



Global Illumination

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Princeton University
COS 526, Fall 2002



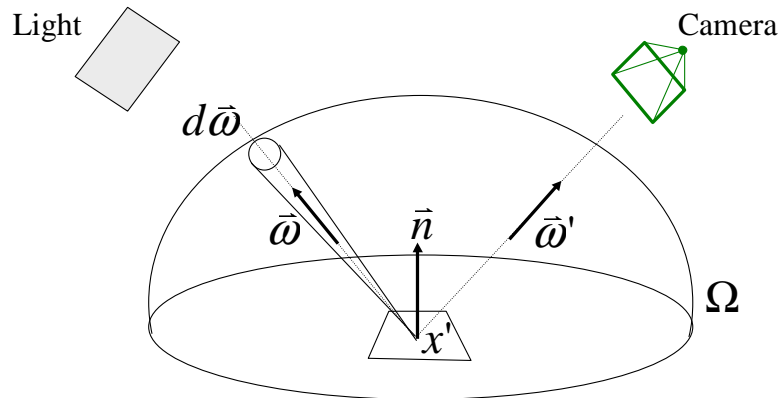
Overview

- Global illumination
- Rendering equation
- Overview of solution methods
- Programming assignment #1

Direct Illumination



$$L_o(x', \bar{\omega}') = L_e(x', \bar{\omega}') + \int_{\Omega_L} f_r(x', \bar{\omega}, \bar{\omega}') L_i(x', \bar{\omega}) (\bar{\omega} \cdot \bar{n}) d\bar{\omega}$$



Direct Illumination

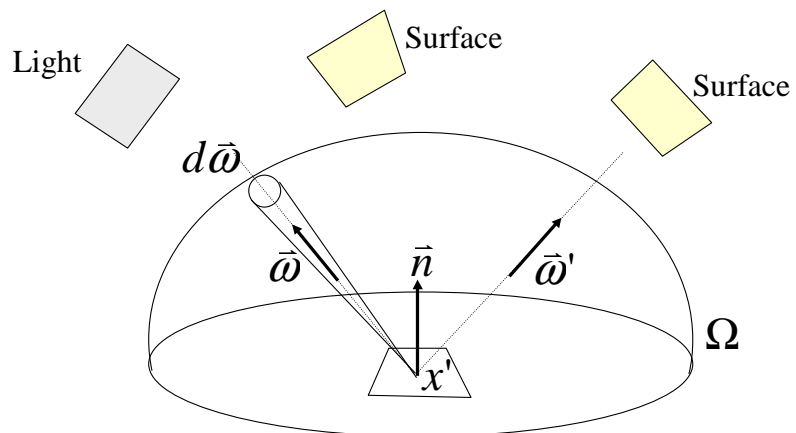


Philip Dutré

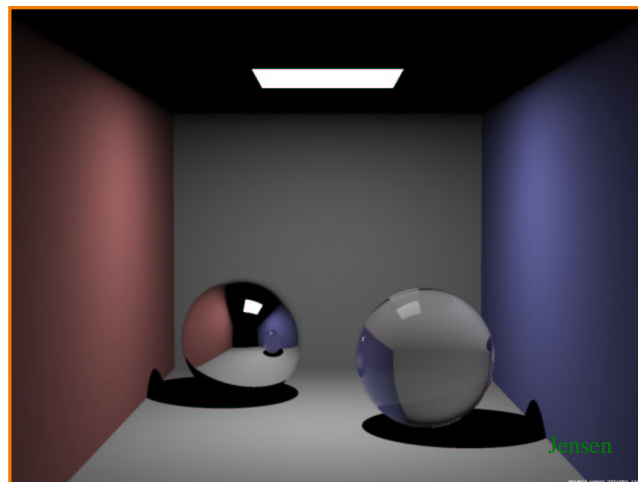
Global Illumination



$$L_o(x', \bar{\omega}') = L_e(x', \bar{\omega}') + \int_{\Omega} f_r(x', \bar{\omega}, \bar{\omega}') L_i(x', \bar{\omega}) (\bar{\omega} \cdot \bar{n}) d\bar{\omega}$$



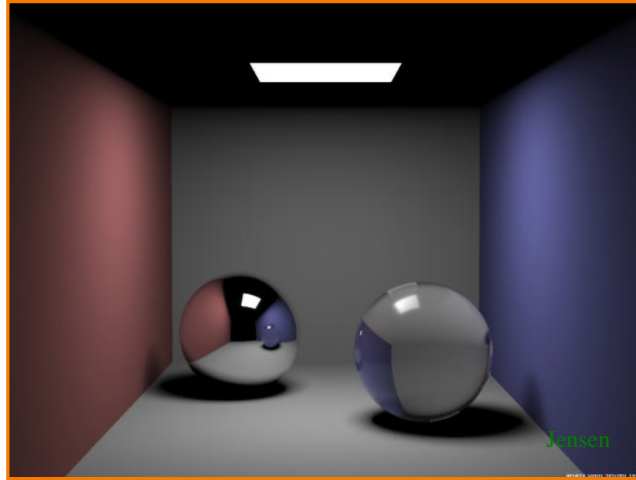
Global Illumination



Ray tracing

Henrik Wann Jensen

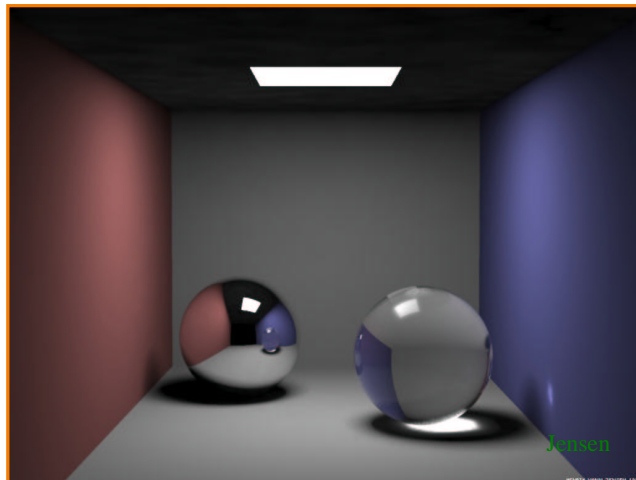
Global Illumination



+ soft shadows

Henrik Wann Jensen

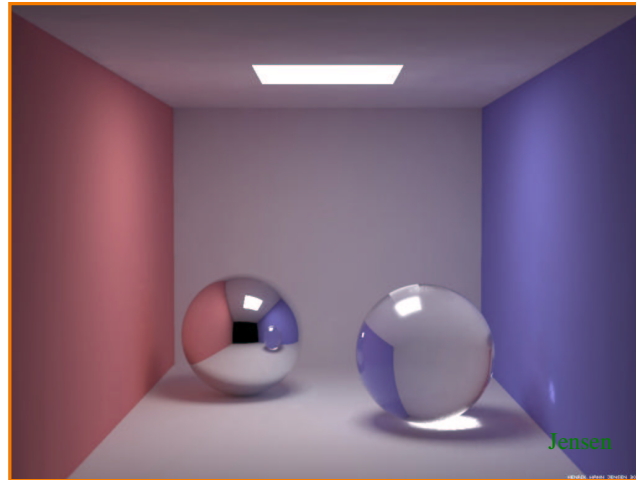
Global Illumination



+ caustics

Henrik Wann Jensen

Global Illumination



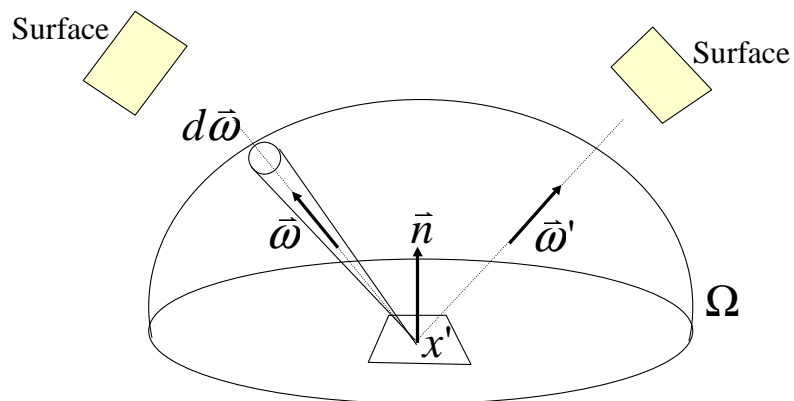
+ indirect diffuse illumination

Henrik Wann Jensen

Rendering Equation



$$L_o(x', \vec{\omega}') = L_e(x', \vec{\omega}') + \int_{\Omega} f_r(x', \vec{\omega}, \vec{\omega}') L_i(x', \vec{\omega}) (\vec{\omega} \cdot \vec{n}) d\vec{\omega}$$

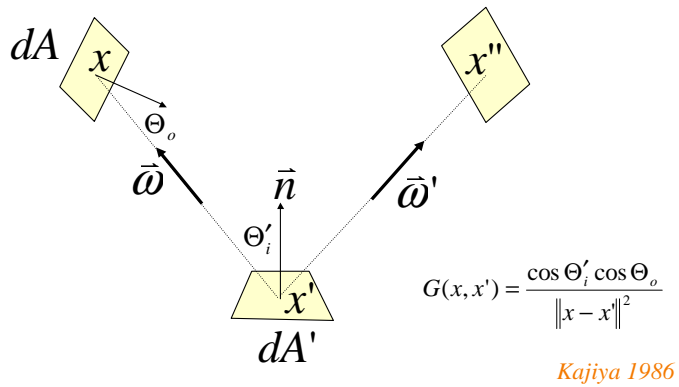


Kajiya 1986

Rendering Equation (2)



$$L(x' \rightarrow x'') = L_e(x' \rightarrow x'') + \int_S f_r(x \rightarrow x' \rightarrow x'') L(x \rightarrow x') V(x, x') G(x, x') dA$$

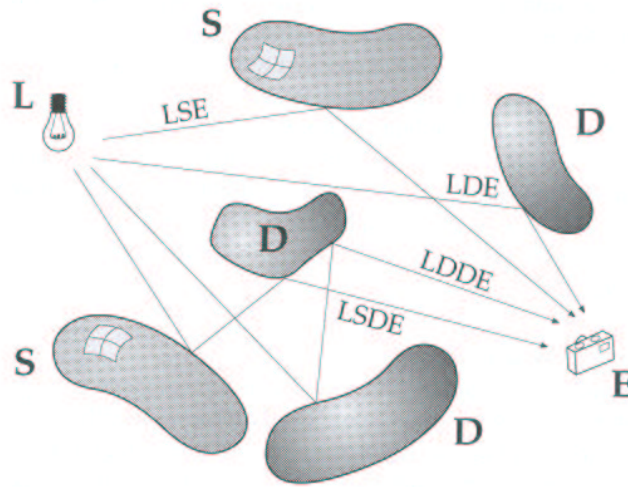


Solution Methods

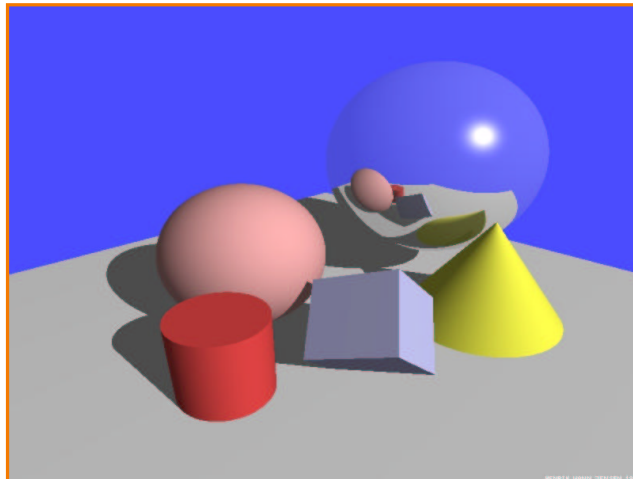


- OpenGL
- Radiosity
- Ray tracing
- Distribution ray tracing
- Path tracing

Path Types



Path Types?



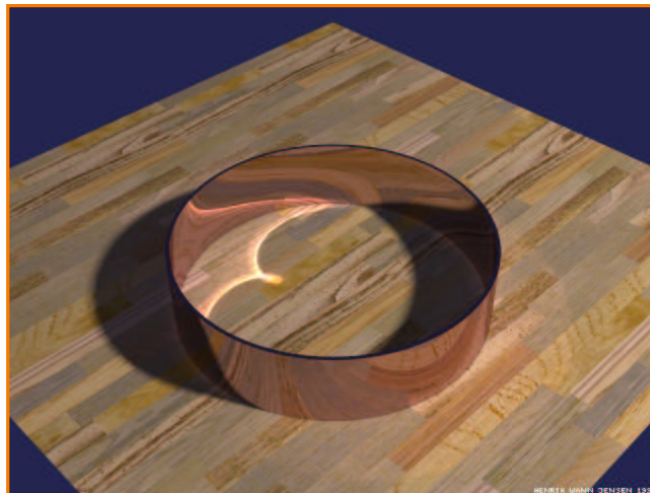
Henrik Wann Jensen

Path Types?



Paul Debevec

Path Types?



Henrik Wann Jensen

Path Types?

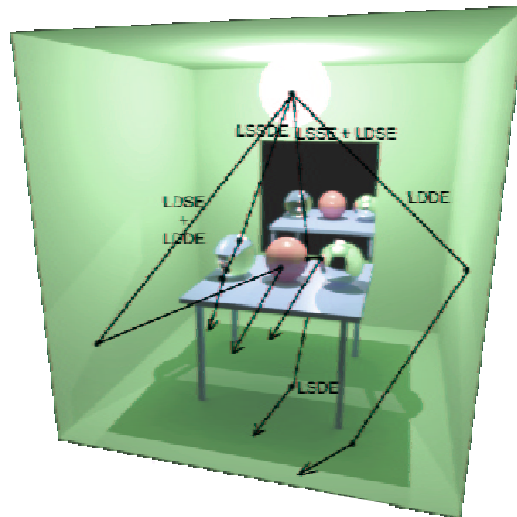


RenderPark

Path Types



- OpenGL
 - LDE
- Ray tracing
 - LDS^*E
- Radiosity
 - LD^*E
- Path tracing
 - $L(D|S)^*E$



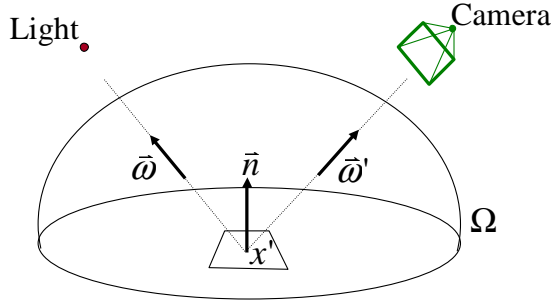
John Hart

OpenGL



$$L_o(x', \vec{\omega}') = L_e(x', \vec{\omega}') + \int_{\Omega} f_r(x', \vec{\omega}, \vec{\omega}') L_i(x', \vec{\omega}) (\vec{\omega} \cdot \vec{n}) d\vec{\omega}$$

Assume direct illumination from point lights and ignore visibility



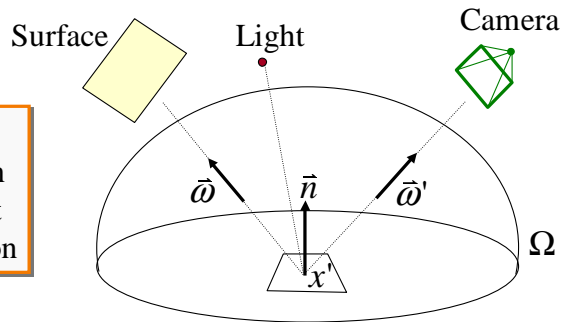
$$L_o(x', \vec{\omega}') = L_e(x', \vec{\omega}') + \sum_{i=1}^{nlights} f_r(x', \vec{\omega}, \vec{\omega}') L_i(x', \vec{\omega}) (\vec{\omega} \cdot \vec{n})$$

Ray Tracing



$$L_o(x', \vec{\omega}') = L_e(x', \vec{\omega}') + \int_{\Omega} f_r(x', \vec{\omega}, \vec{\omega}') L_i(x', \vec{\omega}) (\vec{\omega} \cdot \vec{n}) d\vec{\omega}$$

Assume specular reflection is only significant indirect illumination



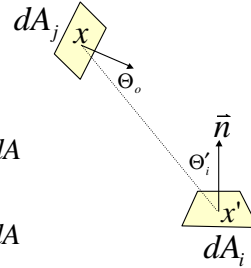
$$L_o(x', \vec{\omega}') = L_e(x', \vec{\omega}') + \sum_{i=1}^{nlights} f_r(x', \vec{\omega}, \vec{\omega}') L_i(x', \vec{\omega}) (\vec{\omega} \cdot \vec{n}) + specular$$

Radiosity



$$L(x' \rightarrow x'') = L_e(x' \rightarrow x'') + \int_S f_r(x \rightarrow x' \rightarrow x'') L(x \rightarrow x') V(x, x') G(x, x') dA$$

Assume everything is Lambertian



$$B(x') = B_e(x') + \int_S f_{r,d}(x') B(x) V(x, x') G(x, x') dA$$

$$B(x') = B_e(x') + \frac{\rho_d(x')}{\pi} \int_S B(x) V(x, x') G(x, x') dA$$

$$B_i = B_{e,i} + \rho_i \sum_{j=1}^N B_j F_{ij} \quad \text{where} \quad F_{ij} = \frac{1}{A_i} \iint_{A_i, A_j} \frac{V(x, x') G(x, x')}{\pi} dA_j dA_i$$

Path Tracing



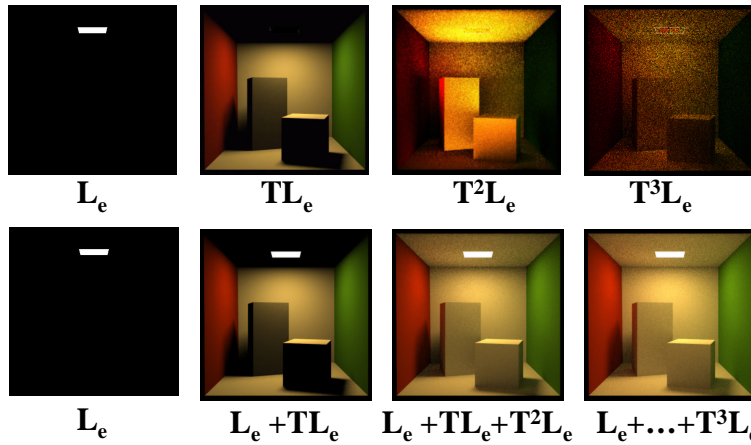
$$L_o(x', \bar{\omega}') = L_e(x', \bar{\omega}') + \int_{\Omega} f_r(x', \bar{\omega}, \bar{\omega}') L_i(x', \bar{\omega}) (\bar{\omega} \cdot \bar{n}) d\bar{\omega}$$

Perform Neumann series expansion

$$L = L_e + TL \quad \text{where} \quad T(x, \bar{\omega}') = \int_{\Omega} f_r(x', \bar{\omega}, \bar{\omega}') g(x, \bar{\omega}) (\bar{\omega} \cdot \bar{n}) d\bar{\omega}$$

$$L = L_e + TL_e + T^2 L_e + T^3 L_e + \dots$$

Path Tracing



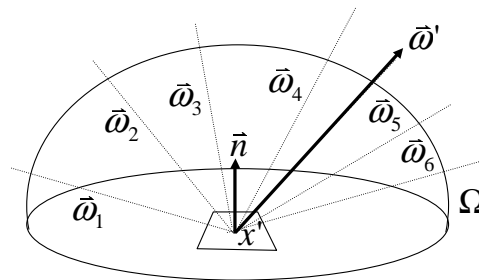
Philip Dutré

Distribution Ray Tracing



$$L_o(x', \bar{\omega}') = L_e(x', \bar{\omega}') + \int_{\Omega} f_r(x', \bar{\omega}, \bar{\omega}') L_i(x', \bar{\omega}) (\bar{\omega} \cdot \bar{n}) d\bar{\omega}$$

Estimate integral
for each reflection
by random sampling



- Also:
- Depth of field
 - Motion blur
 - etc.

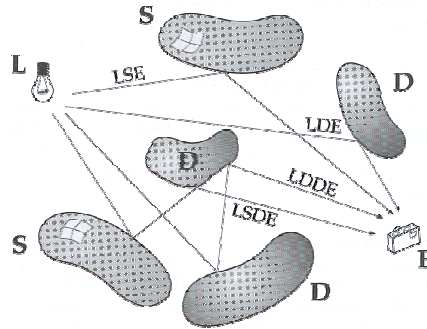
Monte Carlo Path Tracing



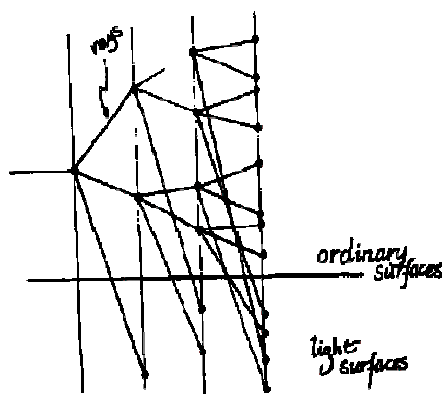
$$L_o(x', \bar{\omega}') = L_e(x', \bar{\omega}') + \int_{\Omega} f_r(x', \bar{\omega}, \bar{\omega}') L_i(x', \bar{\omega}) (\bar{\omega} \cdot \bar{n}) d\bar{\omega}$$

Estimate integral for each pixel by random sampling

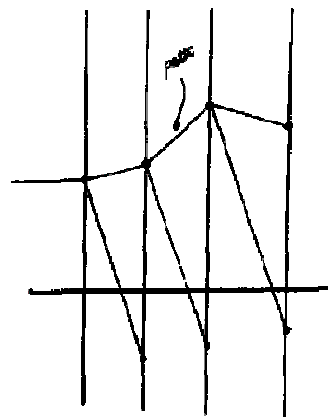
- Also:
- Depth of field
 - Motion blur
 - etc.



Ray Tracing vs. Path Tracing



Ray tracing



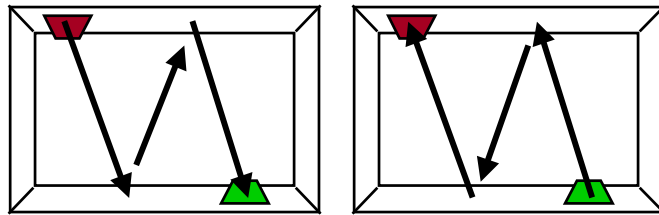
Path tracing

Jim Kajiya

Bidirectional Path Tracing

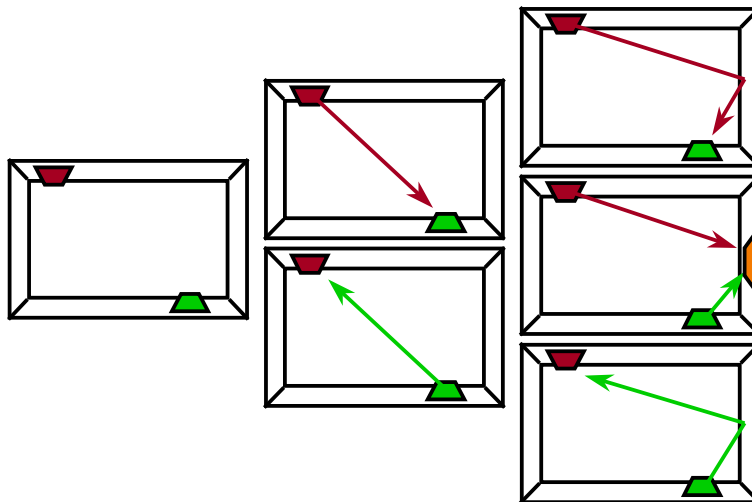


- Role of source and receiver can be switched, flux does not change



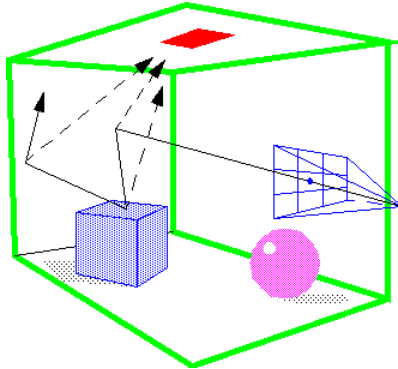
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Bidirectional Path Tracing



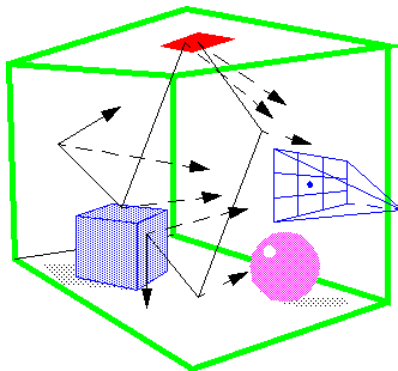
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Tracing From Eye



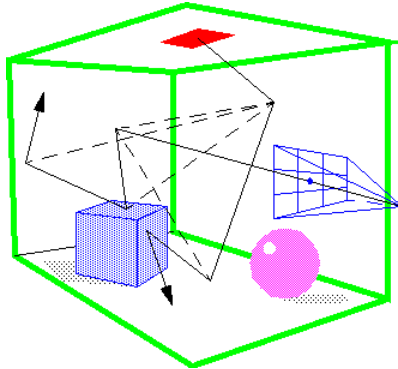
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Tracing from Lights



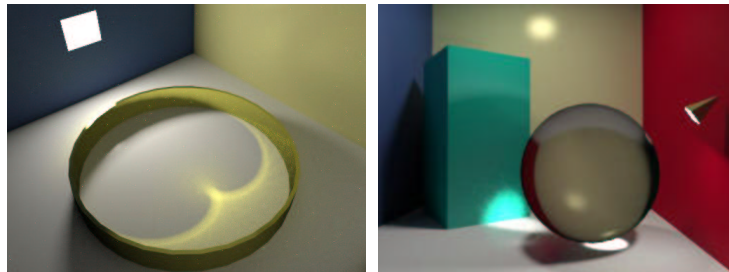
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Bidirectional Path Tracing



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Bidirectional Path Tracing



(RenderPark 98)

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Summary



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