COS526: Advanced Computer Graphics

Tom Funkhouser

Fall 2014

Background

Image Processing

- Basic signal processing
- Filtering, resampling, warping, ...

Rendering

- Polygon rendering pipeline
- Basic ray tracing

Modeling

- Basic 3D object representations
- Polygonal meshes

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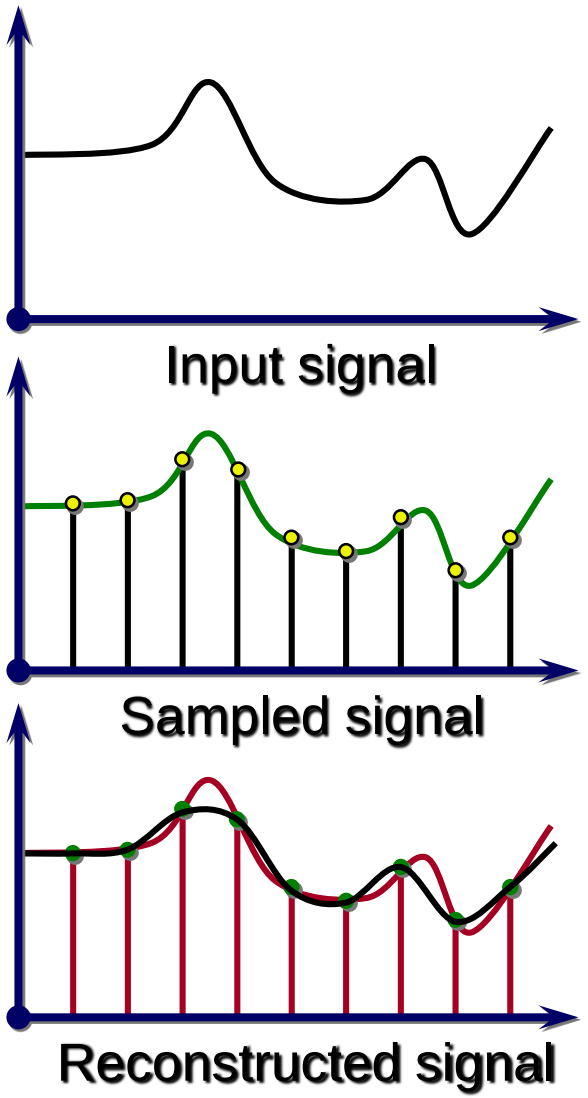

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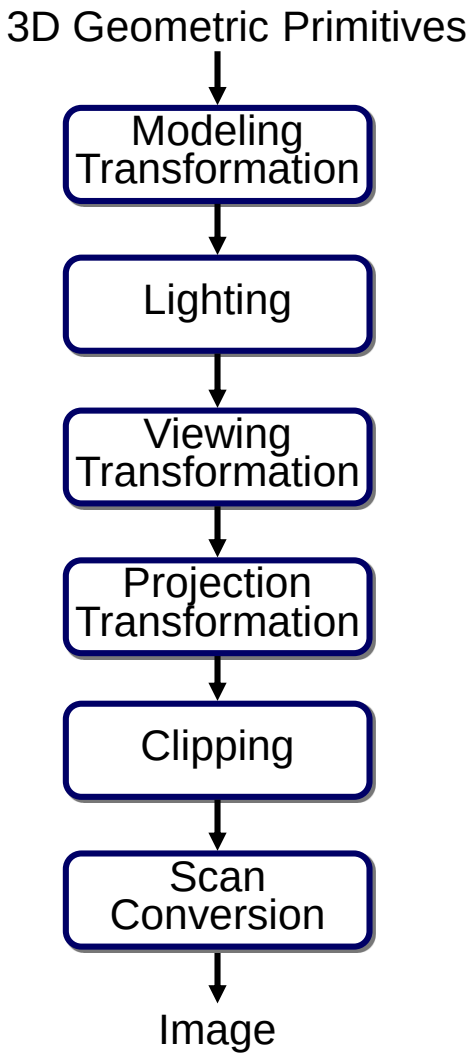

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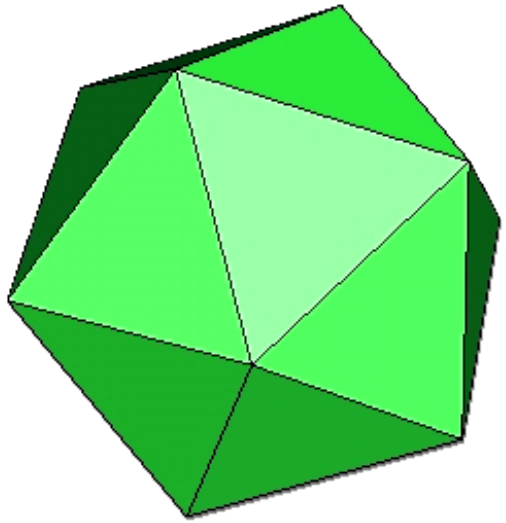

CS526 Syllabus

Global illumination
- Photon mapping
- Monte Carlo path tracing

Computational Photography
- Image composition
- Texture synthesis
- Image-based rendering

Geometric Representations
- Multiresolution meshes
- Laplacian meshes
- Point representations

Shape Analysis
- Feature detection
- Segmentation
- Correspondence

Jensen

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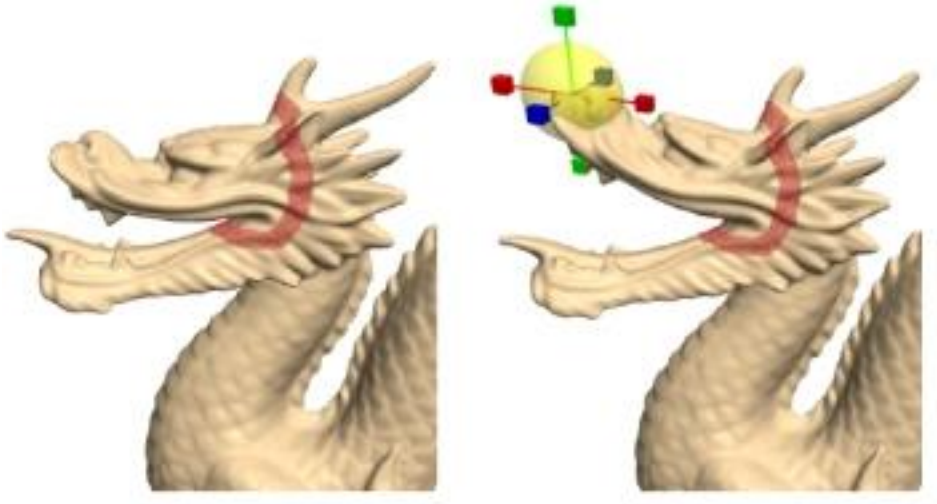

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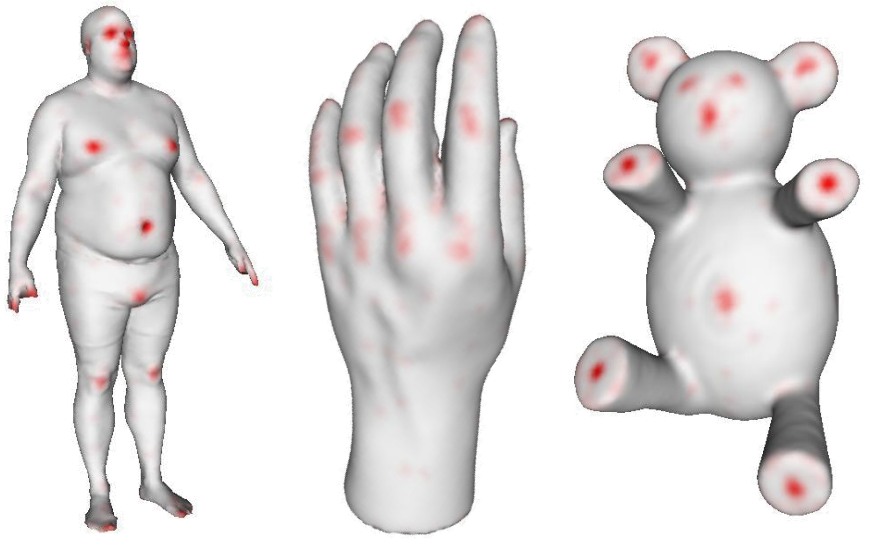
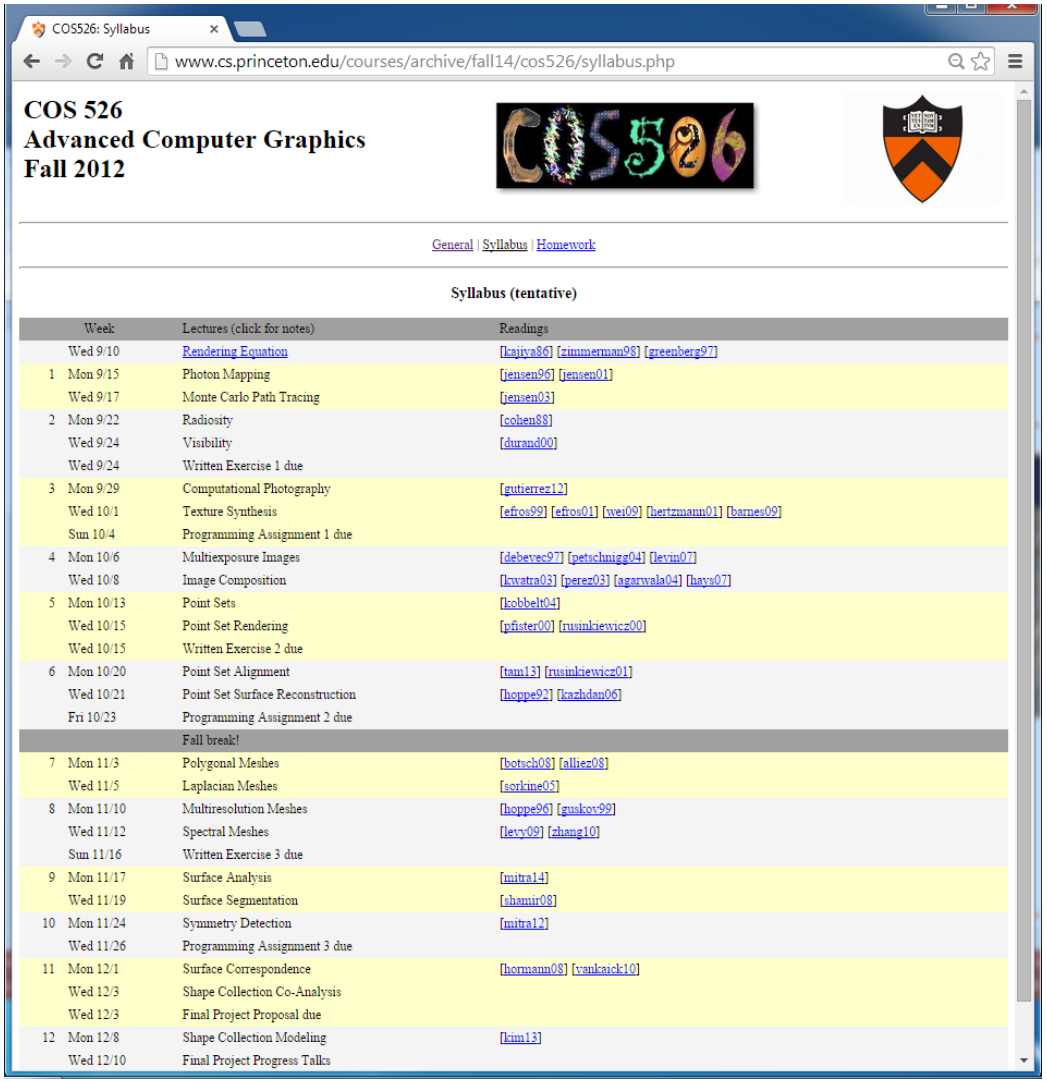


CS526 Syllabus



COS 526
Advanced Computer Graphics
Fall 2012

General | Syllabus | Homework

Syllabus (tentative)

	Week	Lectures (click for notes)	Readings
	Wed 9/10	Rendering Equation	[kajiya86] [zimmerman98] [greenberg97]
1	Mon 9/15	Photon Mapping	[jensen96] [jensen01]
	Wed 9/17	Monte Carlo Path Tracing	[jensen03]
2	Mon 9/22	Radiosity	[cohen88]
	Wed 9/24	Visibility	[durand00]
	Wed 9/24	Written Exercise 1 due	
3	Mon 9/29	Computational Photography	[gutierrez12]
	Wed 10/1	Texture Synthesis	[efros99] [efros01] [wei09] [hertzmann01] [barnes09]
	Sun 10/4	Programming Assignment 1 due	
4	Mon 10/6	Multiexposure Images	[debevec97] [petschnigg04] [levin07]
	Wed 10/8	Image Composition	[kwatra03] [perez03] [agarwala04] [hays07]
5	Mon 10/13	Point Sets	[kobbelt04]
	Wed 10/15	Point Set Rendering	[pfister00] [rusinkiewicz00]
	Wed 10/15	Written Exercise 2 due	
6	Mon 10/20	Point Set Alignment	[tam13] [rusinkiewicz01]
	Wed 10/21	Point Set Surface Reconstruction	[hoppe92] [kazhdan06]
	Fri 10/23	Programming Assignment 2 due	
		Fall break!	
7	Mon 11/3	Polygonal Meshes	[botsch08] [alliez08]
	Wed 11/5	Laplacian Meshes	[sorkine05]
8	Mon 11/10	Multiresolution Meshes	[hoppe96] [guskov99]
	Wed 11/12	Spectral Meshes	[levy09] [zhang10]
	Sun 11/16	Written Exercise 3 due	
9	Mon 11/17	Surface Analysis	[mitra14]
	Wed 11/19	Surface Segmentation	[shamir08]
10	Mon 11/24	Symmetry Detection	[mitra12]
	Wed 11/26	Programming Assignment 3 due	
11	Mon 12/1	Surface Correspondence	[hormann08] [vankaick10]
	Wed 12/3	Shape Collection Co-Analysis	
	Wed 12/3	Final Project Proposal due	
12	Mon 12/8	Shape Collection Modeling	[kim13]
	Wed 12/10	Final Project Progress Talks	

Coursework

3 Short written exercises

3 Programming assignments

Final project

Global Illumination

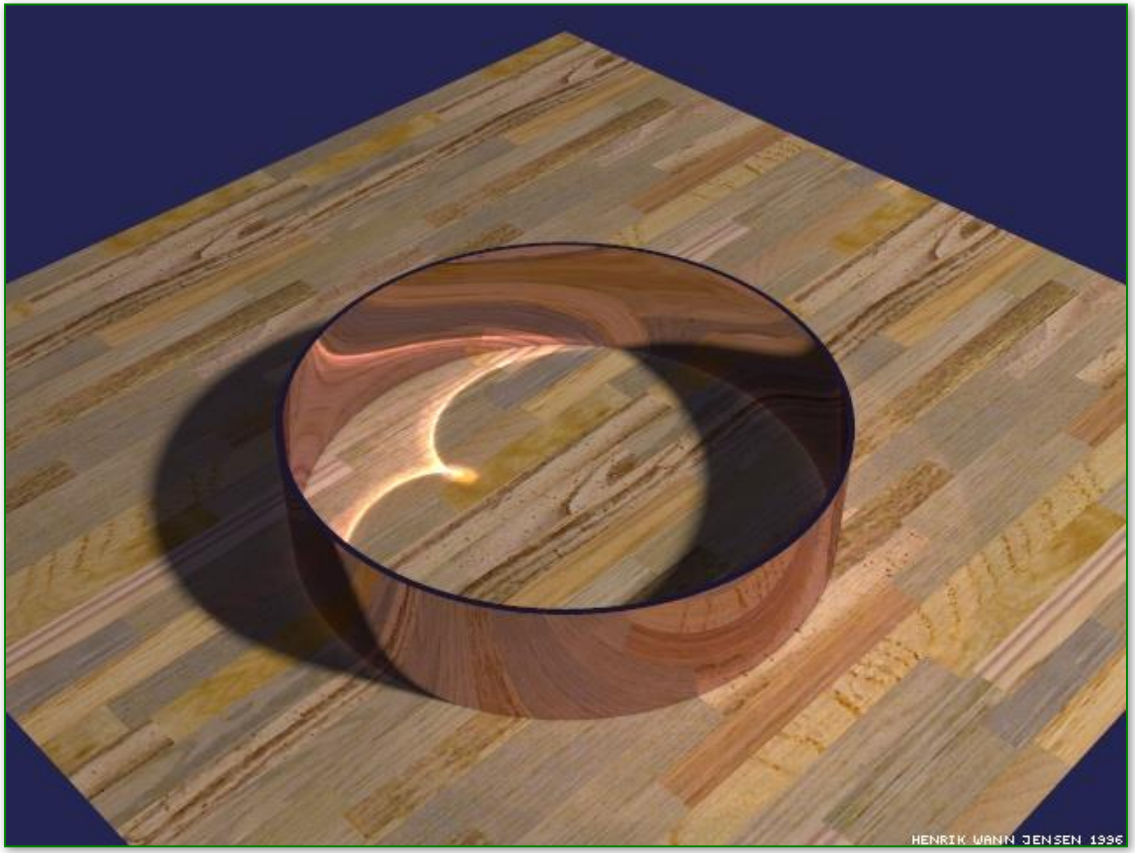
Tom Funkhouser

Princeton University

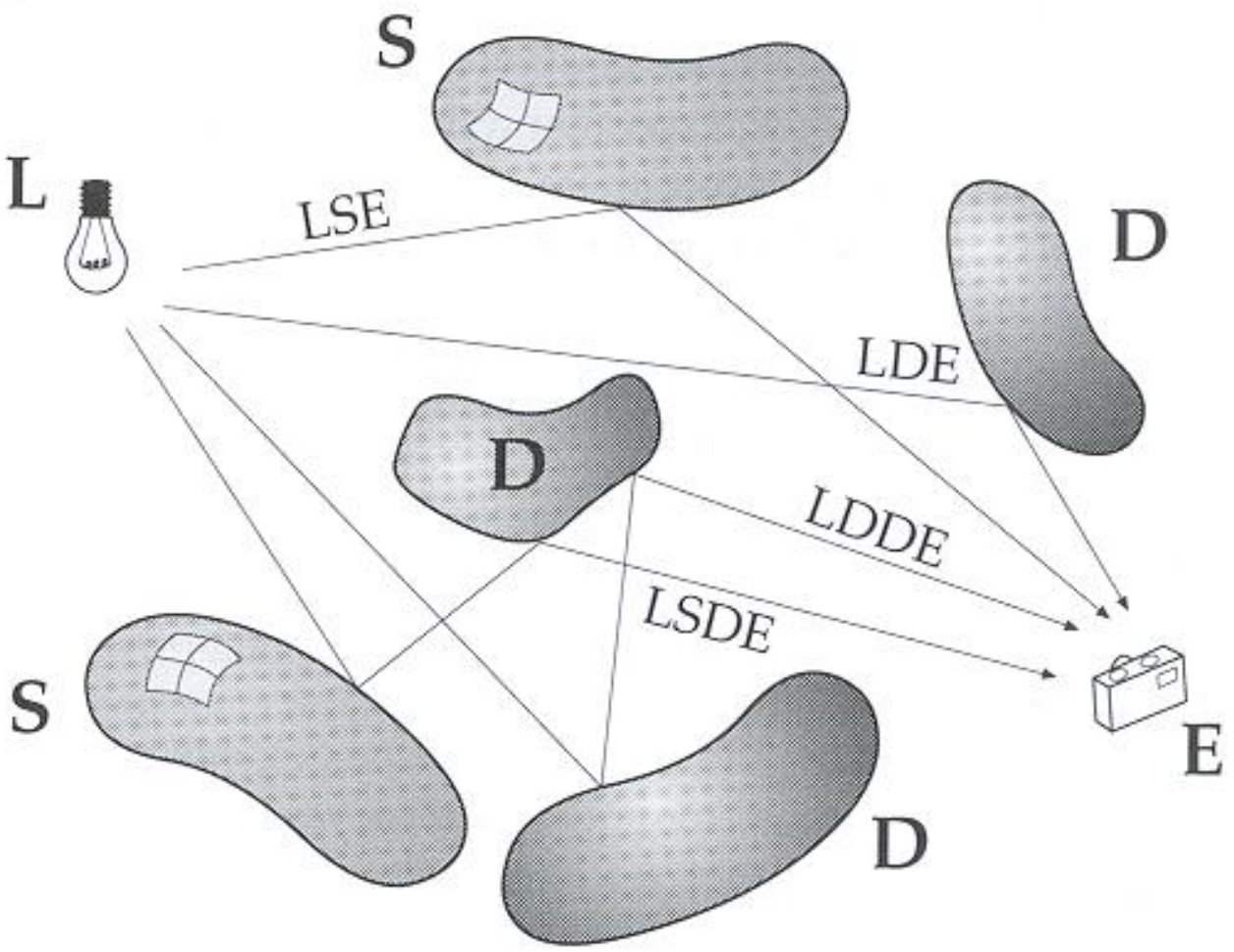
COS 526, Fall 2014

Global Illumination

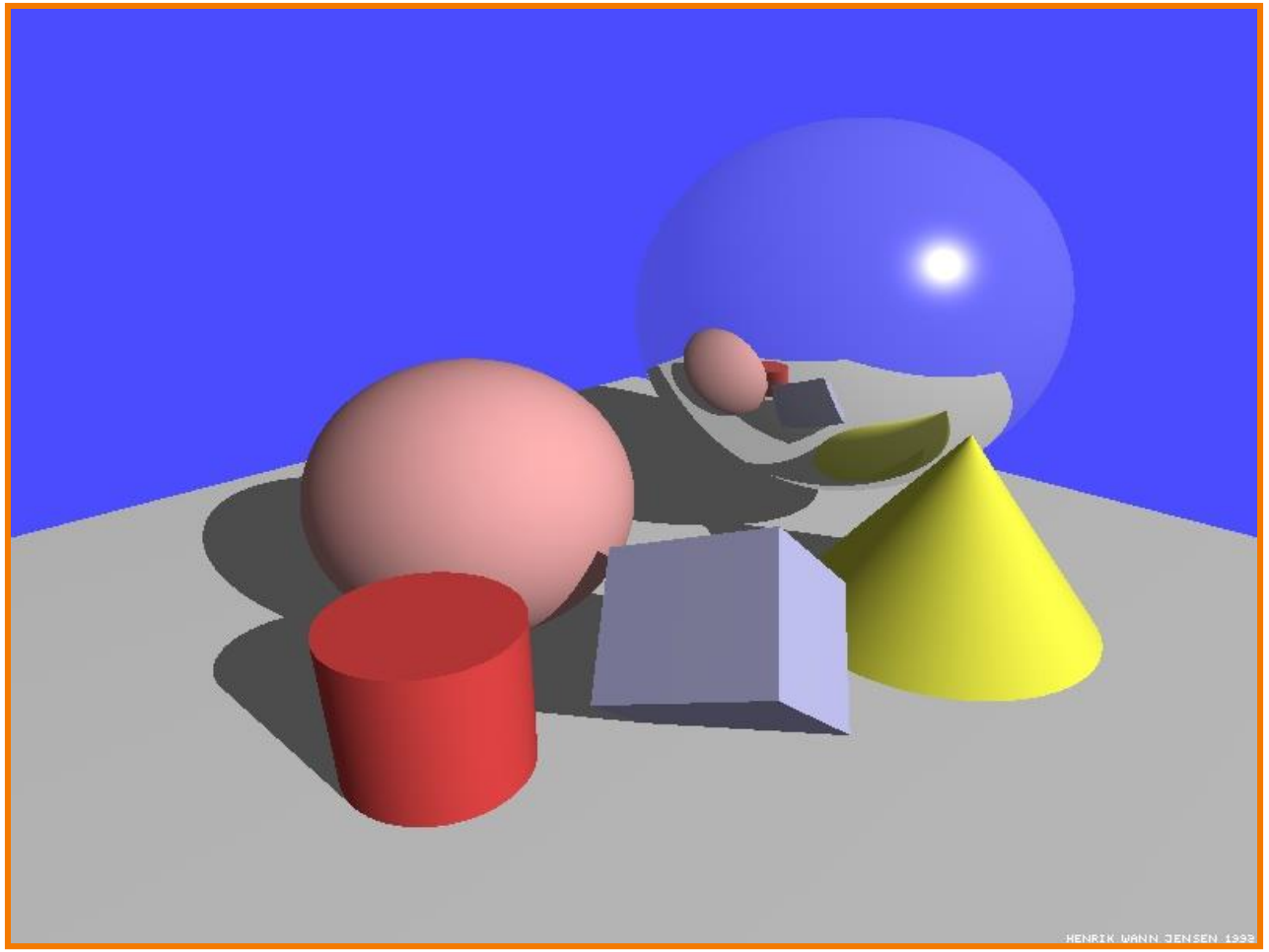
Synthesize image of a 3D scene accounting for all light transport (including indirect illumination)



Path Types



Path Types?



Henrik Wann Jensen

Path Types?

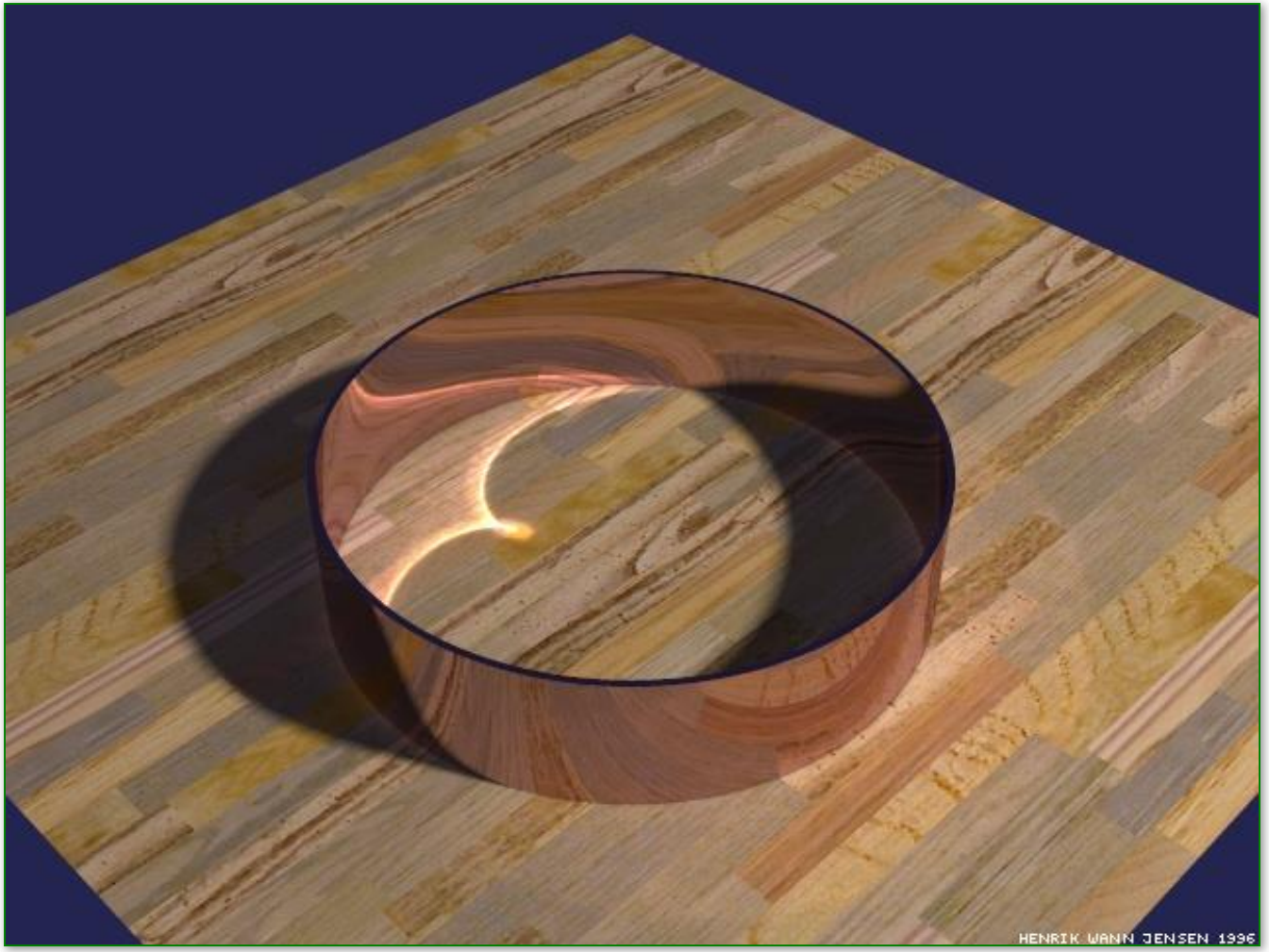
Herf

Path Types?

Paul Debevec

Path Types?

Path Types?



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Path Types?

Overview

Rendering equation

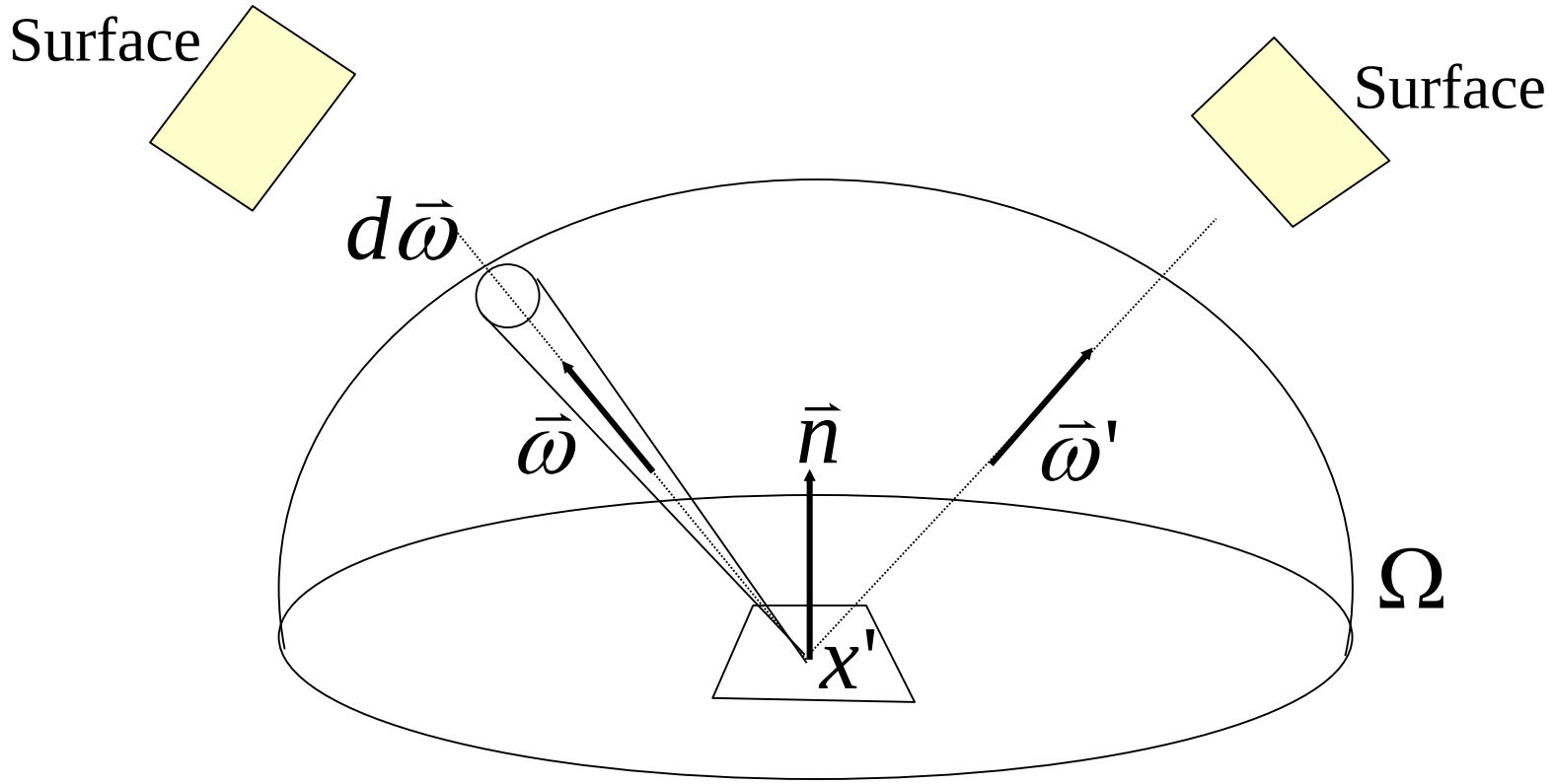
- Rendering is integration

Solution methods

- Direct illumination
- Recursive ray tracing
- Distribution ray tracing
- Path tracing
- Photon Mapping
- Radiosity
- etc.

Rendering Equation

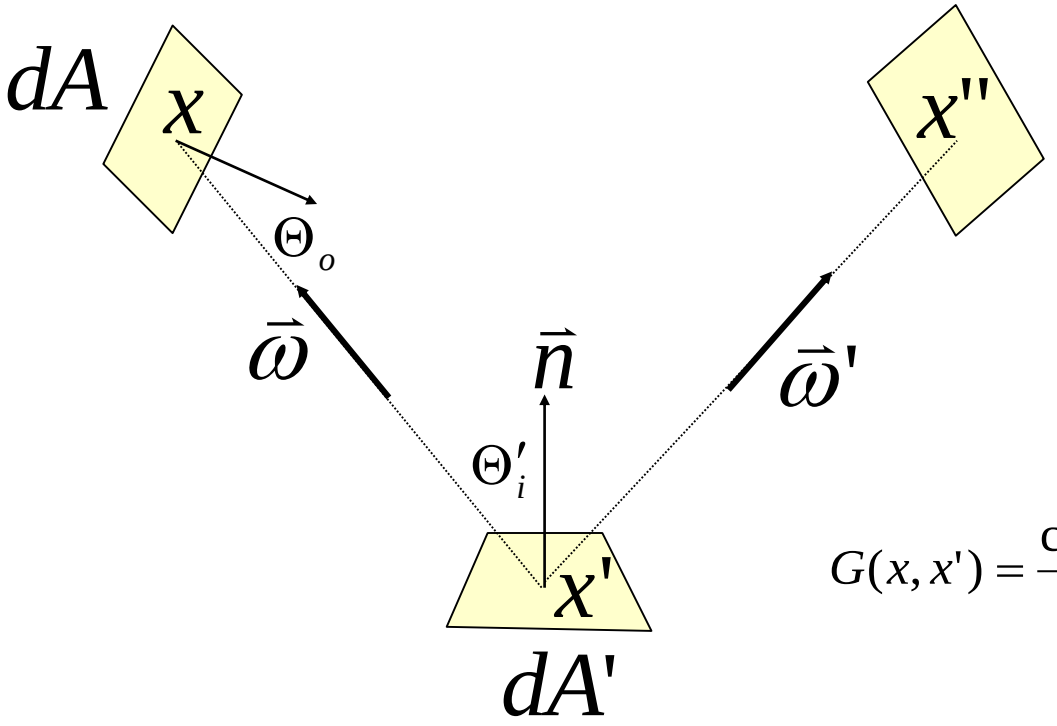
$$L_o(x', \vec{\omega}') = L_e(x', \vec{\omega}') + \int_{\Omega} f_r(x', \vec{\omega}, \vec{\omega}') L_i(x', \vec{\omega})(\vec{\omega} \bullet \vec{n}) d\vec{\omega}$$



Kajiya 1986

Rendering Equation (2)

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



$$G(x, x') = \frac{\cos \Theta_i' \cos \Theta_o}{\|x - x'\|^2}$$

Kajiya 1986

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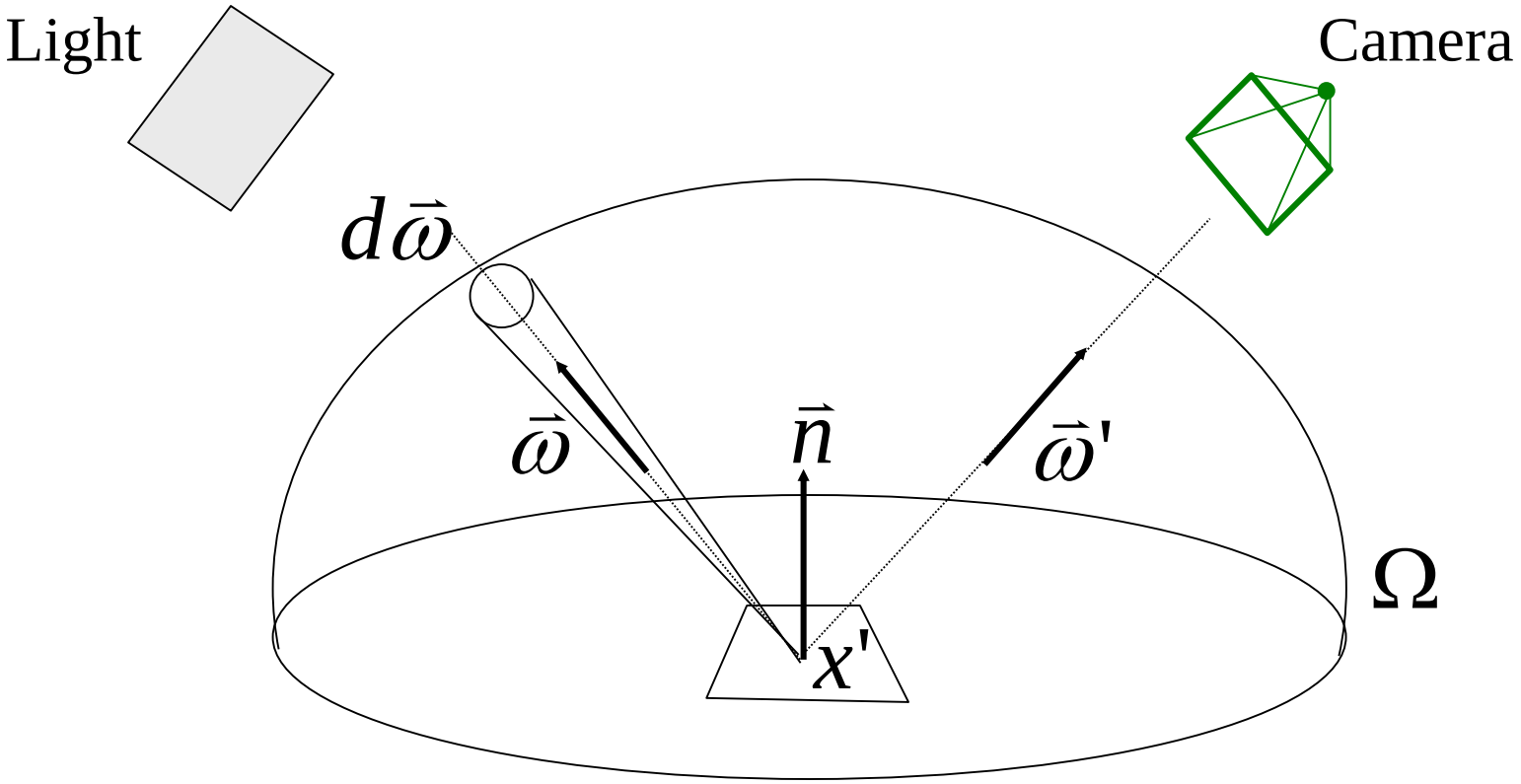
Direct Illumination

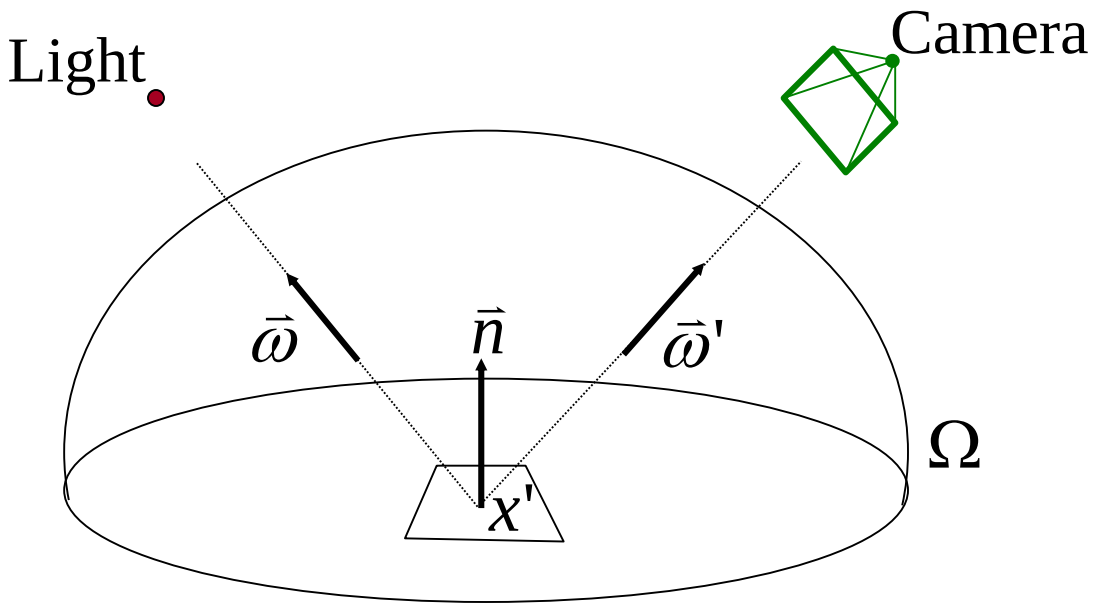
$$L_o(x',\vec{\omega}') = L_e(x',\vec{\omega}') + \int_{\Omega_L} f_r(x',\vec{\omega},\vec{\omega}')L_i(x',\vec{\omega})(\vec{\omega}\bullet\vec{n})d\vec{\omega}$$



OpenGL

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

Assume
direct illumination
from point lights
and ignore visibility



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

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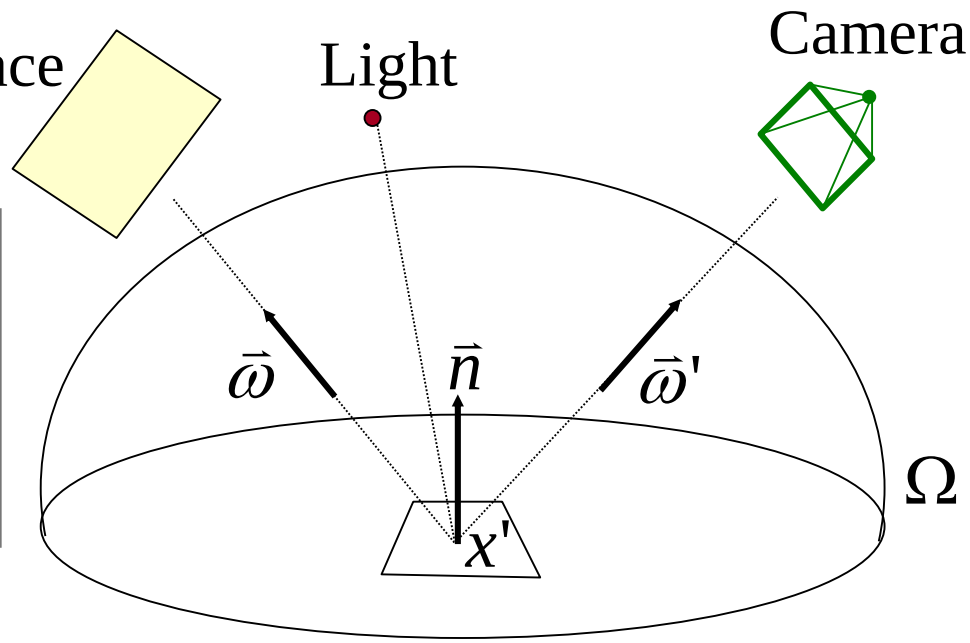
Recursive Ray Tracing

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



Assume only significant indirect illumination due to perfect specular reflection and refraction

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

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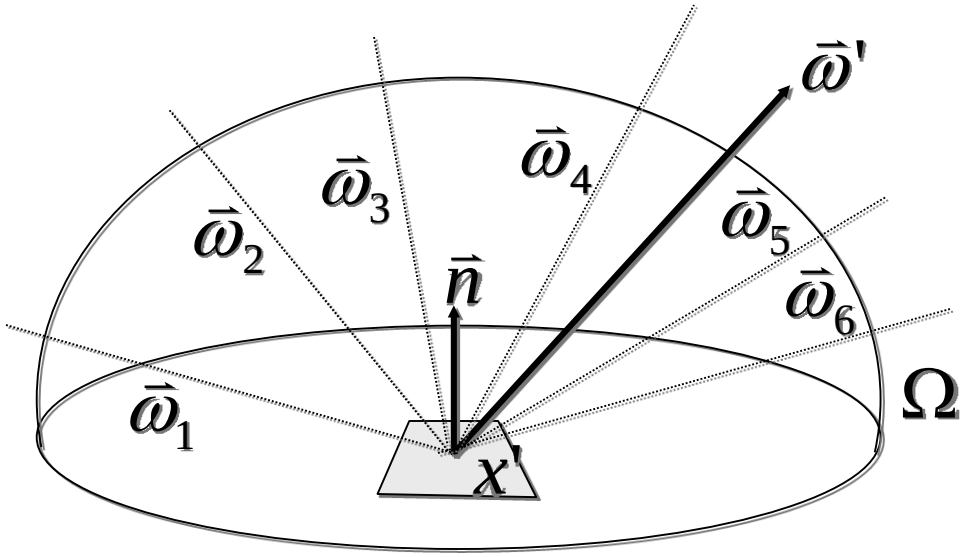
Distribution Ray Tracing

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

Estimate integral
for each reflection
by random sampling



Also:

- Depth of field
- Motion blur
- etc.

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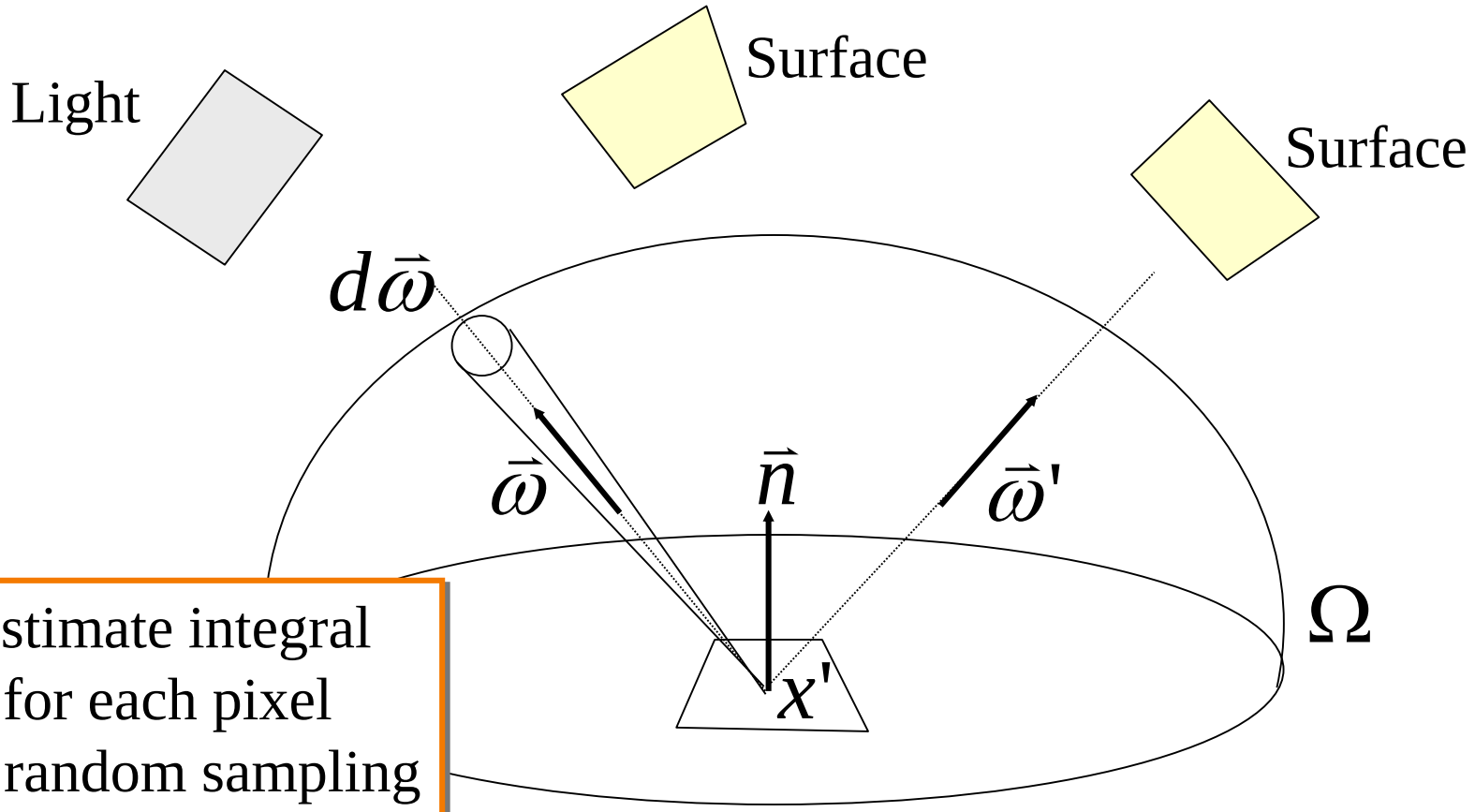
Path Tracing

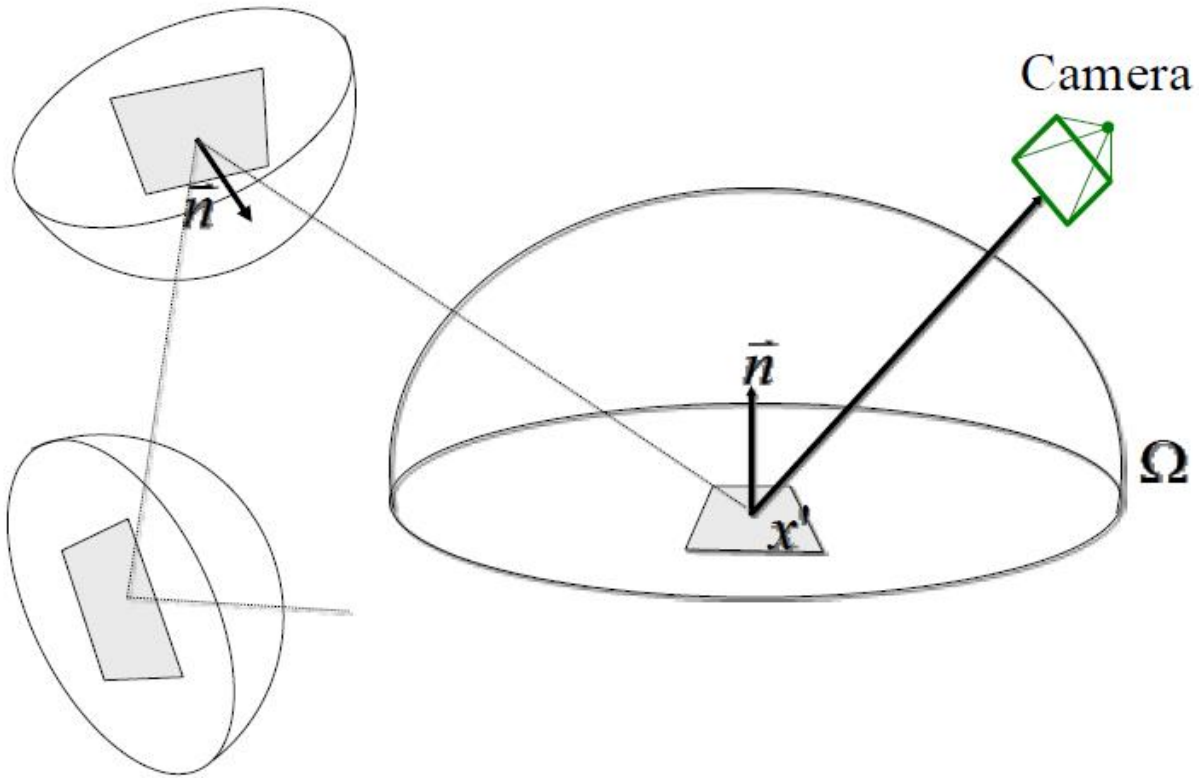
$$L_o(x',\vec{\omega}') = L_e(x',\vec{\omega}') + \int_{\Omega} f_r(x',\vec{\omega},\vec{\omega}') L_i(x',\vec{\omega})(\vec{\omega} \bullet \vec{n}) d\vec{\omega}$$



Estimate integral
for each pixel
by random sampling

Path Tracing

Estimate integral for each pixel by sampling paths from the camera



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Photon Mapping

Two pass method:

1. Build photon map by tracing paths from lights
2. Render image by tracing paths from camera

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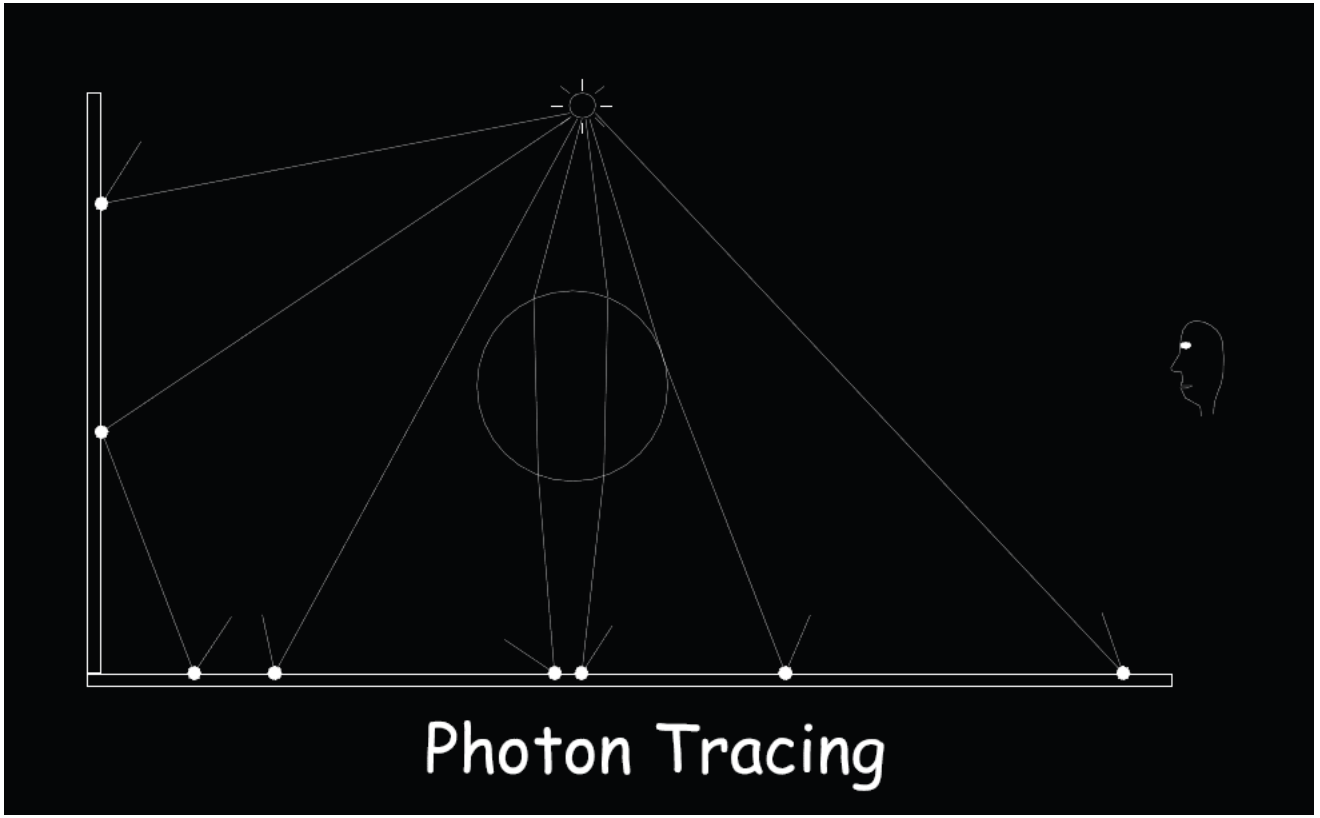

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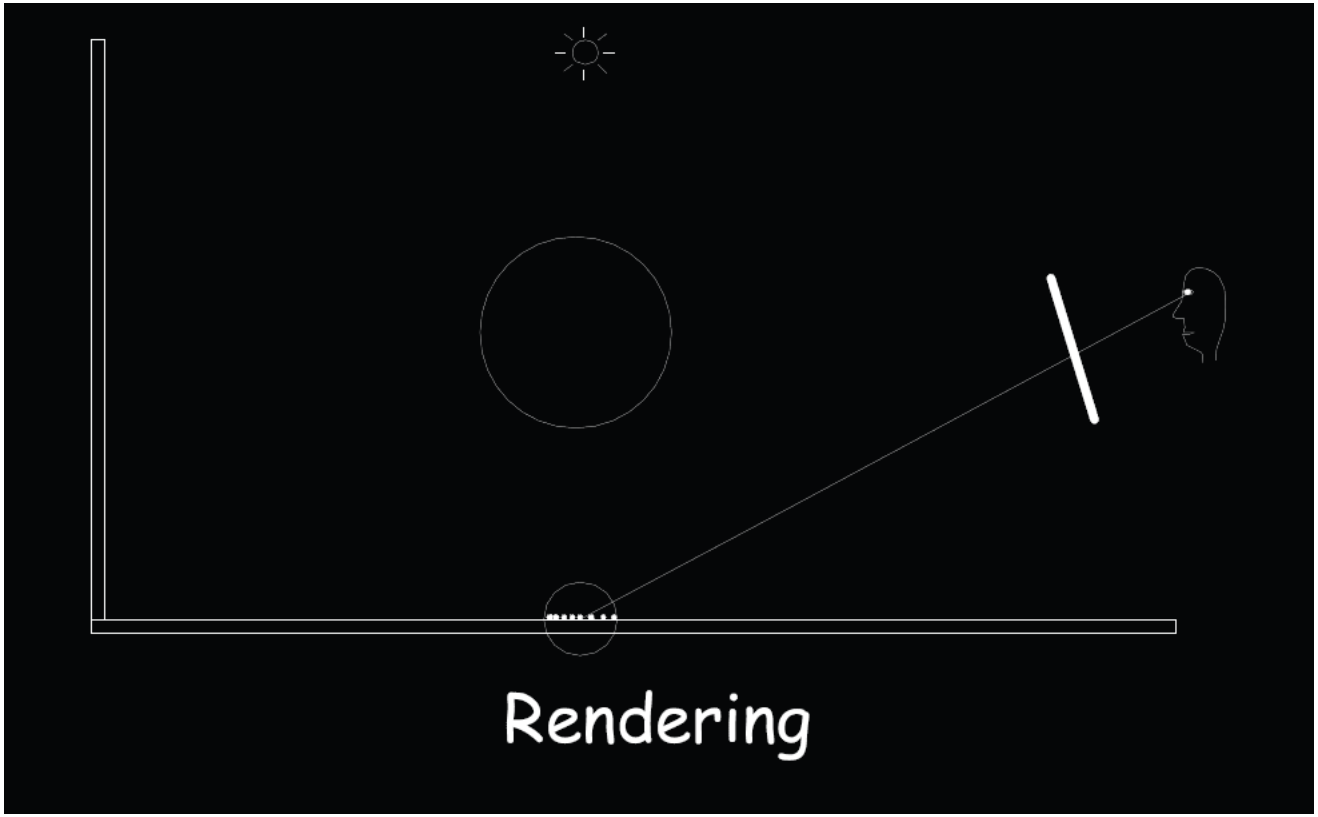

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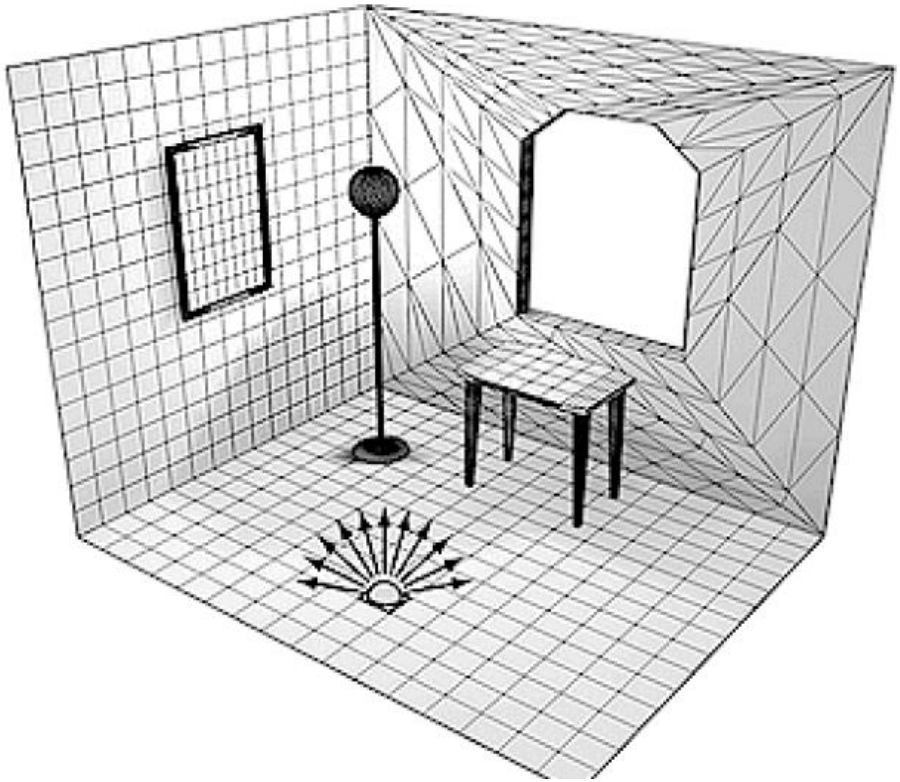
Radiosity

Discretize surfaces into small patches

Radiosity

Assume simple function (constant) is good approximation for radiosity (sum of all energy leaving a point) within a patch



Thadani

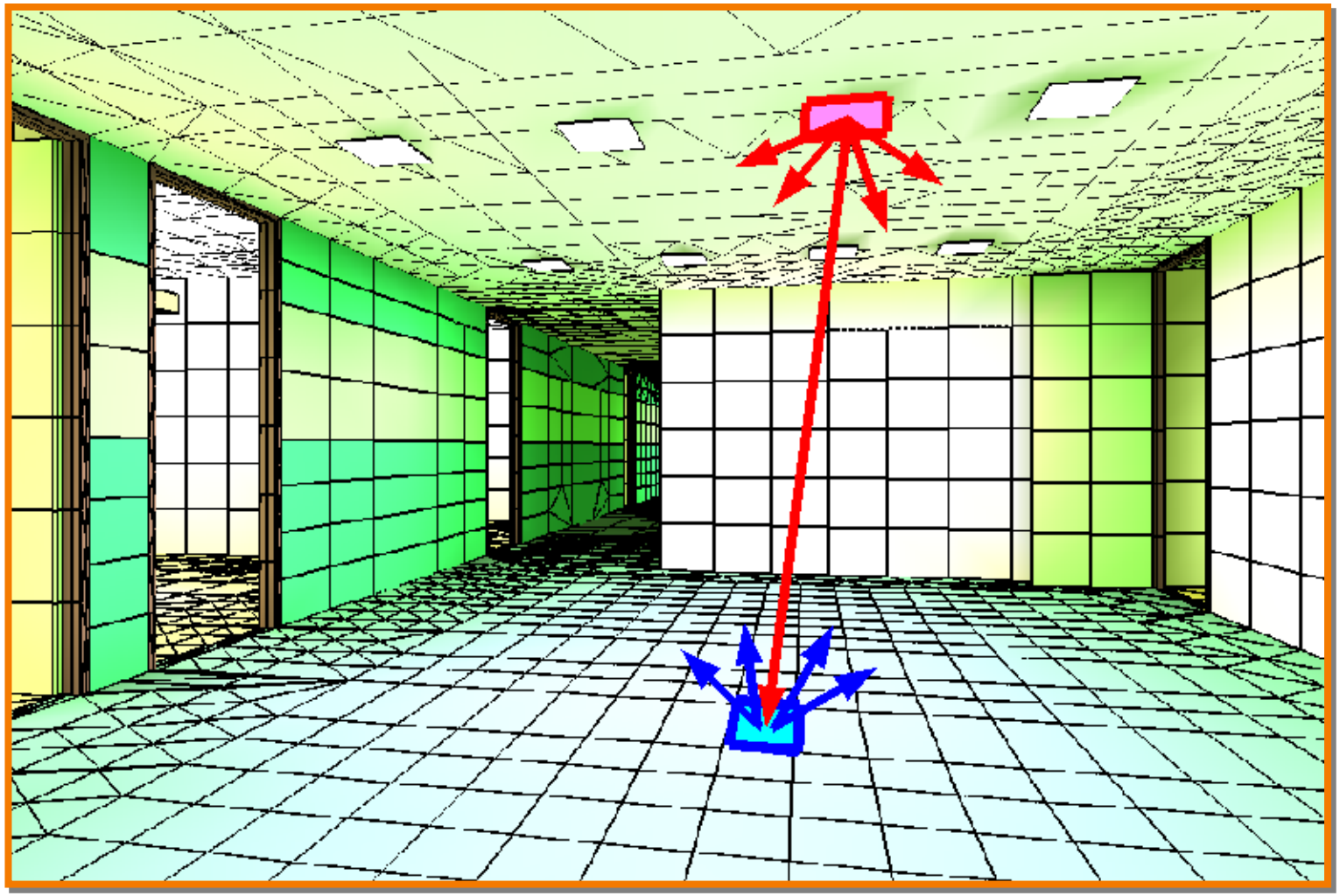
Radiosity

Leads to sparse linear system of equations

$$B_i A_i = E_i A_i + \rho_i \sum_{j=1}^{N} F_{ji} B_j A_j$$

$$\begin{bmatrix} 1-\rho_1 F_{1,1} & . & . & . & -\rho_1 F_{1,n} \\ -\rho_2 F_{2,1} & 1-\rho_2 F_{2,2} & . & . & -\rho_2 F_{2,n} \\ . & . & . & . & . \\ . & . & . & . & . \\ -\rho_{n-1} F_{n-1,1} & . & . & . & -\rho_{n-1} F_{n-1,n} \\ -\rho_n F_{n,1} & . & . & . & 1-\rho_n F_{n,n} \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ . \\ . \\ . \\ B_n \end{bmatrix} = \begin{bmatrix} E_1 \\ E_2 \\ . \\ . \\ . \\ E_n \end{bmatrix}$$

Radiosity



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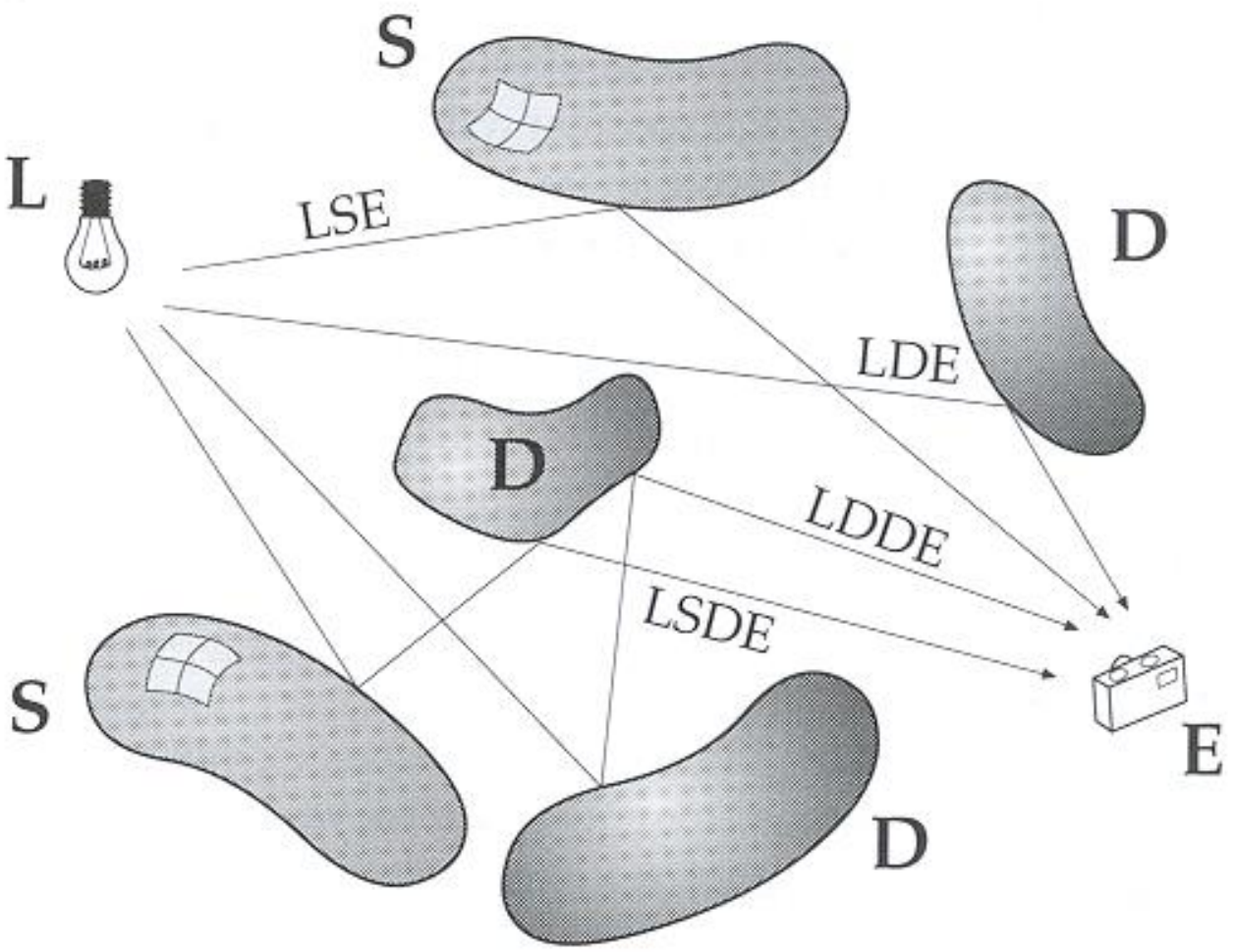
Which method is best?

Path Types



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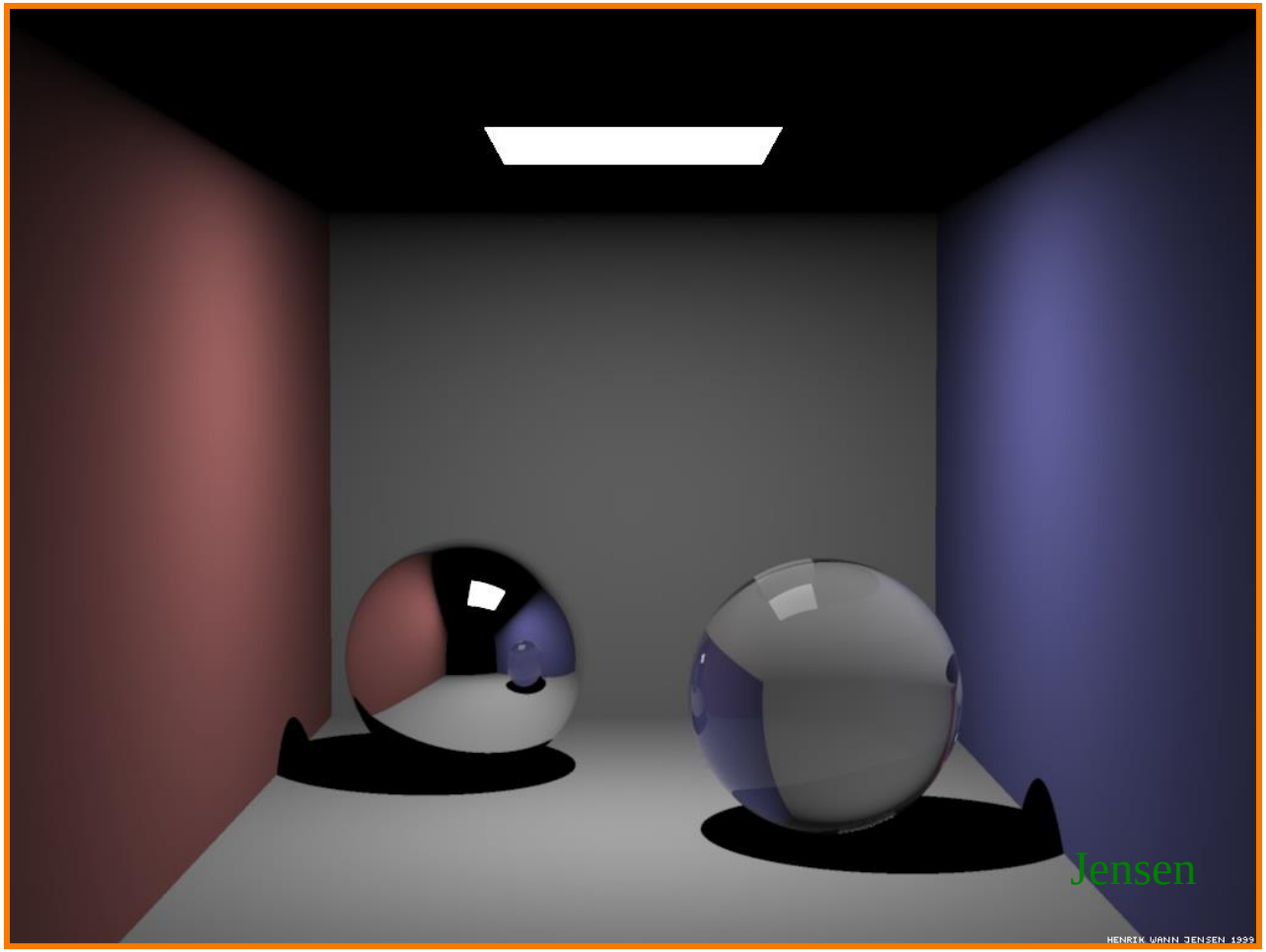

Ray tracing

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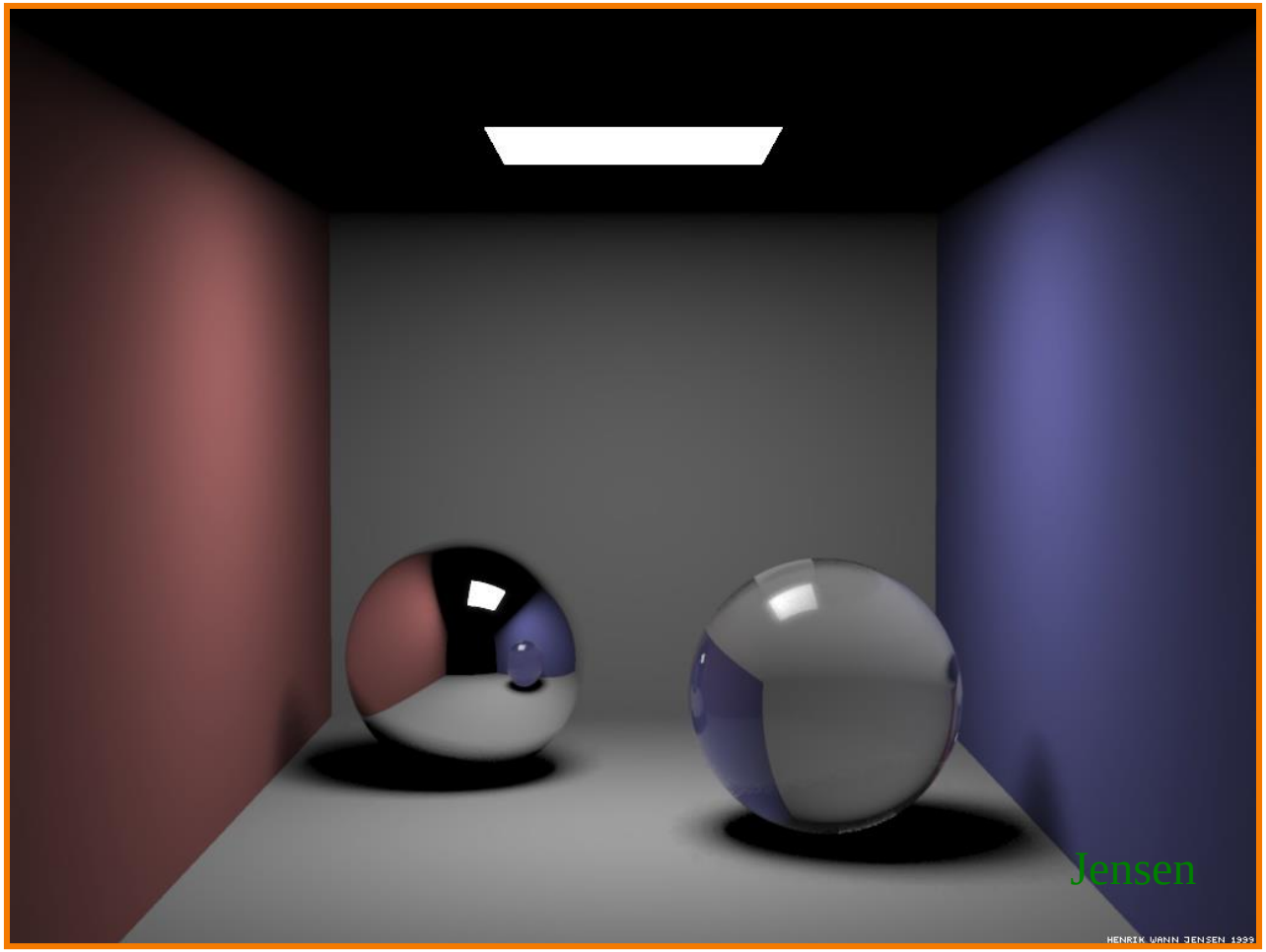
Path Types



+ soft shadows

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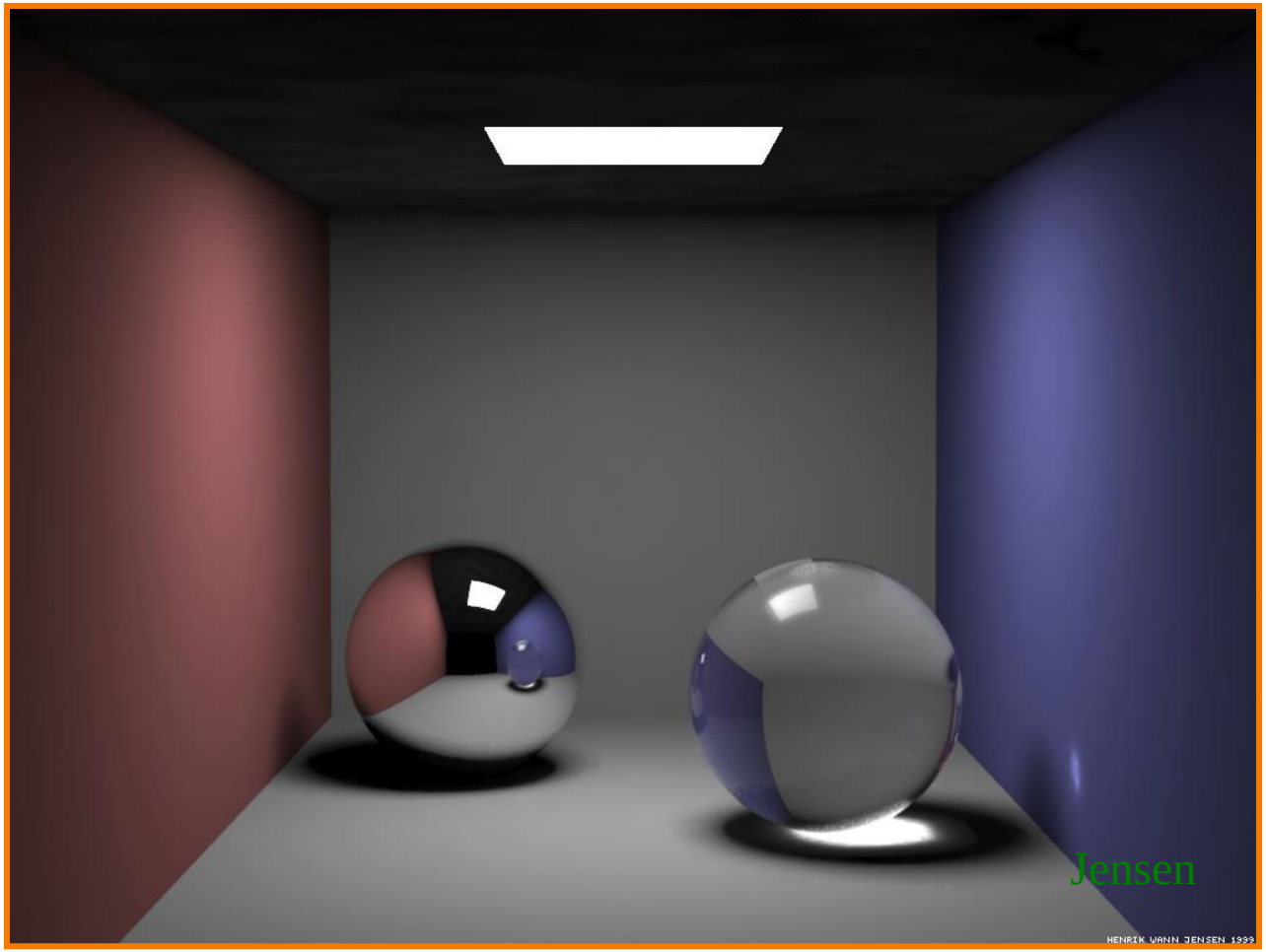
Path Types



+ caustics

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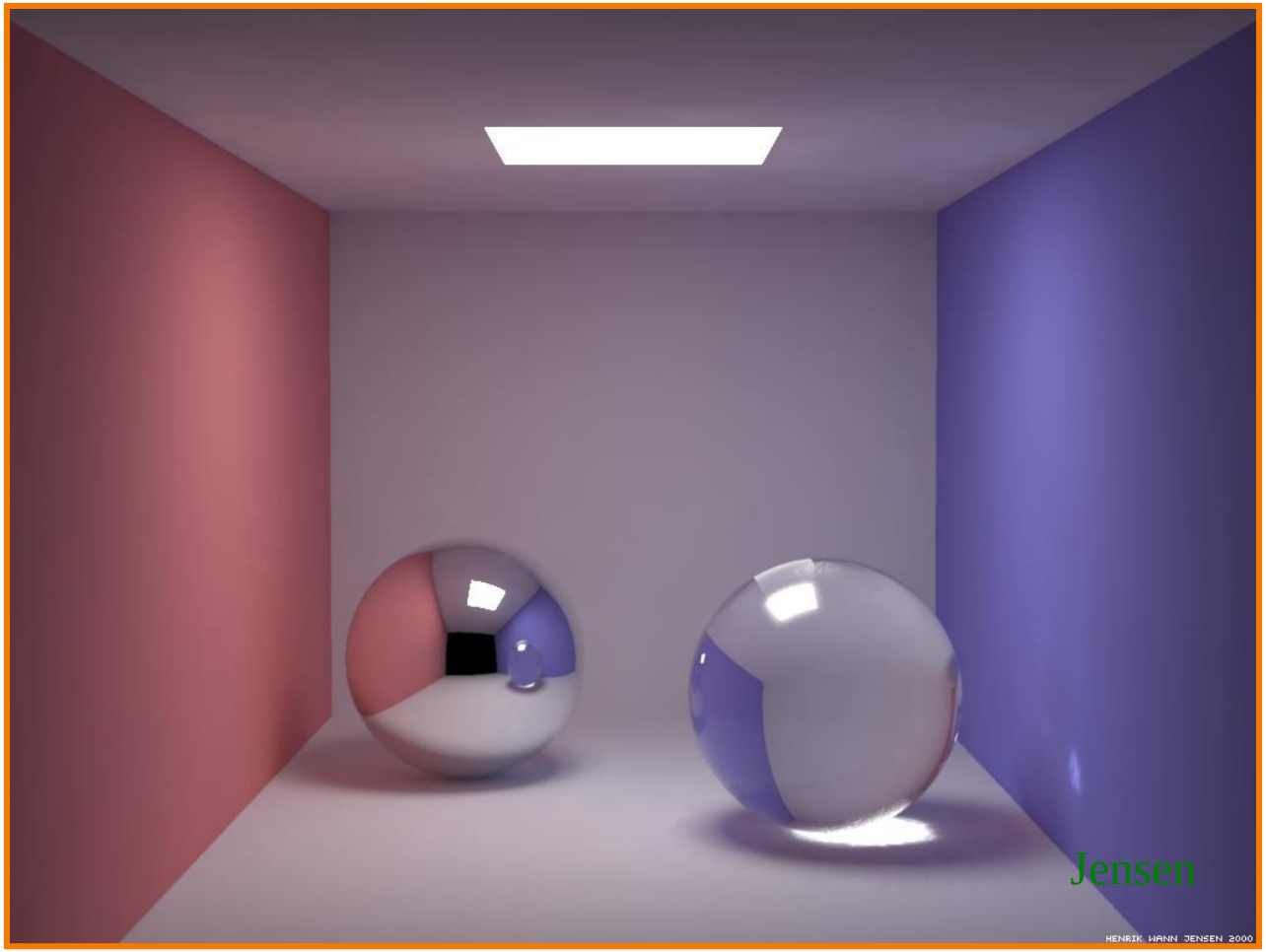
Path Types



+ indirect diffuse illumination

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Summary

Rendering equation

- Rendering is integration

Different solution methods are best for different types of scenes (depending on path types)

- Direct illumination - LDE
- Recursive ray tracing - LDS*E
- Distribution ray tracing – L(SD)*E
- Path tracing– L(SD)*E
- Photon Mapping– L(SD)*E (biased)
- Radiosity – LD*E
- etc.