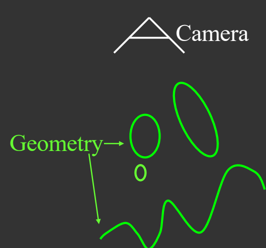
## Layered Depth Images [Shade 98]




Slide from Agrawala, Ramamoorthi, Heirich, Moll, SIGGRAPH 2000

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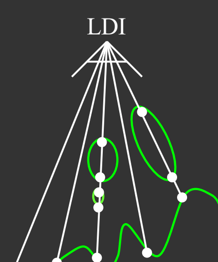
## Layered Depth Images [Shade 98]

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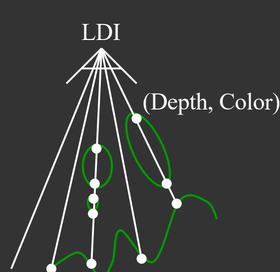


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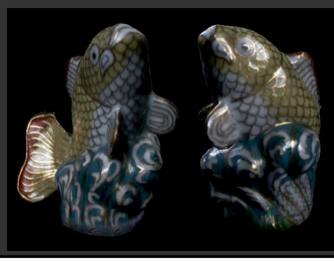
## Surface Light Fields

- Miller 98, Nishino 99, Wood 00
- Reflected light field (lumisphere) on surface
- Explicit geometry as against light fields.  Easier compress



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## Acquiring Reflectance Field of Human Face [Debevec et al. SIGGRAPH 00]

Illuminate subject from many incident directions

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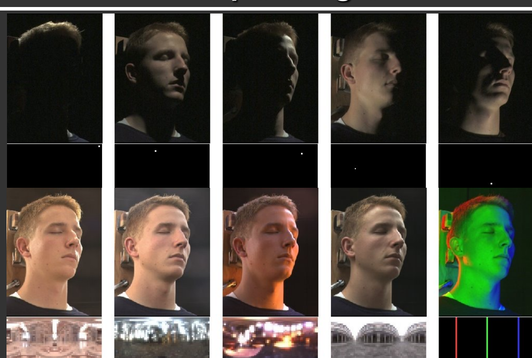
## Example Images



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