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Non-uniform illumination representation based on HDR light probe sequences

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Image Based Lighting

- Image-based lighting is the process of illuminating scenes or objects with image of light from the real world.
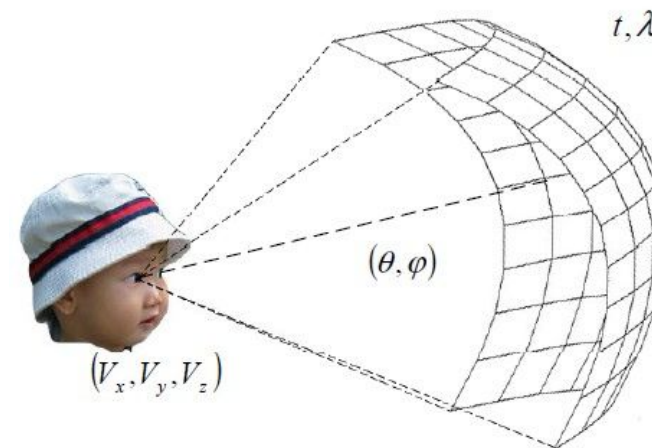
Light Field

- Light Field - a function that describes the amount of light faring in every direction through every point in space.

- Plenoptic Function

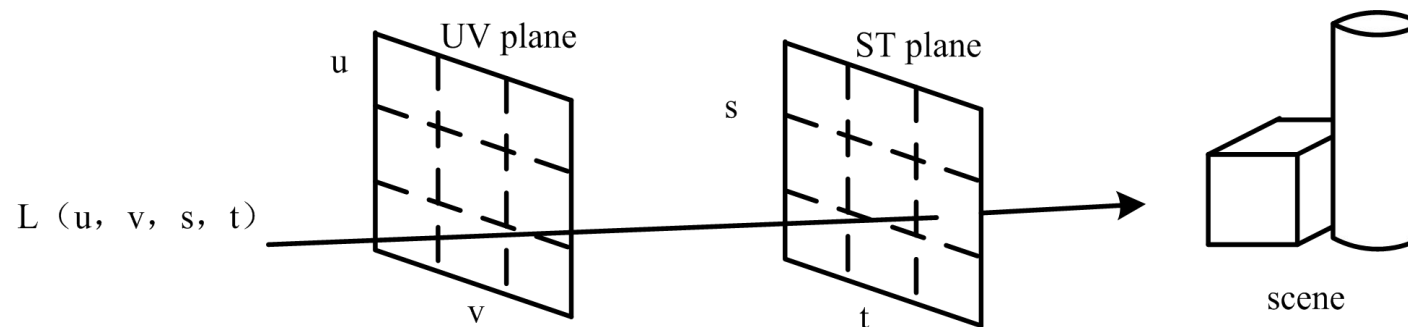$$p_7 = p(V_x, V_y, V_z, \theta, \varphi, \lambda, t)$$

- 5D light field (Plenoptic modeling)

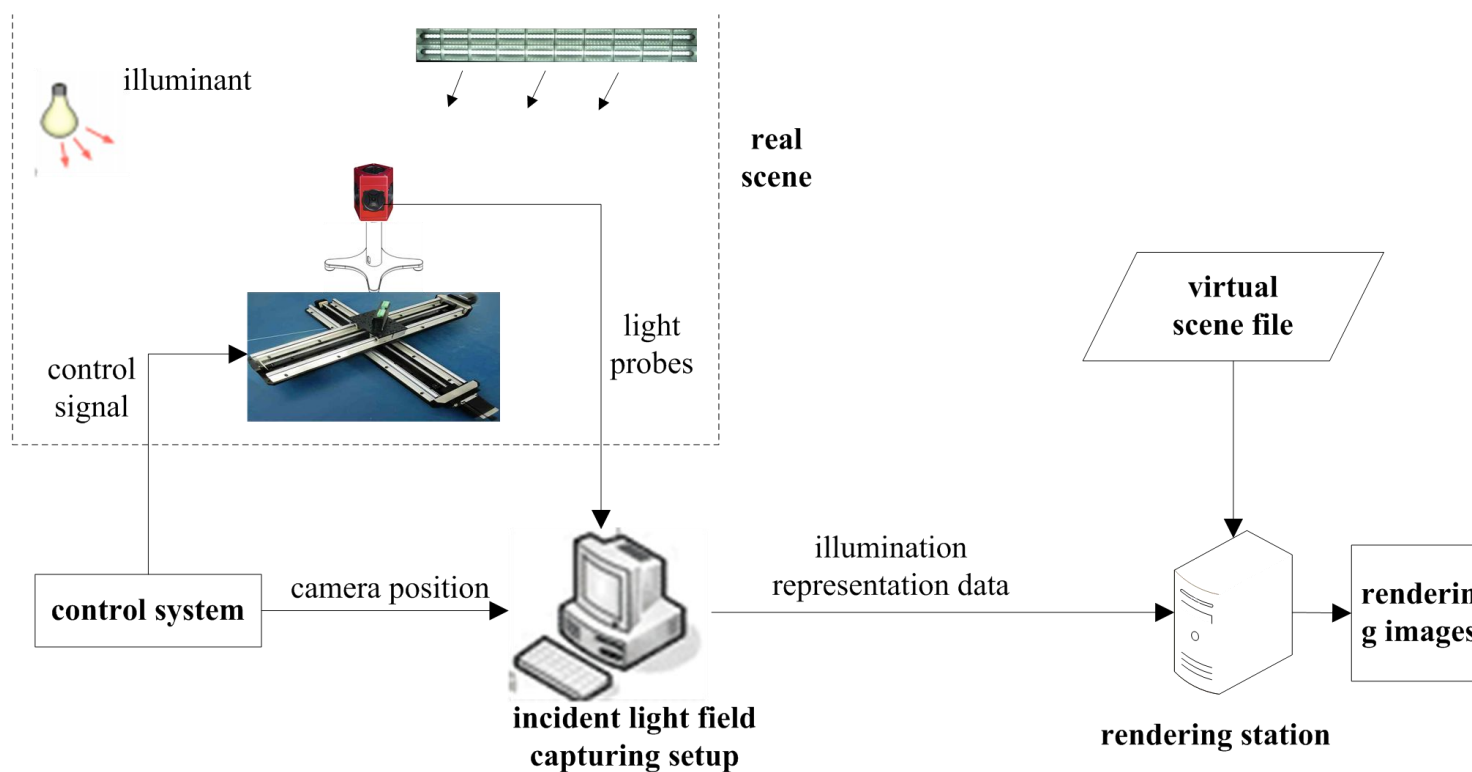$$I = L(x, y, z, \theta, \varphi)$$

Incident Light Field

- Incident light field is a description of the illumination incident at all points in a region from all directions.

Overview

illuminant

real scene

control signal

light probes

virtual scene file

control system — camera position → **incident light field capturing setup** — illumination representation data → **rendering station** → **rendering images**

Capturing

- **Capture Setup**
  - ☐ Panoramic Camera(Max 2048×2048)
  - ☐ 2-dimensional translation stage
  - ☐ Control system
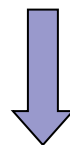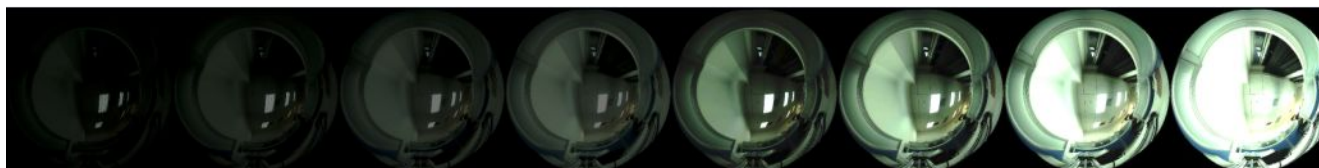 - ☐ Controlled light source

Capturing

- **Capture Strategy**
  - Adaptive
  - Non-uniform
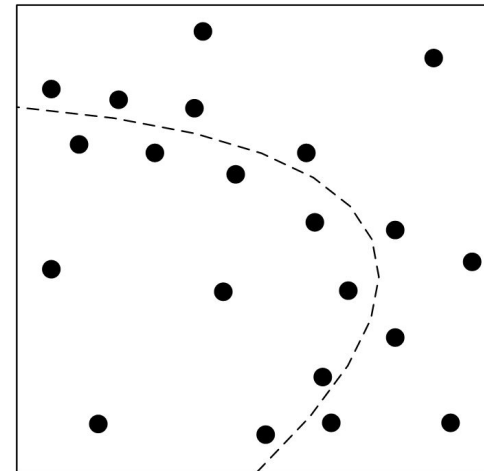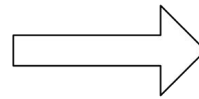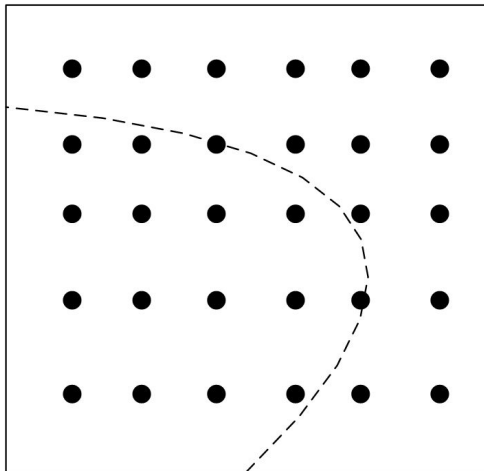
Data Process

■ HDR Light Probe Composition

  □ 8 exposure time from 0.004s to 1s
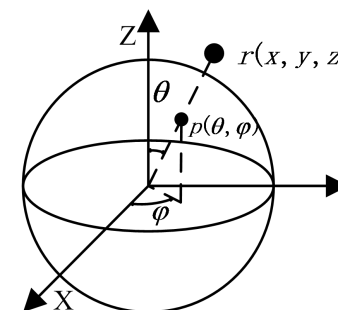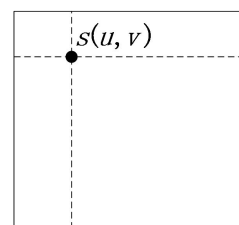
  □ Spherical Panorama

Data Process

- Calibration

  - Camrea Intrinsics

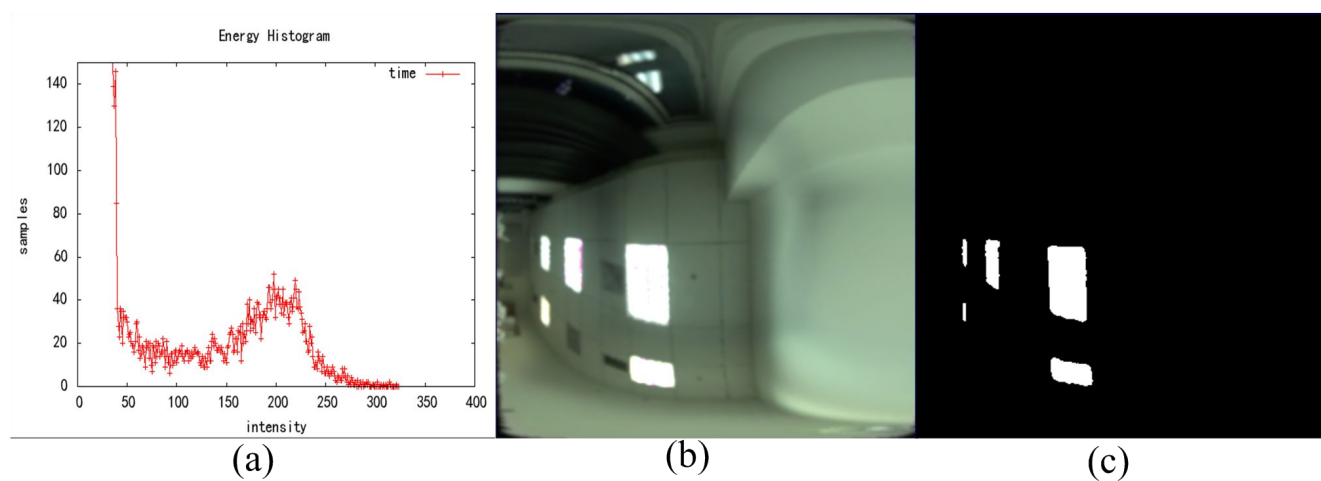 $$\begin{cases} \varphi = \arctan \dfrac{v - 0.5}{u - 0.5} \\ \theta = 2\pi\sqrt{\left(u - 0.5\right)^2 + \left(v - 0.5\right)^2} \end{cases}$$

  - Camrea Extrinsics

  $$m \cong \begin{bmatrix} R & T \end{bmatrix} \cdot P_W$$
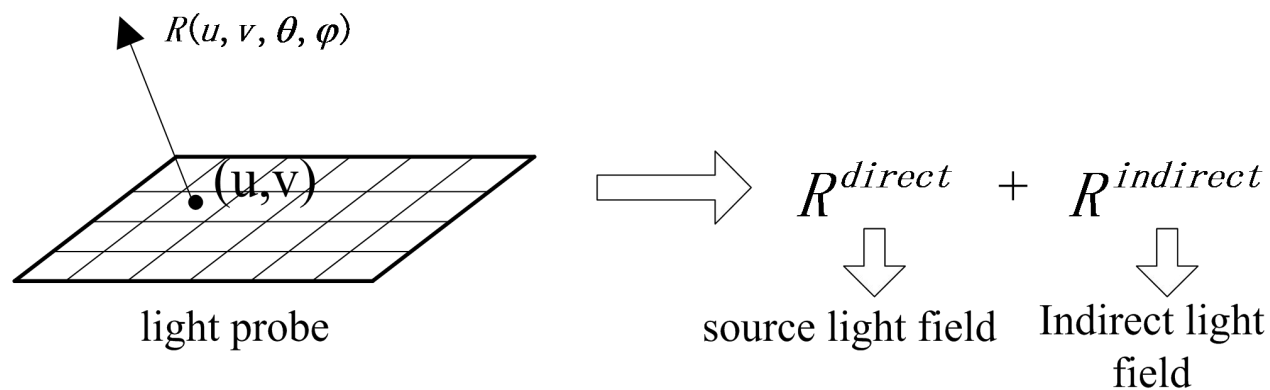
Data Process

- Light Source Extraction
  - Energy histogram drafting
  - Gaussian smoothing
  - Binaryzation threshold

(a) (b) (c)

Illumination Representation

- **Direct Illumination**
  - Non-uniform representation
  - Source light field — 4D incident light field
- **Indirect Illumination**
  - HDR texture map

$R(u, v, \theta, \varphi)$

(u,v)

light probe

$R^{direct} \quad + \quad R^{indirect}$

source light field   Indirect light field

Illumination Representation

- Source light field establishment
  - Clustering the intersection of sample light and virtual plane
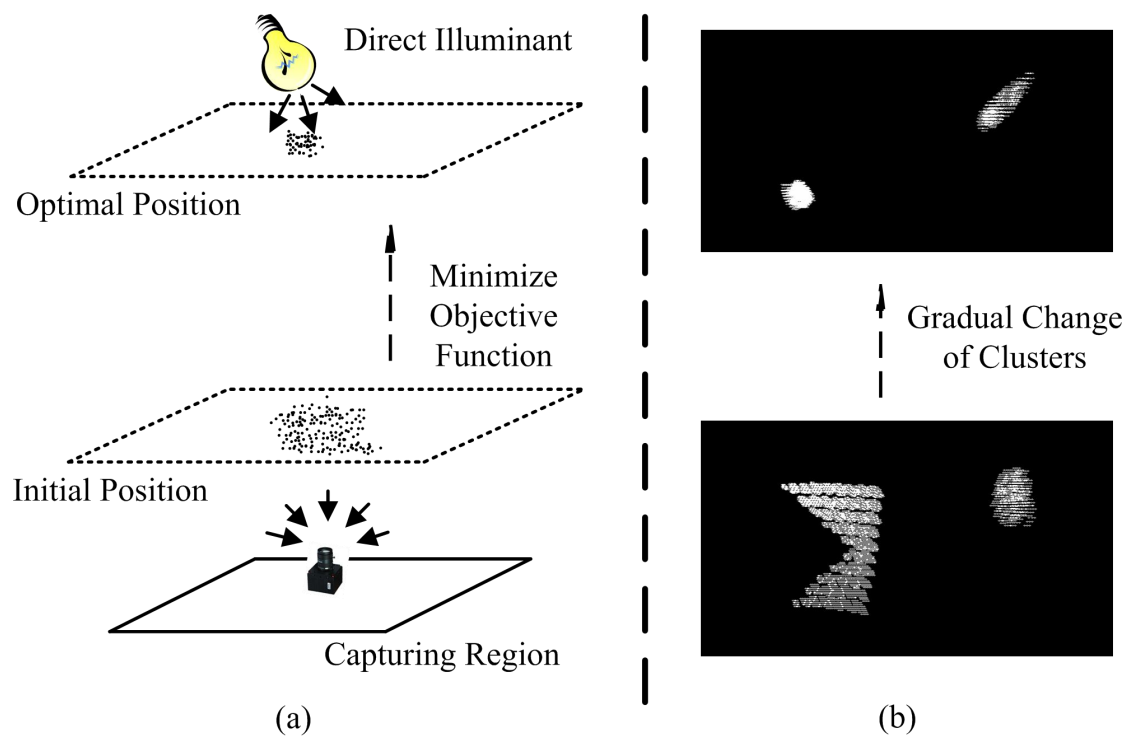
  $$R = \left\{ r \mid r = F(u, v, \theta, \varphi) \right\}$$

  - Looking for the optimal position of virtual plane

 $$f(h_i) = f_{area}(f_{cluster}(\bigcup_{i=1}^{n} p_{(i, h_i)}))$$

Illumination Representation

☐ Source light field virtual plane

Direct Illuminant

Optimal Position

Minimize
Objective
Function

Gradual Change
of Clusters

Initial Position

Capturing Region

(a)   (b)

Illumination Representation

- Representation of source light field in the virtual plane
  - Non-uniform
  - Discrete points in virtual plane
 - Discrete sample rays in angular dimension

Representative Point   Virtual Plane

Sample Rays
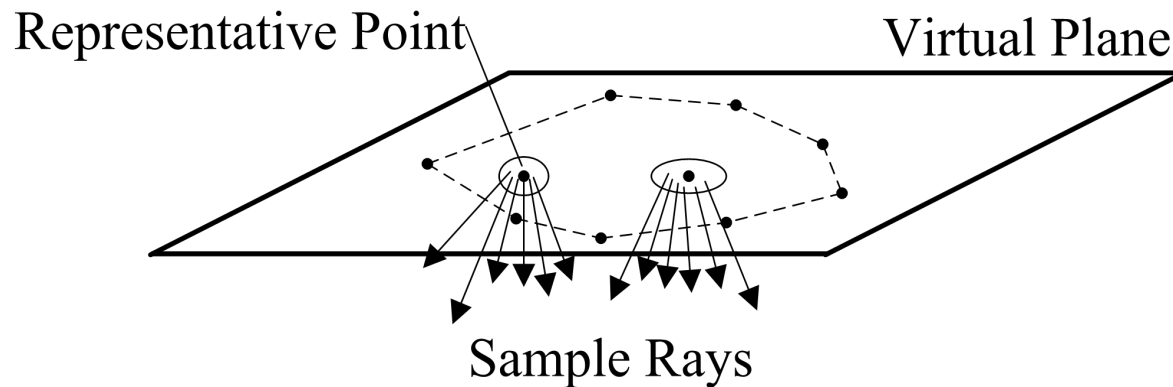
Illumination Representation

- Estimate error of light source position

Scene	Estimate Count	Lights Position	Estimate Error
Five Area Lights	5	(-376 15026) (-203 150 26) (-33 150 26) (-376 150 270) (-33 150 270)	18.63 17.77 14.30 27.66 20.10
Single Point Light	1	(-105 83 23)	9.68

Illumination Representation

- **Indirect Illumination**
  - □ Extract feature points from light probe sequence
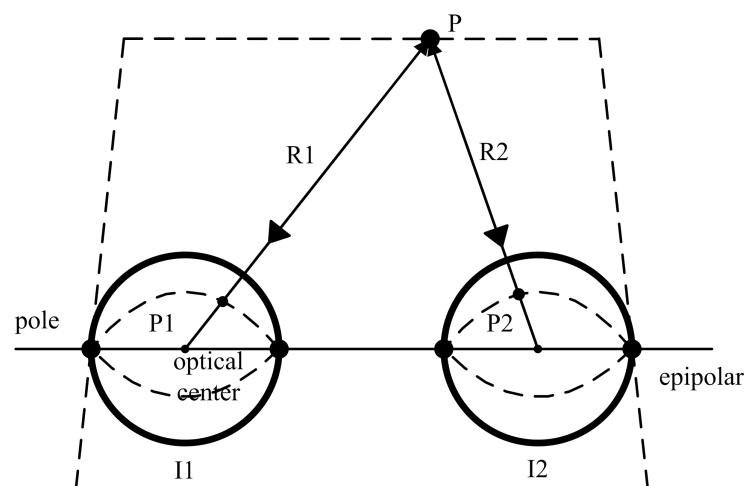
Illumination Representation

□ Delaunay Triangulation

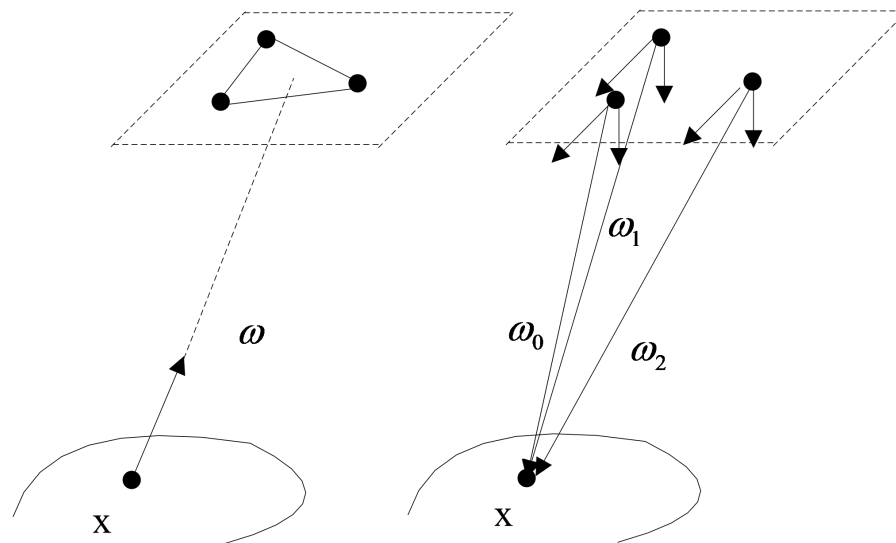□ Equation of the relationship between pixel and radiance

$$E_c = L \frac{\pi}{4} (\frac{d}{f})^2 (1 + \theta^2)^2 \cos^3(\tan^{-1} \theta) \cos \theta$$
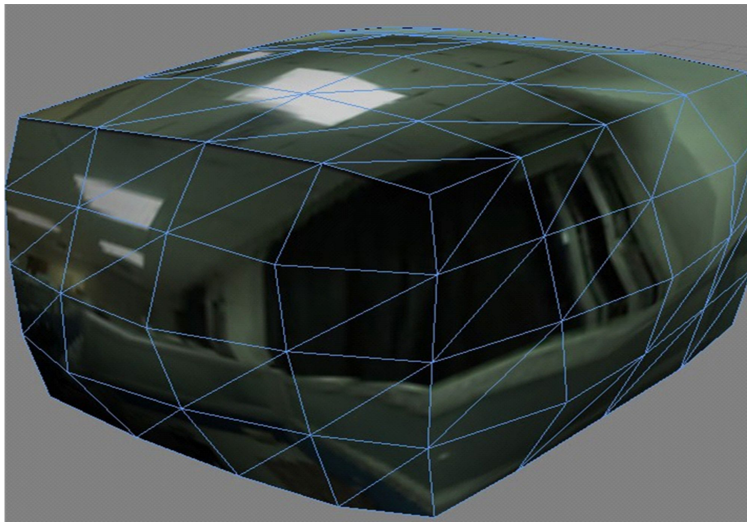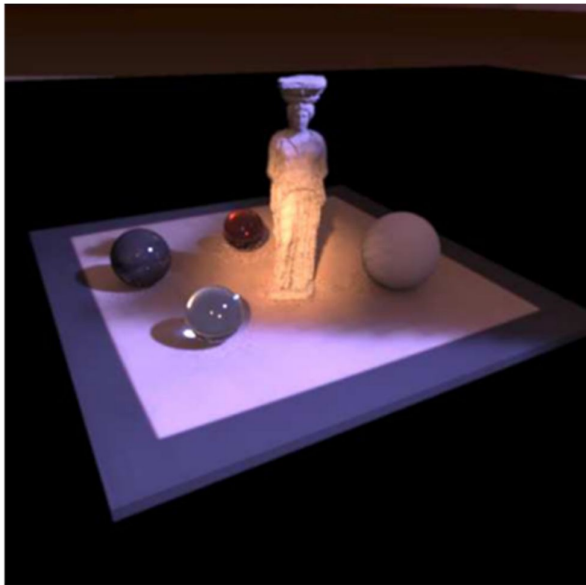
Illumination Representation

- **Resampling**
  - □ Representative Point Delaunay Triangulation
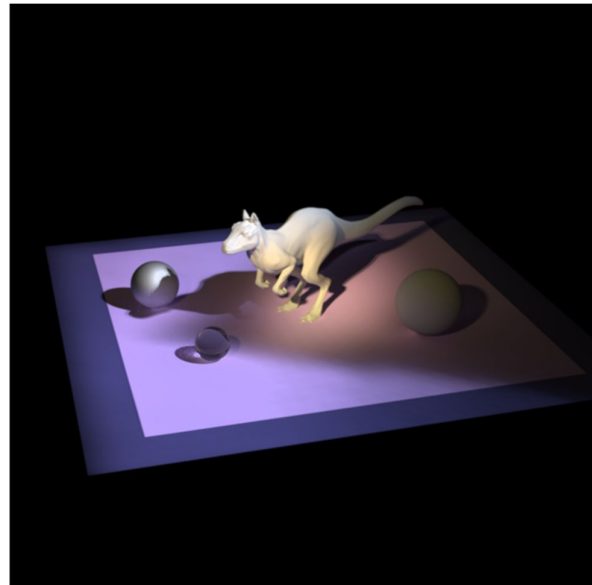 - □ Trigonometric Interpolation

Rendering

- PBRT Rendering Engine

uniform ILF   non-uniform ILF

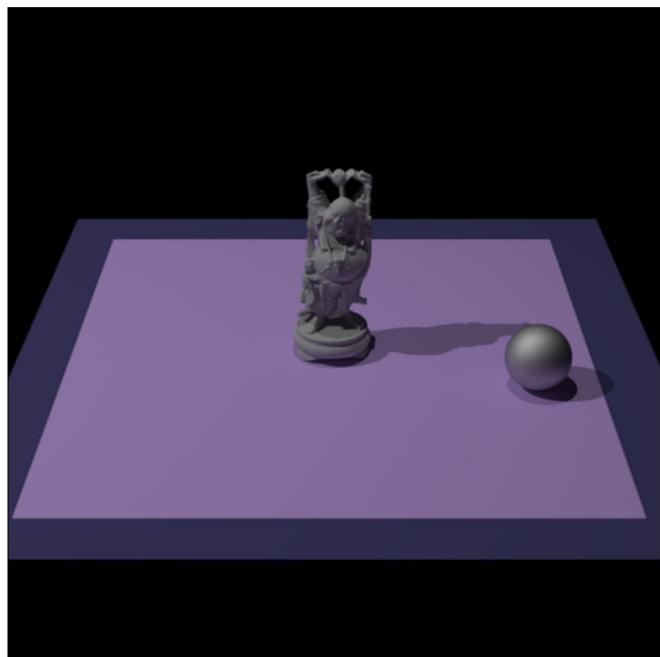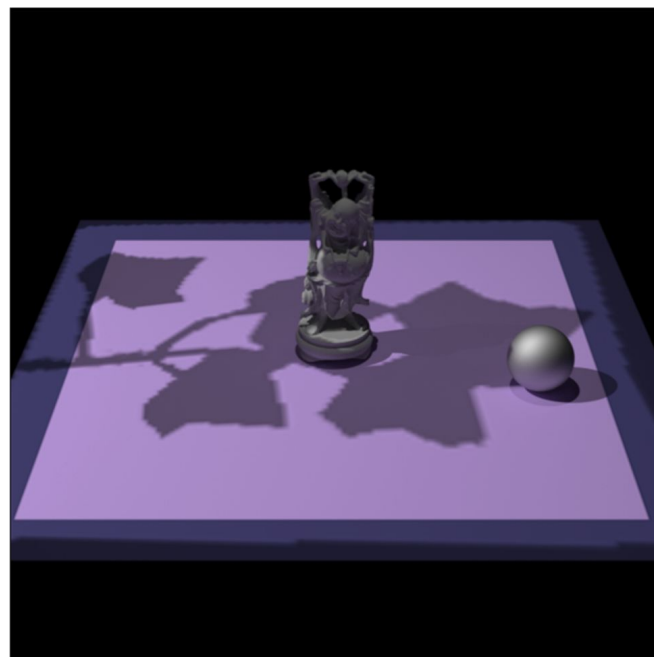# Rendering

light probe

non-uniform ILF

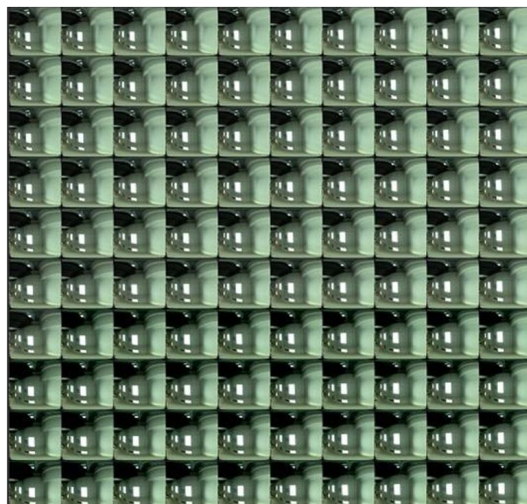# Rendering

Rendering synthetic objects into real scene

Thank you for listening !