Image-based Modeling and Rendering

4. The Lumigraph & Light Field Rendering

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Outline

- How to represent an object with images?
- Construct the plenoptic function:
  - The lumigraph
  - Light field rendering

Ref:

• Image-based Modeling and Rendering, SIGGRAPH’99 course notes.

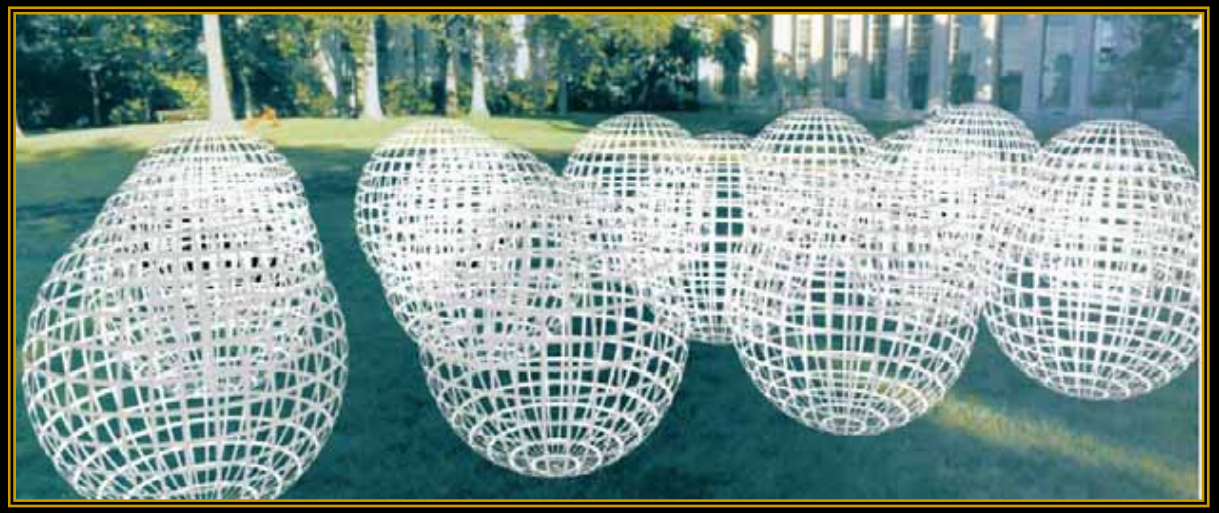
• M. Levoy, P. Hanrahan, "Light Field Rendering", Proc. SIGGRAPH'96, pp.31 - 42, 1996.

• S. J. Gortler, R. Grzeszczuk, R. Szeliski, M.F. Cohen, "The Lumigraph", Proc. SIGGRAPH 96, pp.43 - 54, 1996.

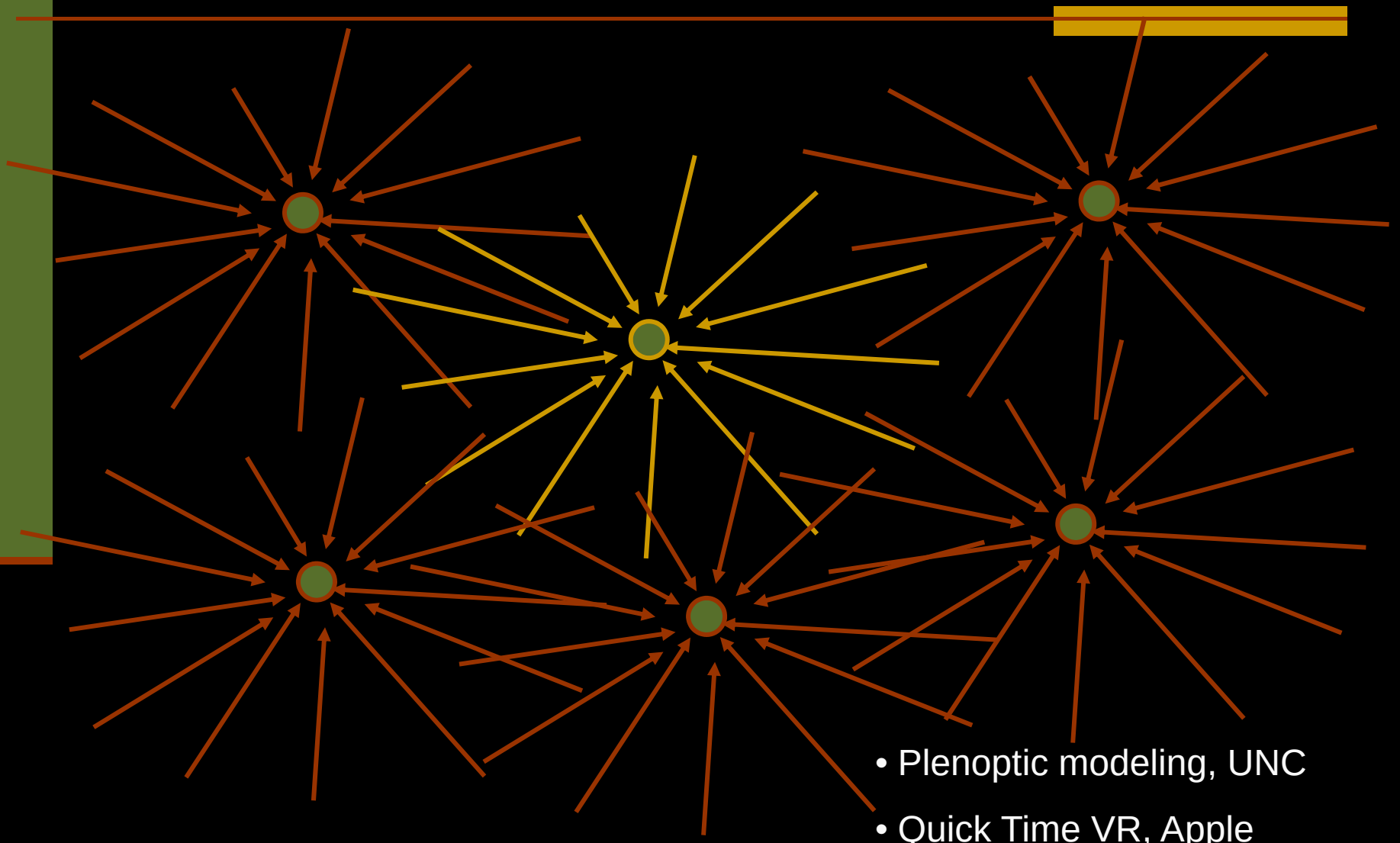
The Plenoptic Function

- Reconstruct every possible view, at every moment, from every position, at every wavelength

$$P(\theta,\phi,\lambda,t,V_X,V_Y,V_Z)$$



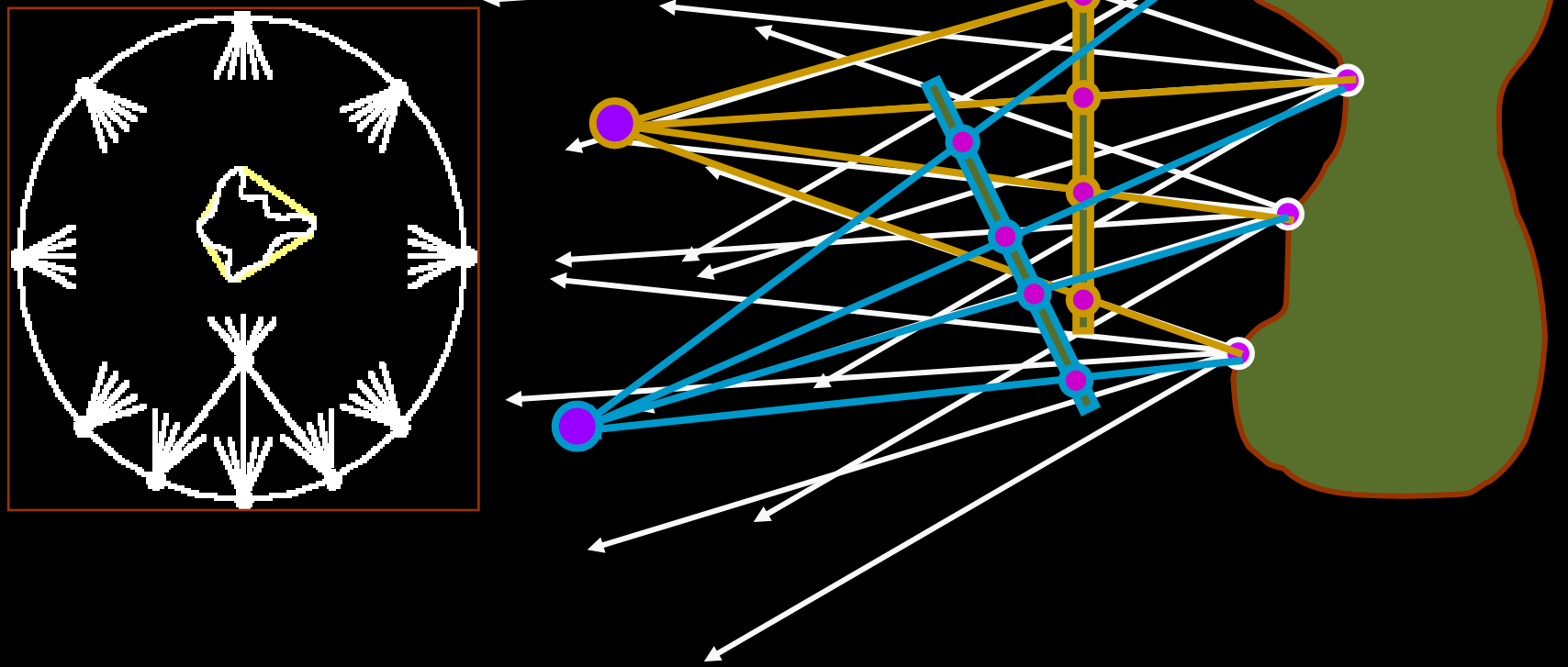
Sampling The Plenoptic Function



- Plenoptic modeling, UNC
- Quick Time VR, Apple

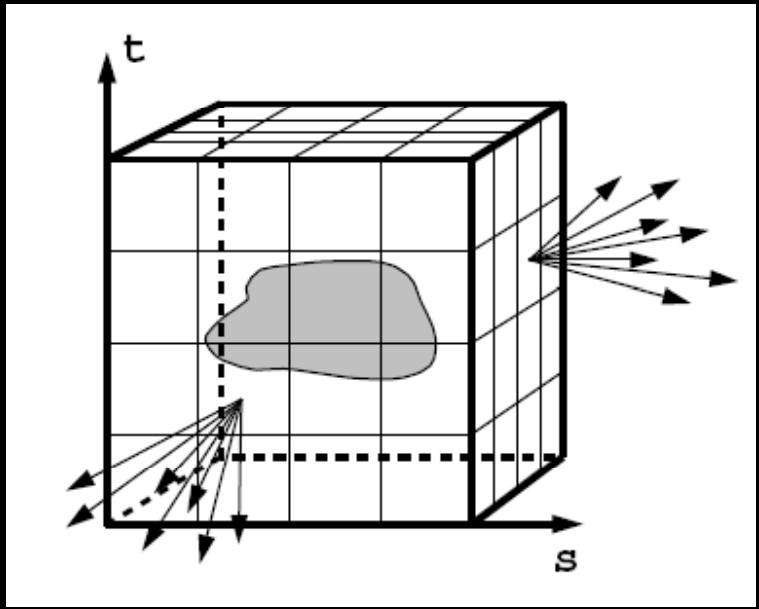
Sampling The Plenoptic Function

- How to reconstruct the plenoptic function for an object?



Only need plenoptic surface

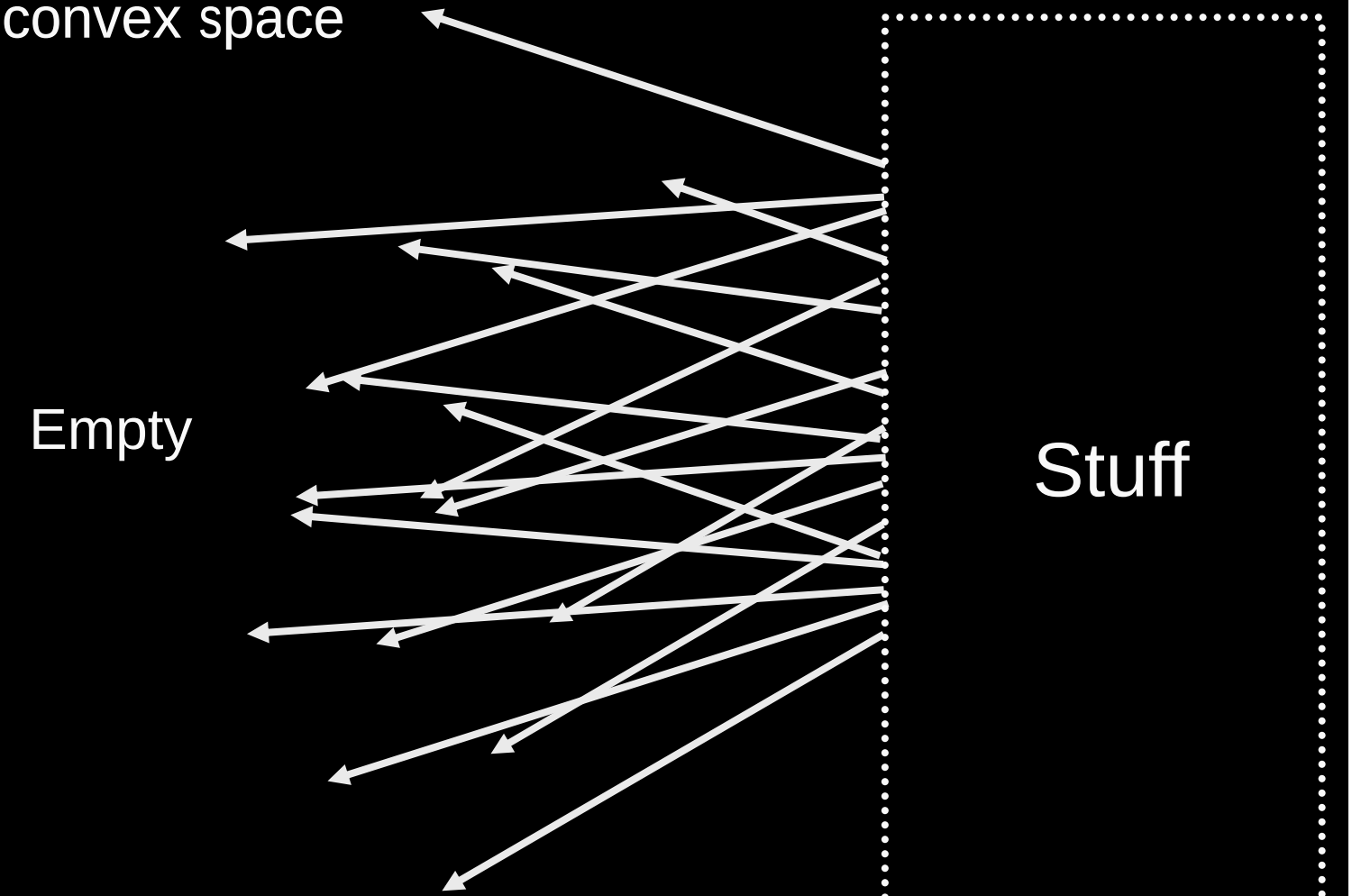
- In “free space” (no occluders) the dimensionality is reduced from 5D to 4D.
  - Exterior of the convex hull of an object
  - Interior of an environment
- An image is a 2D slice of the 4D light field.



The surface of a cube holds all the radiance information due to the enclosed object.

Lumigraph / Lightfield

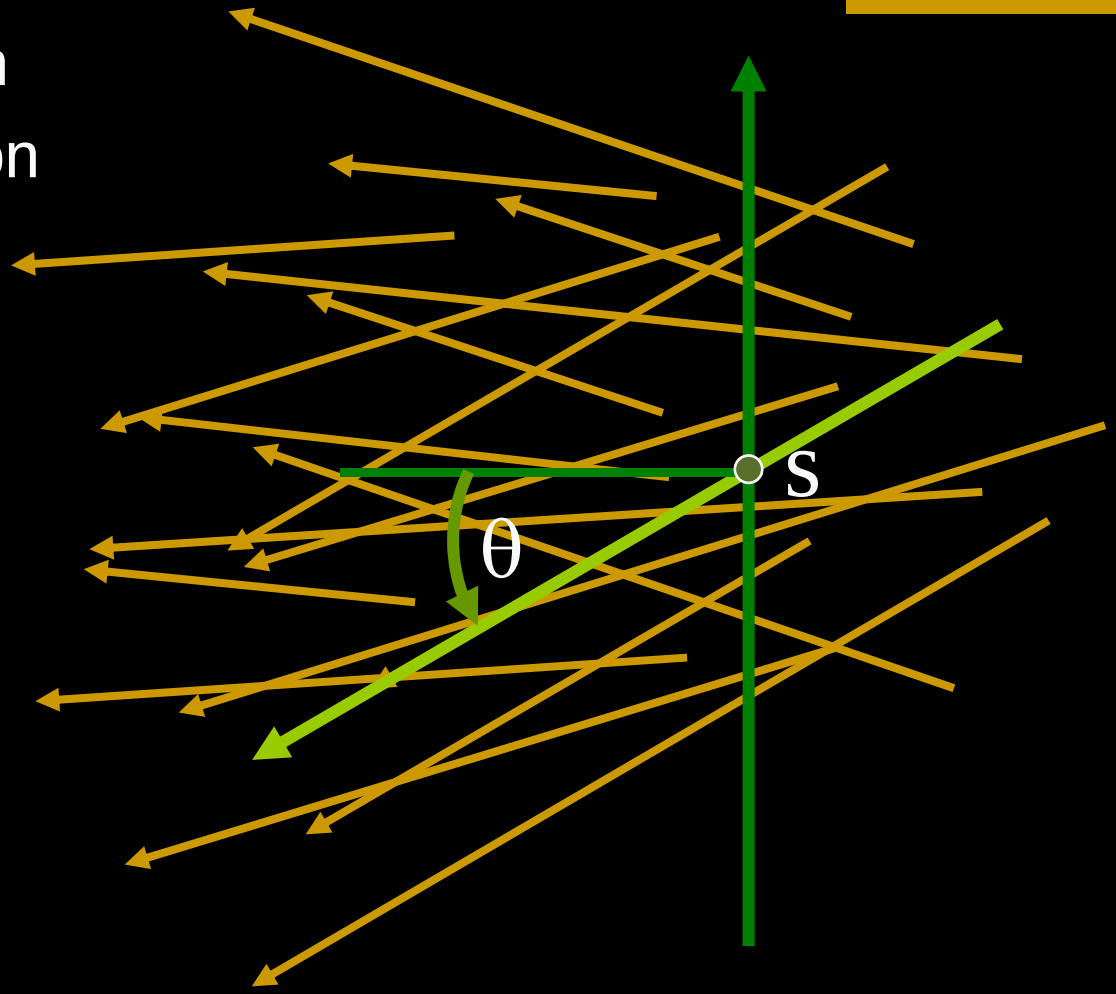
- Outside convex space



4D

Lumigraph / Lightfield

- 2D position
- 2D direction



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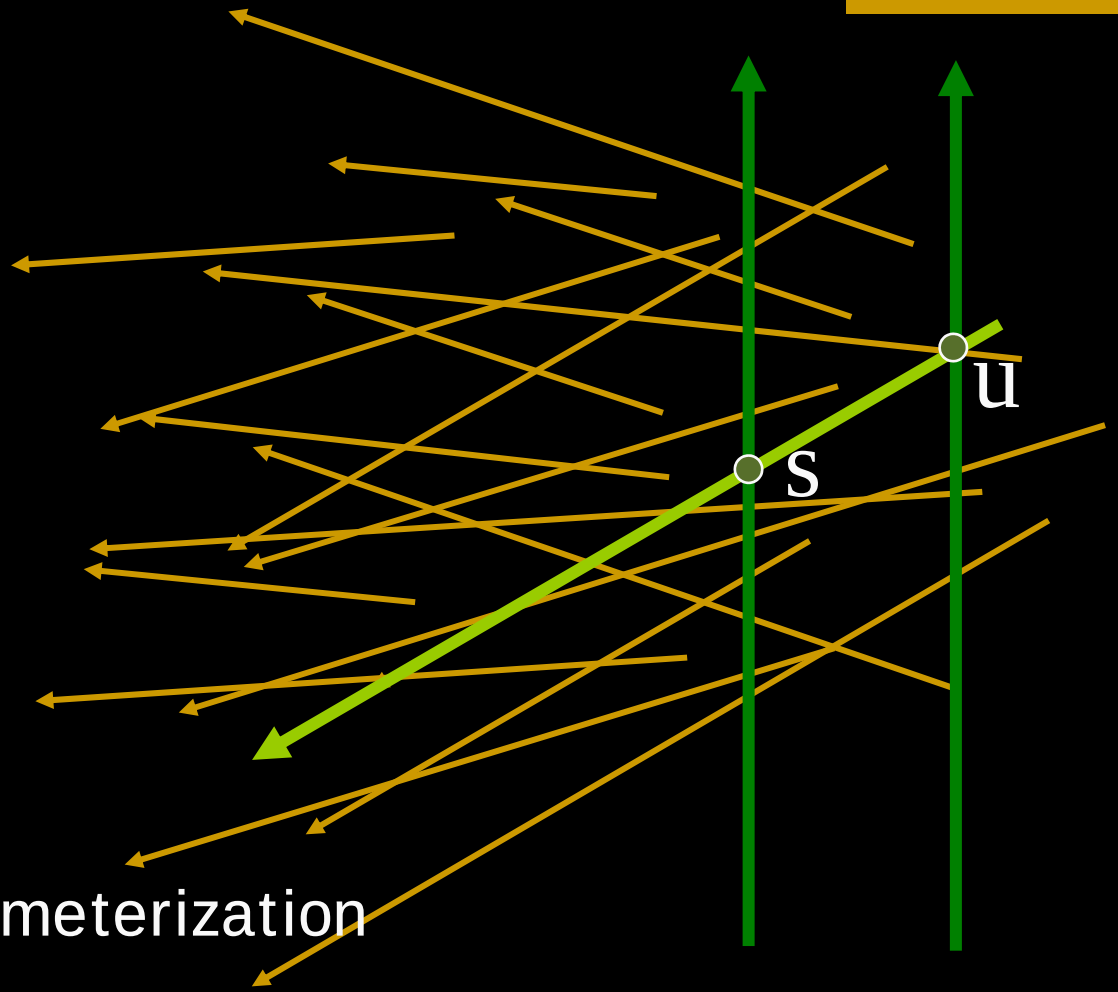
Lumigraph / Lightfield

- 2D position
- 2D position



- 2 plane parameterization

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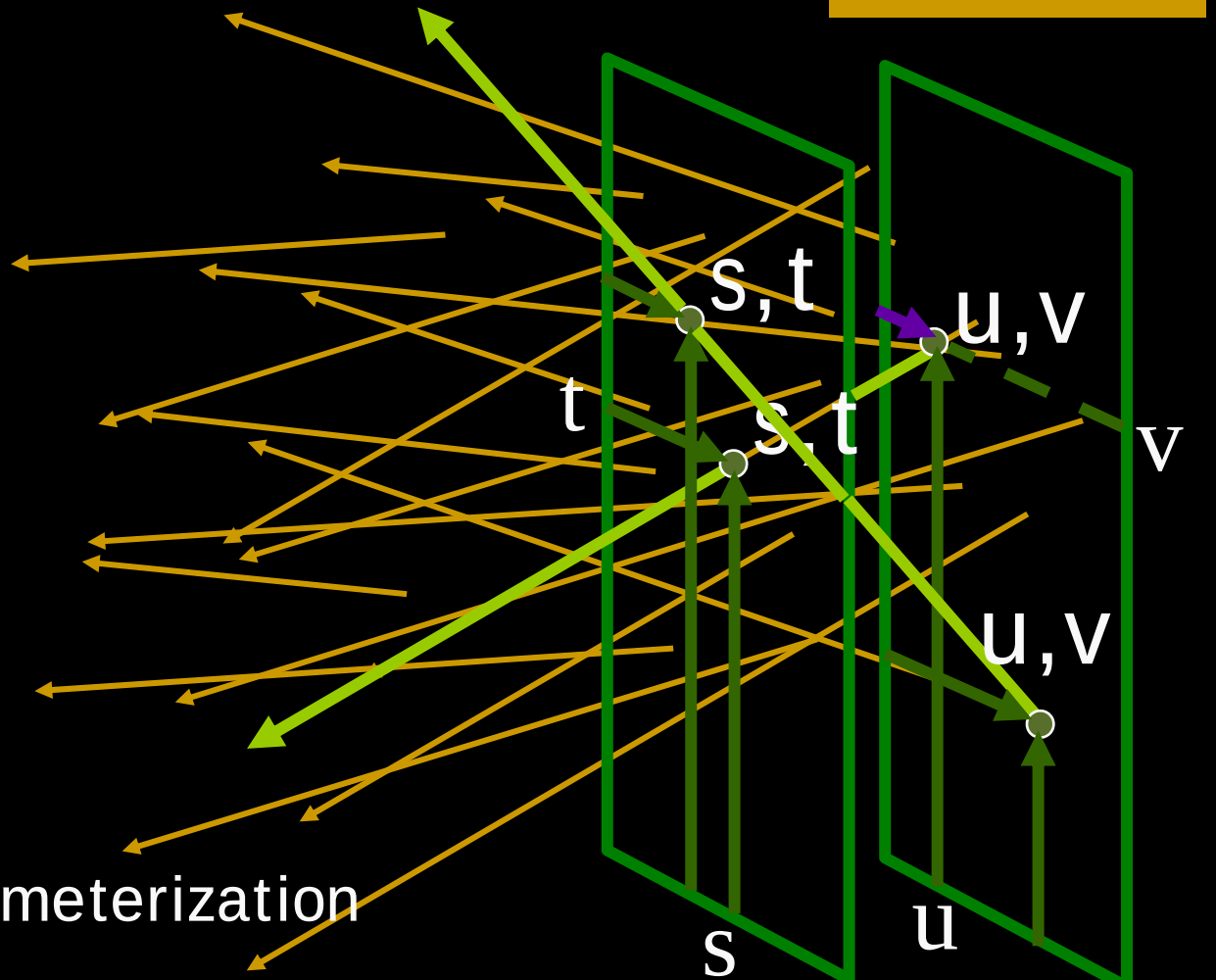
Lumigraph / Lightfield

- 2D position
- 2D position



- 2 plane parameterization

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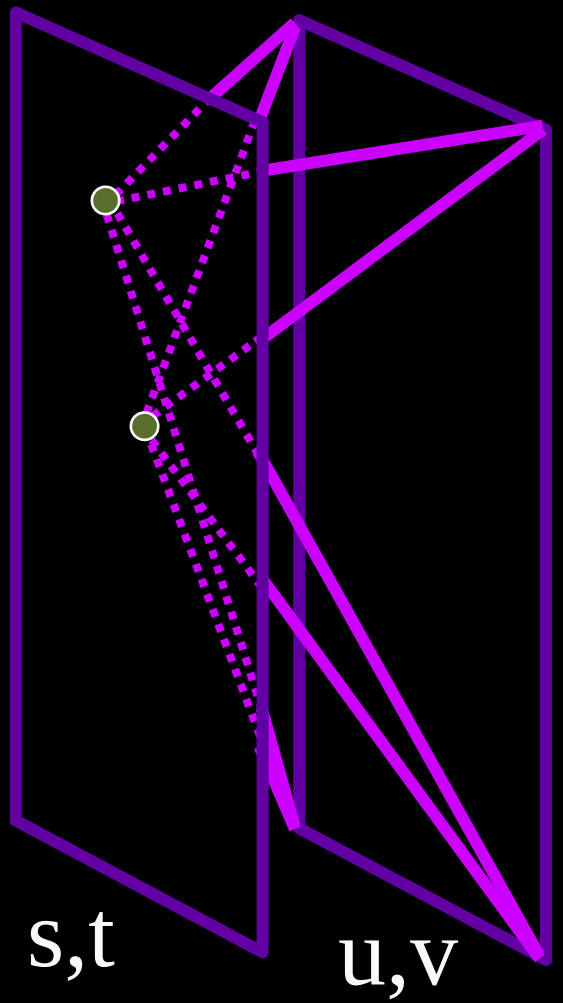
Lumigraph / Lightfield

- Hold s,t constant
- Let u,v vary
- An image



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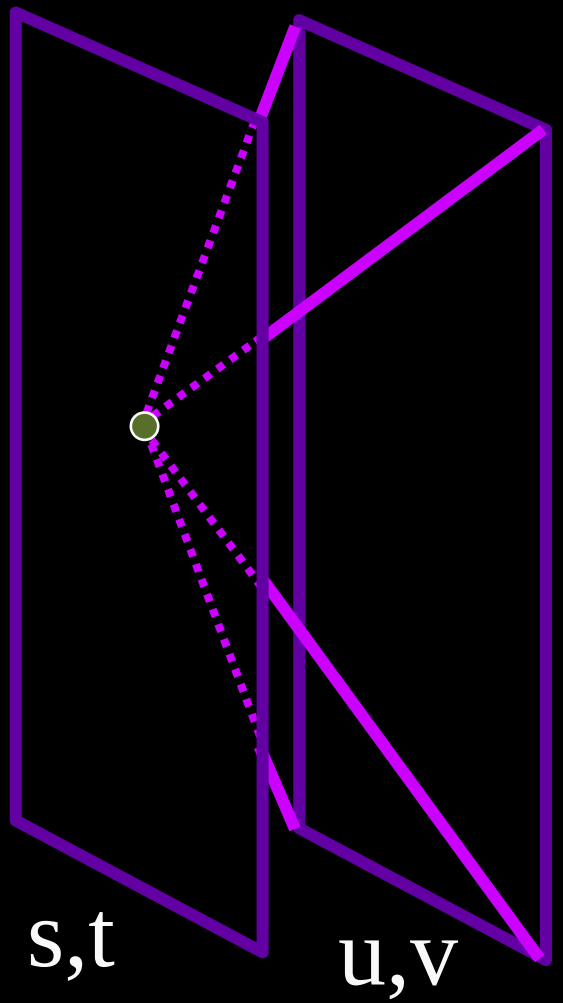
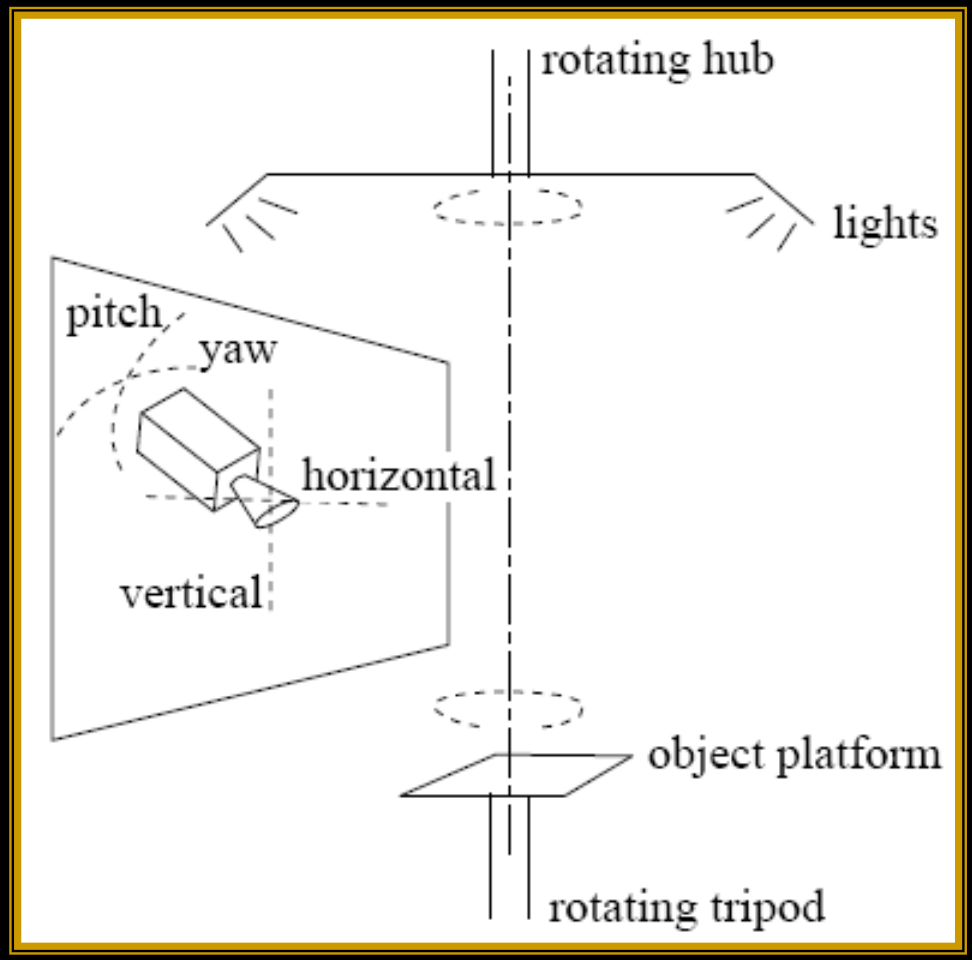
Lightfield - Capture

- Idea 1
  - Move camera carefully over s,t plane
  - Gantry
    - see Lightfield paper



Lightfield - Capture

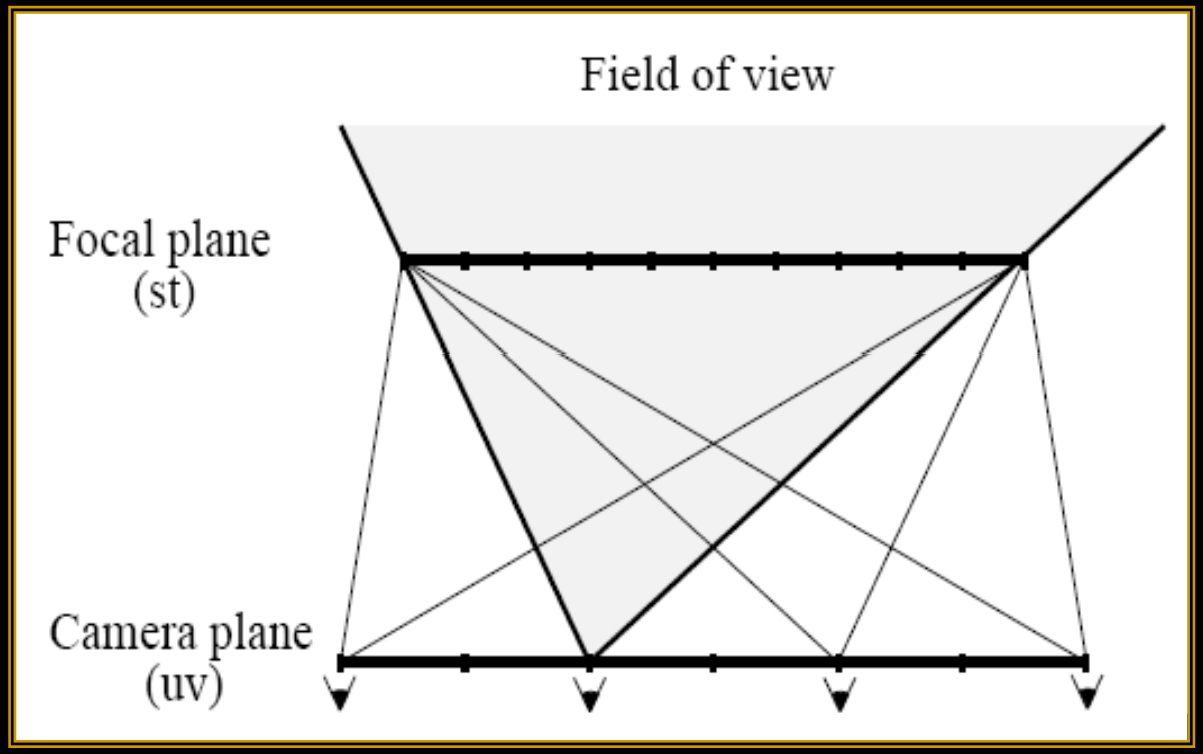


Stanford multi-camera array

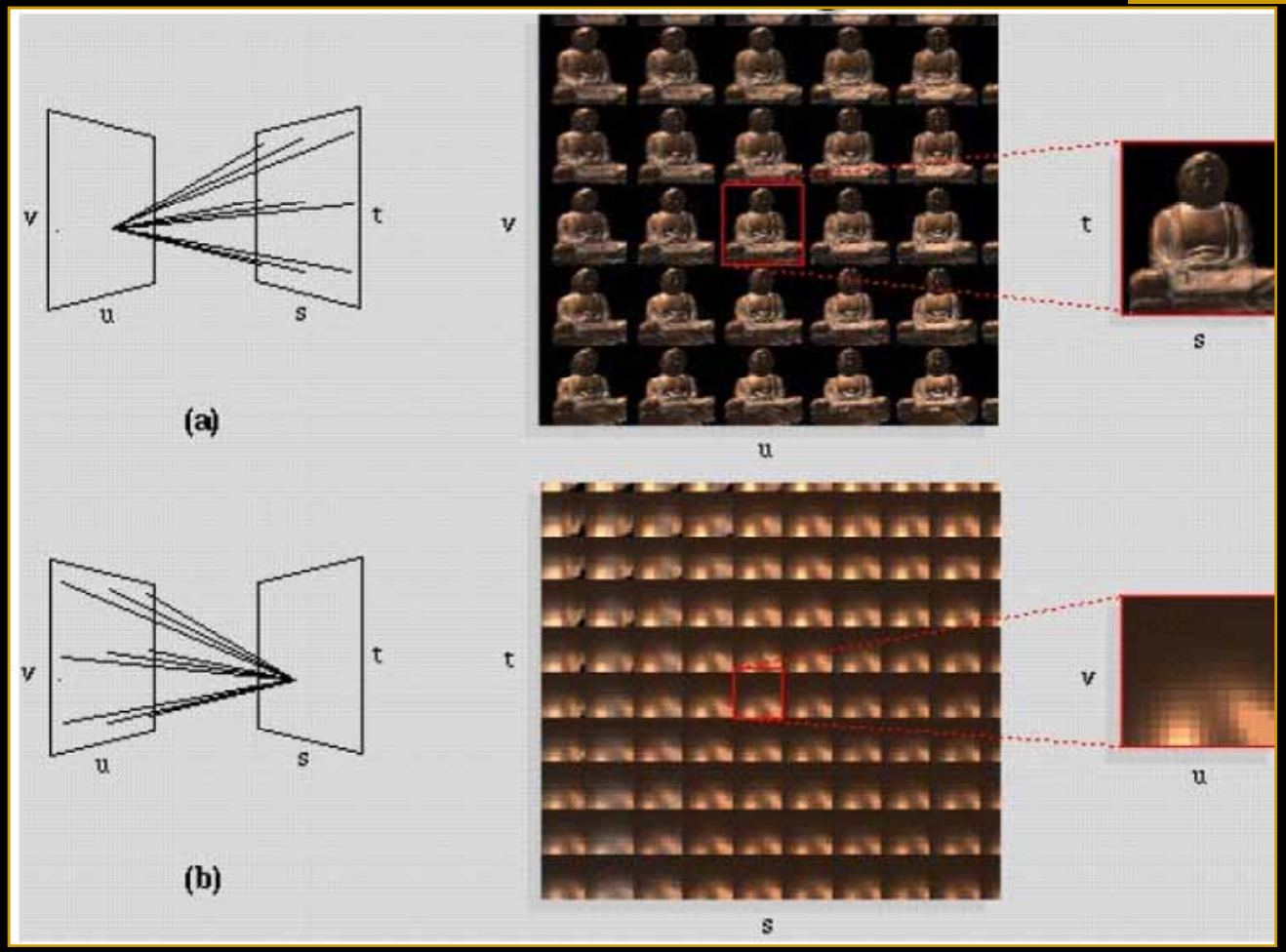
- 640 × 480 pixels × 30 fps × 128 cameras
- synchronized timing
- continuous streaming
- flexible arrangement

Lightfield - Capture

Utilizing sheared perspective transformation



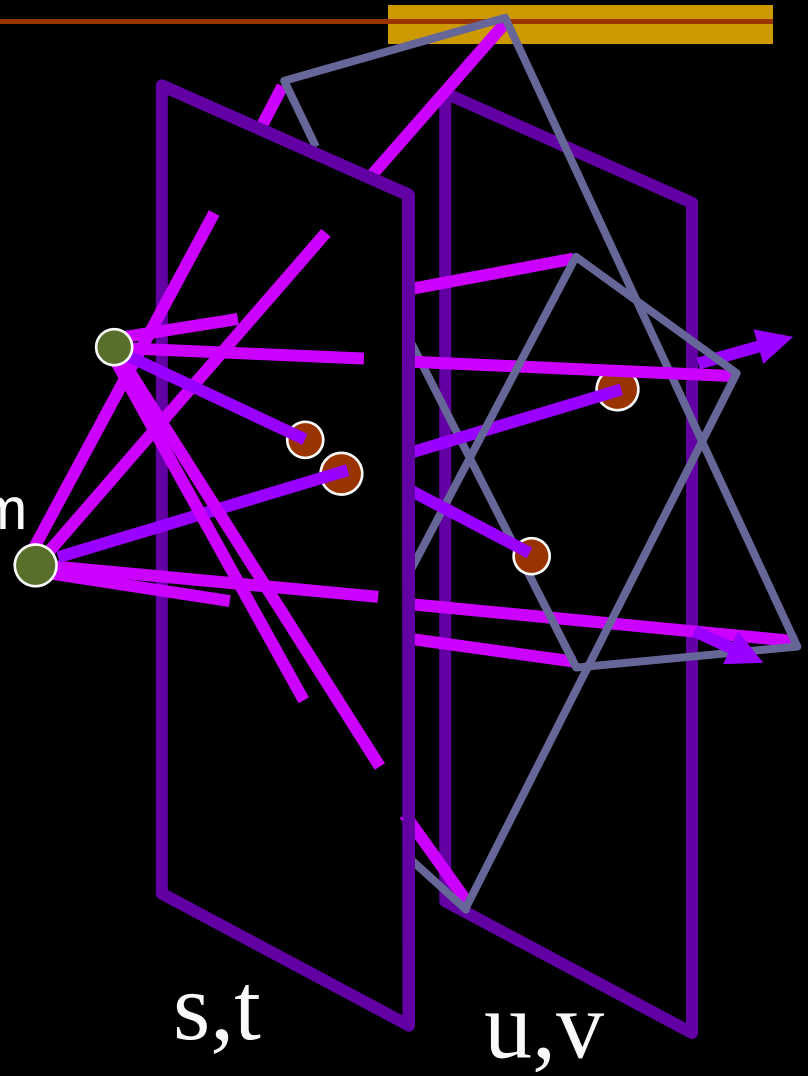
Lumigraph / Lightfield



The notation of st and uv planes are exchanged in papers of Lumigraph and LightField

Lumigraph - Capture

- Idea 2
  - Move camera anywhere
  - Camera intrinsics assumed calibrated
  - Camera pose recovered from markers
  - Rebinning
    - see Lumigraph paper



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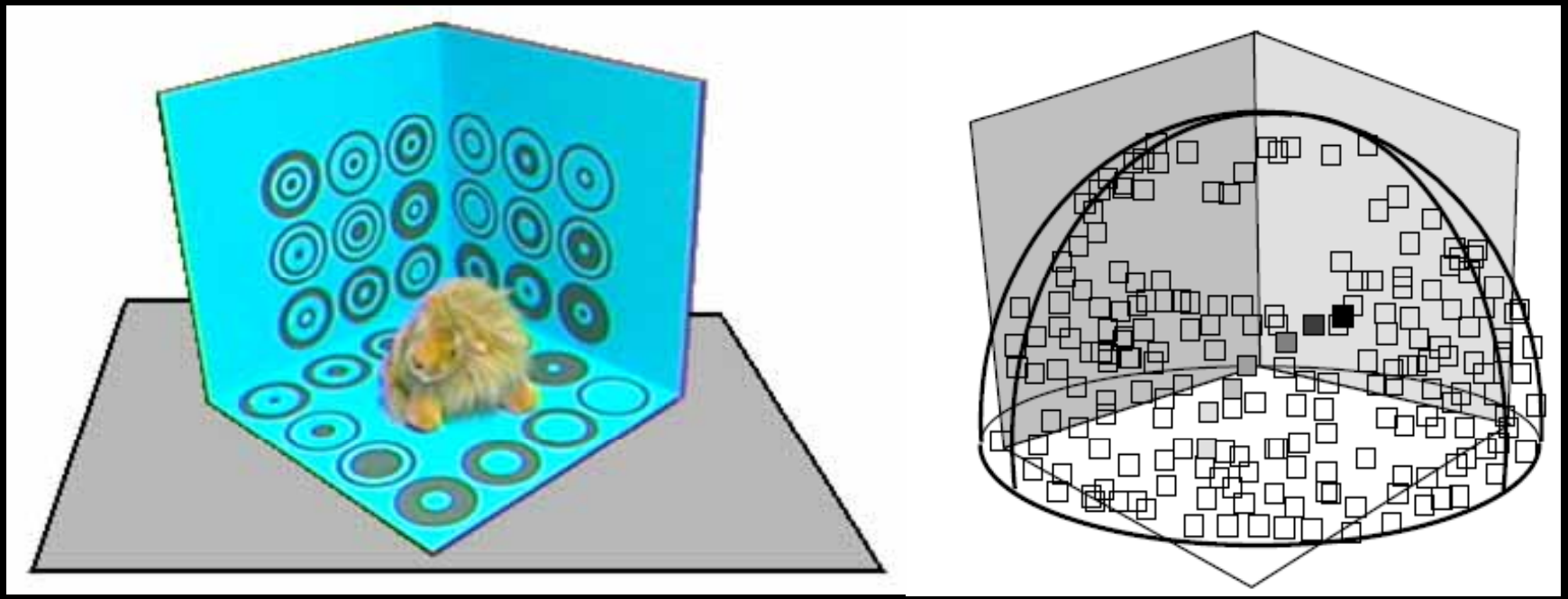
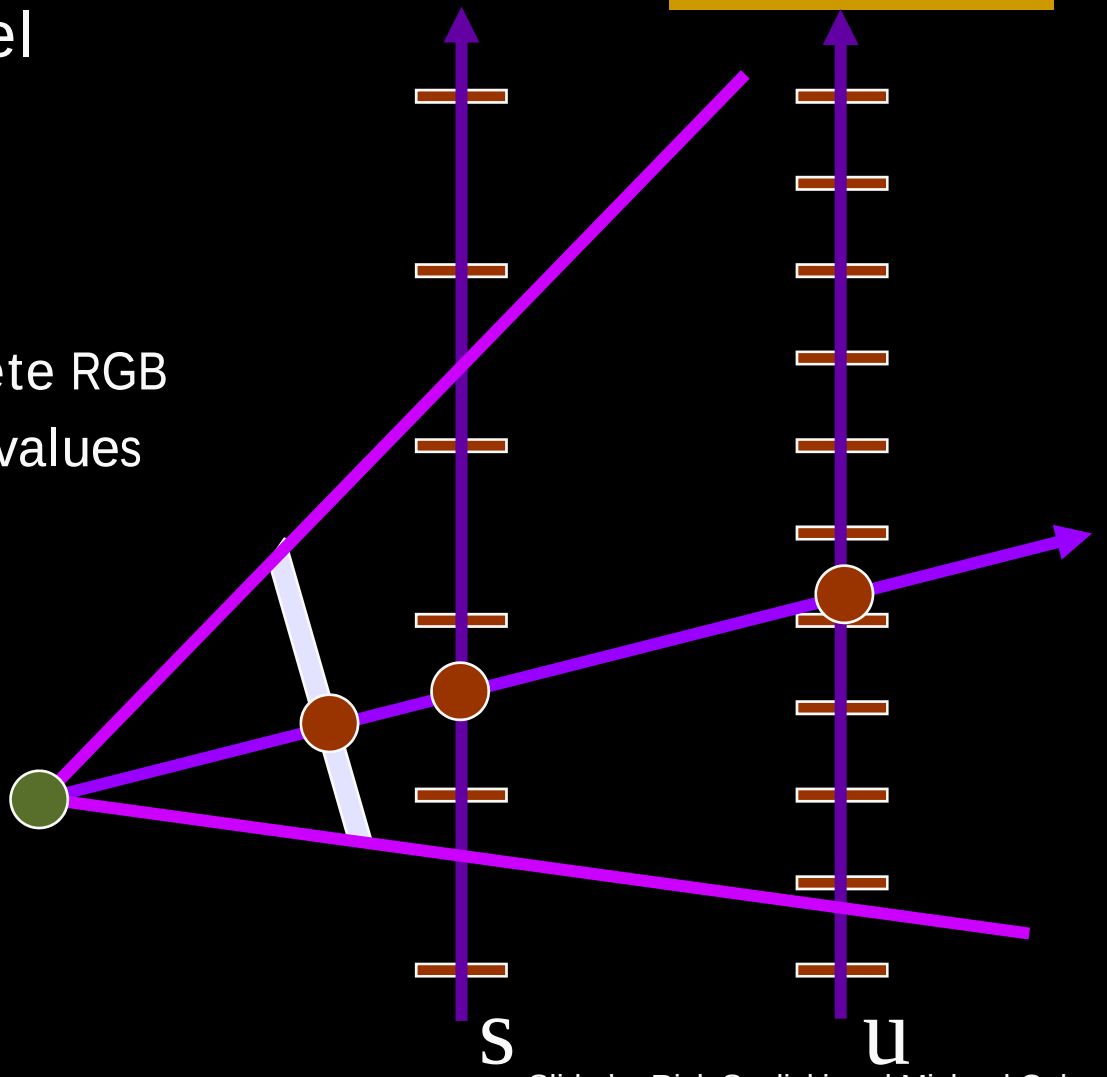
Lumigraph - Capture



Lumigraph / Lightfield - Rendering

- For each output pixel
  - determine s,t,u,v
  - either
    - use closest discrete RGB
    - interpolate near values



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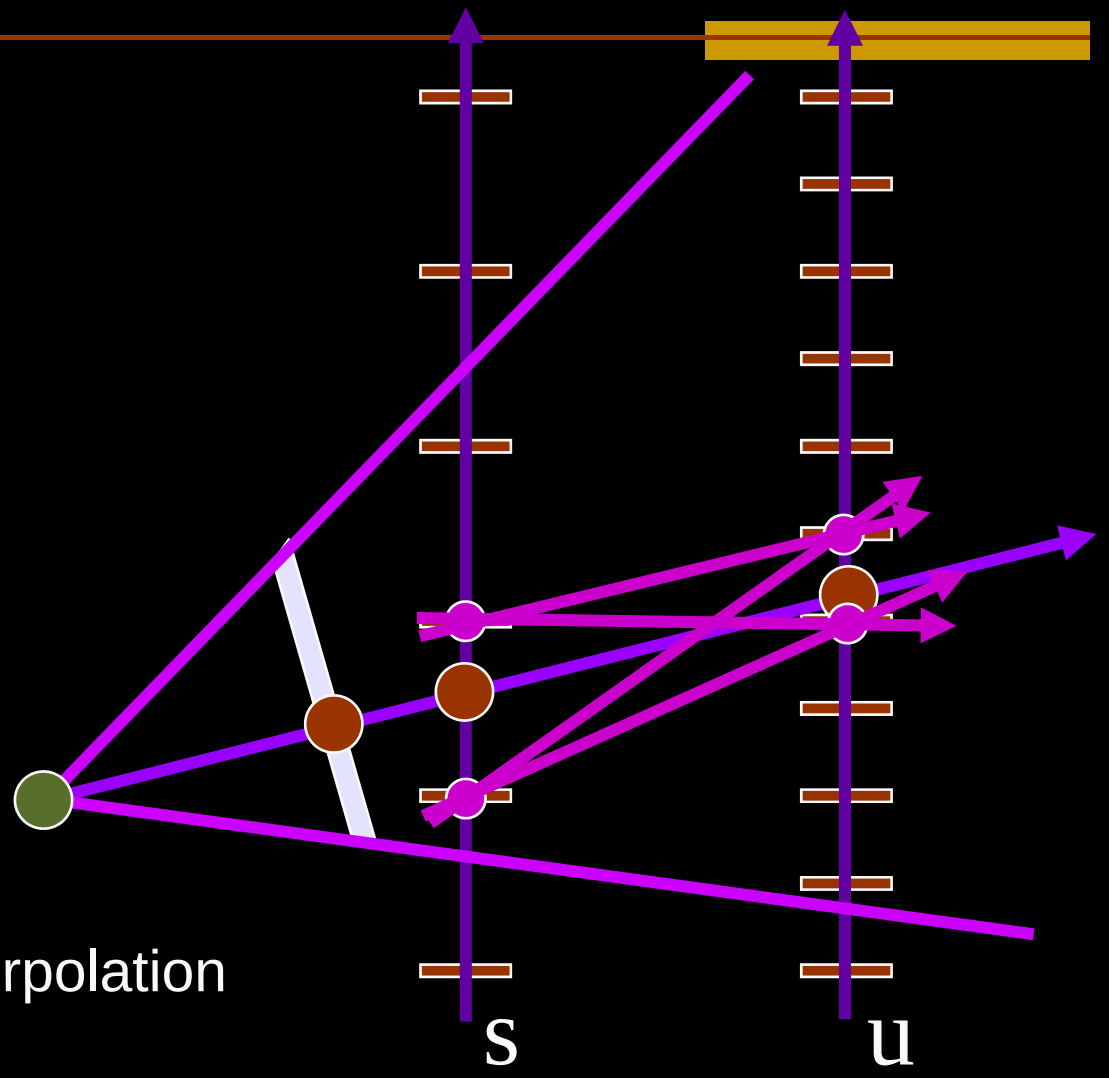
Lumigraph/Lightfield - Rendering

- Nearest
  - closest s
  - closest u
  - draw it
- Blend 16 nearest
  - quadrilinear interpolation



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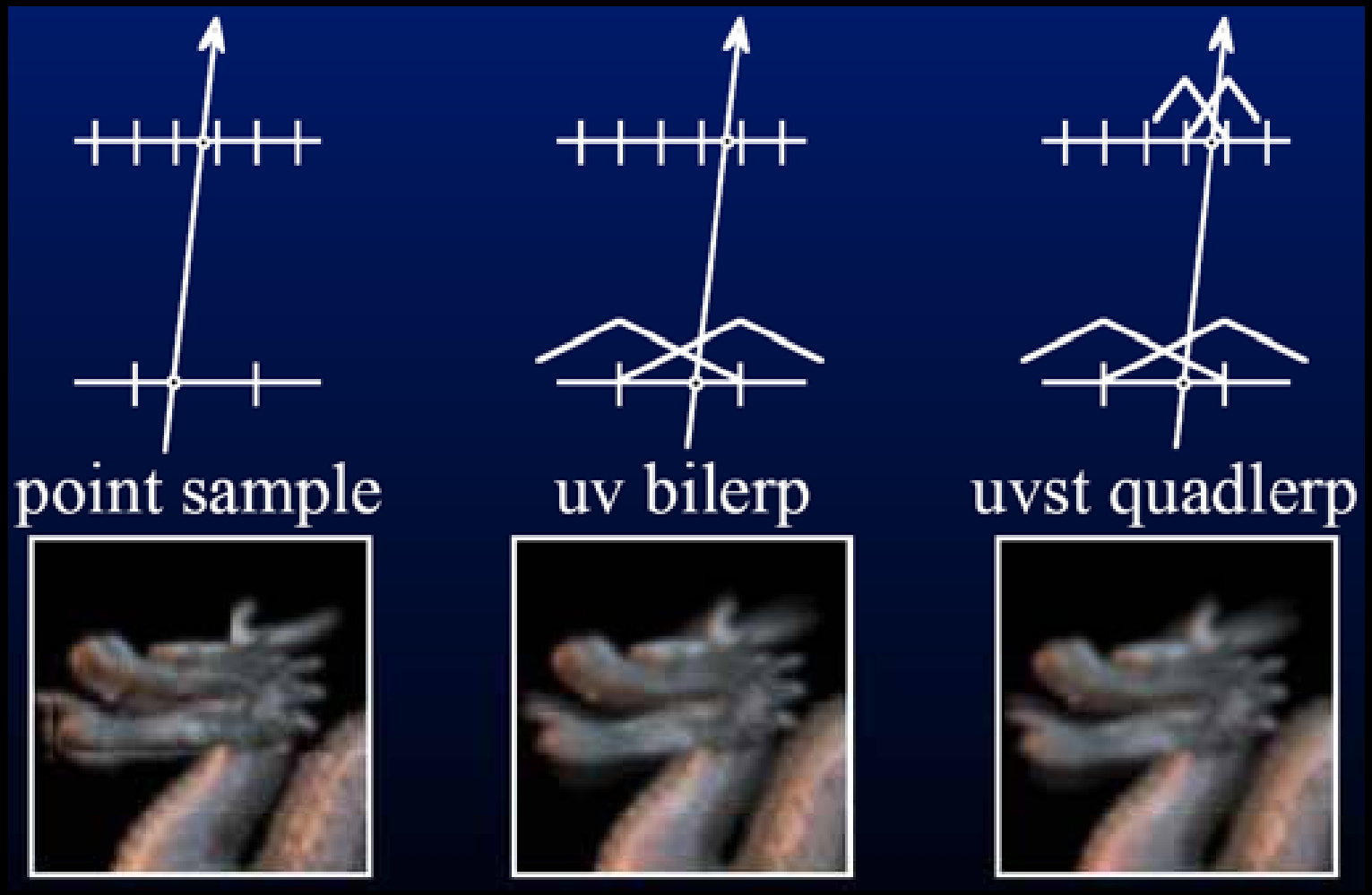
Lumigraph/Lightfield - Rendering

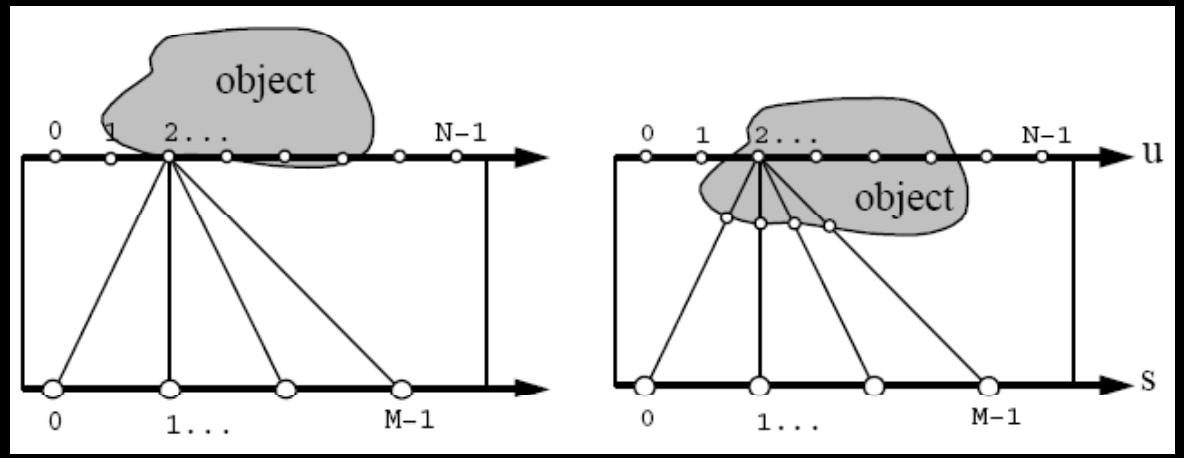


Other issues

- How many samples are sufficient?
- Compression of large image sets.
- Improvement of synthesized image quality.

Resolution

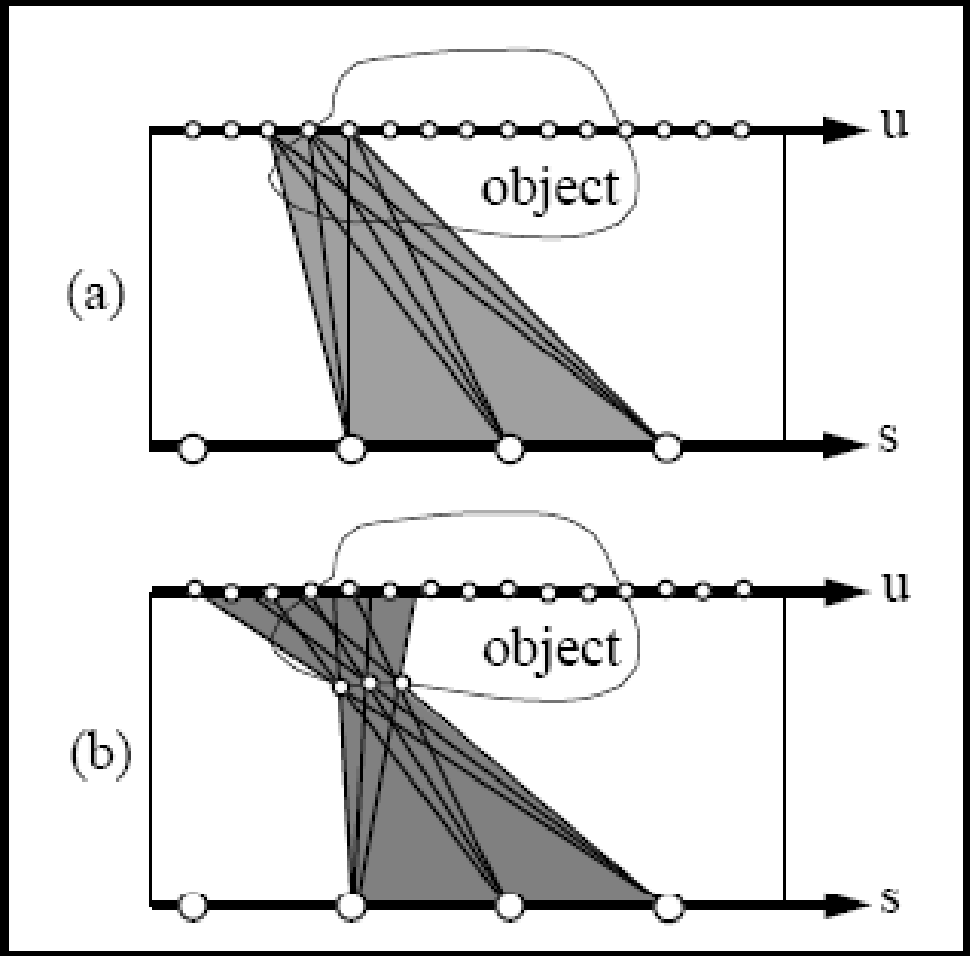
- In Lumigraph paper, they suggested that the far plane needs to have resolution of the desired image.
- The near plane represents the change of view direction; the resolution can be lower.
- Far: 128 to 512
- Near: 16 to 64



Light Field Compression

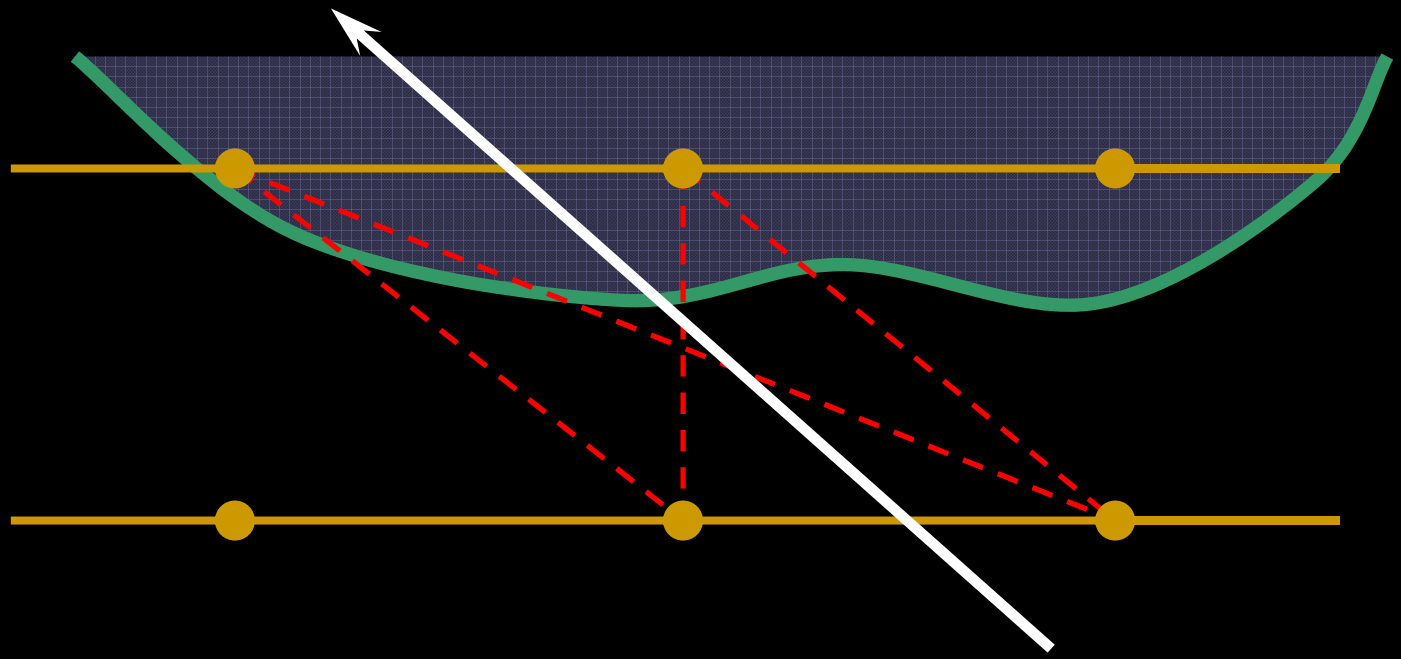
- Compressing based on vector quantization
  - Preprocessing: build a representative codebook
  - Each tile in lightfield represented by index
  - 24:1 compression
- Also applying entropy coding, e.g. Lempel-Ziv, Huffman coding.
  - 5:1 compression
- 120:1 (for 1.6G MB image sets)
- (Lumigraph used other JPEG/MPEG-like compression)

Depth correction



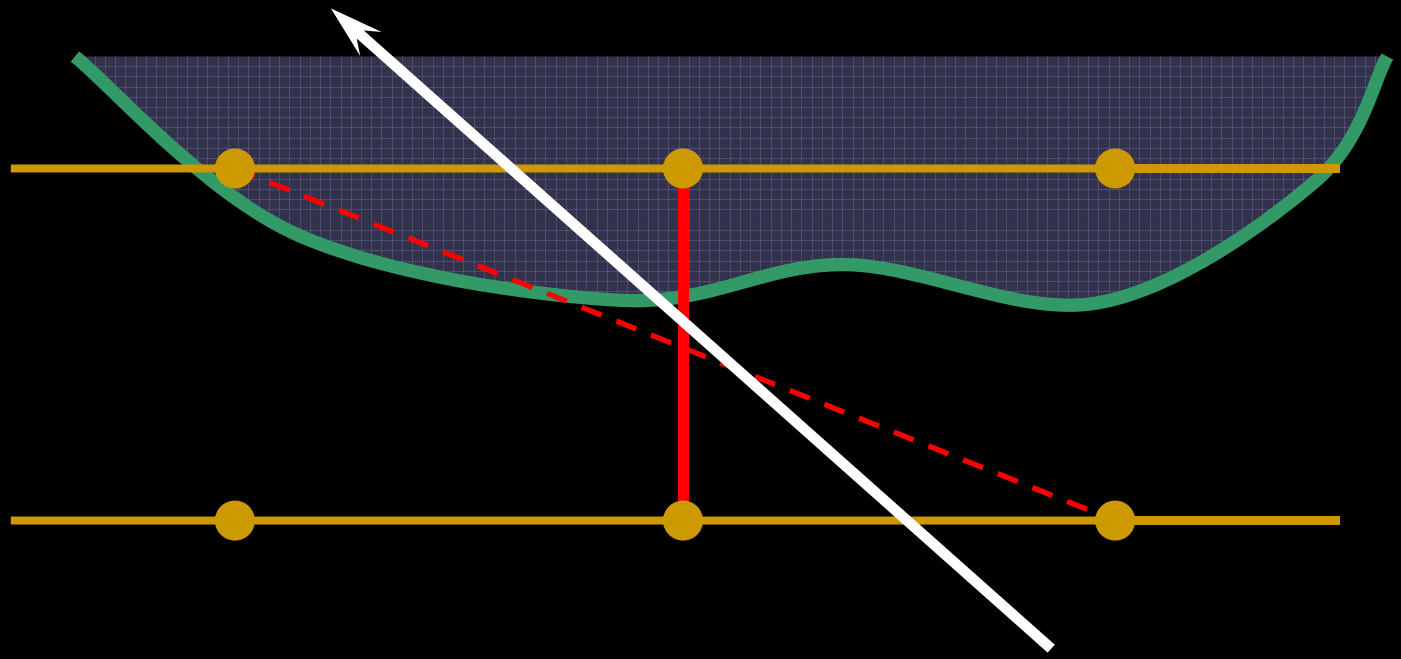
Lumigraph Rendering

- Use rough depth information to improve rendering quality



Lumigraph Rendering (cont.)

- Use rough depth information to improve rendering quality



Depth Correction

QuadralinearDepthCorrect(s,t,u,v,z)

Result $= 0$

$h_{st} = s_1 - s_0$ /* grid spacing */

$h_{uv} = u_1 - u_0$

for each of the four (s_i, t_j) surrounding (s, t)

$u' = u + (s - s_i) * z/(1 - z)$

$v' = v + (t - t_j) * z/(1 - z)$

temp $= 0$

for each of the four (u_p, v_q) surrounding (u', v')

interpWeight$_{uv}$ =

$(h_{uv} - | u_p - u' |) * (h_{uv} - | v_q - v' |)/h_{uv}^2$

temp += interpWeight$_{uv} * L(s_i, t_j, u_p, v_q)$

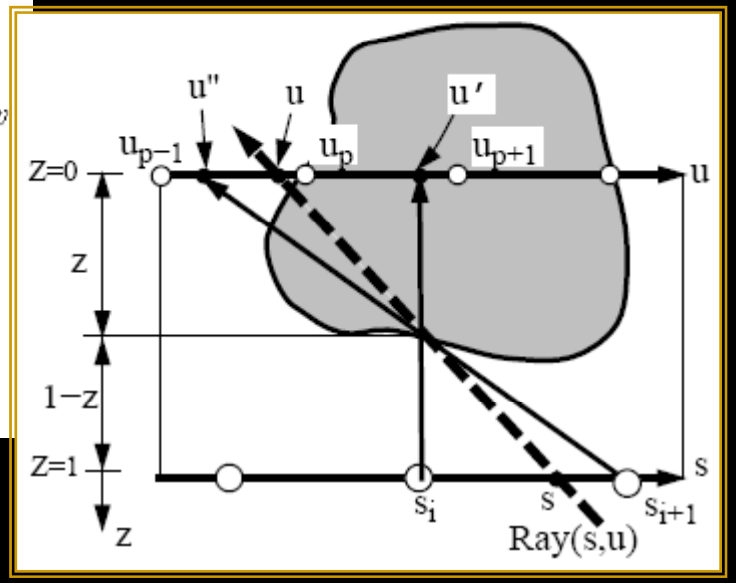
interpWeight$_{st}$ =

$(h_{st} - | s_i - s |) * (h_{st} - | t_j - t |)/h_{st}^2$

Result += interpWeight$_{st}$ * temp

return Result

$$u' = u + (s - s_i)\frac{z}{1-z}$$



Lumigraph Rendering (cont.)

Without using geometry

Using approximate geometry

Approximate Geometry

- Blue screen to find object in each image
  - Use octree to represent volume of object
  - Project, hierarchically, the octree cells
- Subdivide if not fully in/out.
- External polygons collected
  - Smoothed
- Using 4 levels of octree