Global Illumination

Local vs. Global Illumination

Local

- Direct illumination of surfaces by light sources
- e.g. Phong and Cook/Torrence illumination

Global

- all light/surface interactions for entire environment
- Recursive ray tracing and radiosity compute this partially...

Rendering Equation

$$I(x,x') = g(x,x')\left[\varepsilon(x,x') + \int_S \rho(x,x',x'')I(x',x'')dx''\right]$$

I: illumination at first point from second

g: geometry term for visibility and distance

ε: emitted light from second point to first

ρ: reflectivity of light from x'' to x via x'

Note that the equation is recursive

Ray Tracing

Modifies reflectivity term

- **Computes specular interreflections among surfaces**
- **Computes diffuse and specular reflections between light sources and surfaces**

Typically integrates using point sampling of direction space

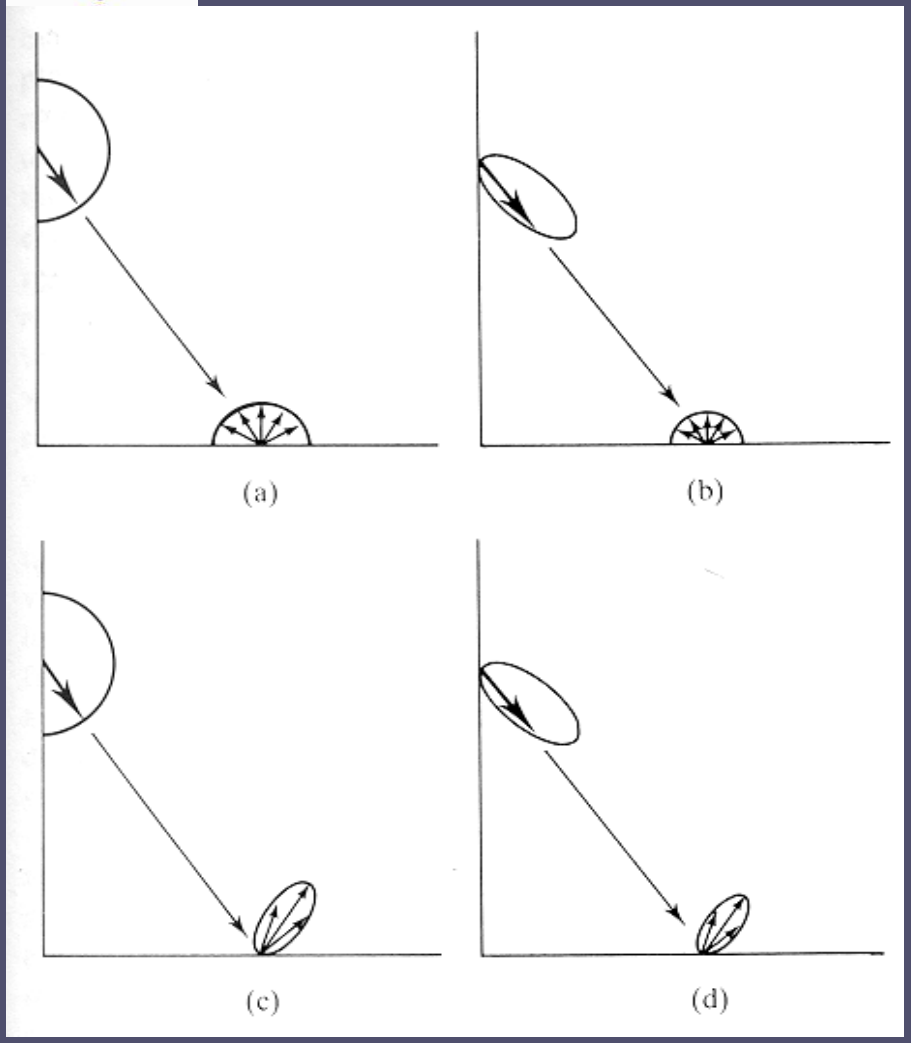
Radiosity

Also modifies reflectivity term

- Computes diffuse interreflections among surfaces (light sources not distinguished)

Integrates by quantizing surface points and summing

Light Transport Models



Specular

- Direction dependent
- High frequency

Diffuse

- Direction independent
- Lower frequency

From Watt and Watt, *Advanced Animation and Rendering Techniques*

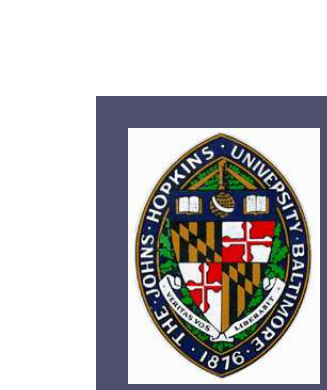
Light Transport in Ray Tracing and Radiosity

Ray Tracing

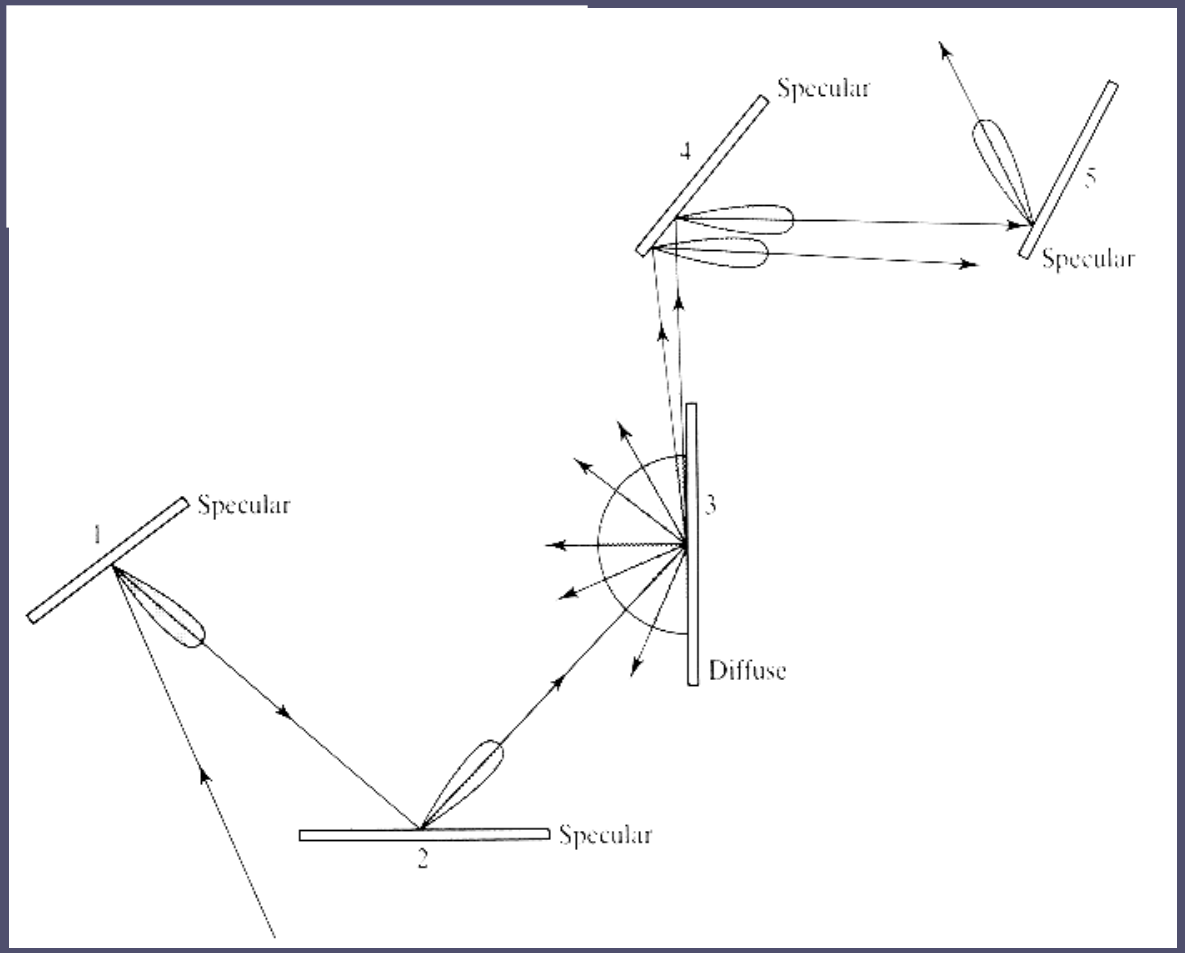
- Handles specular-to-specular and diffuse-to-specular

Radiosity

- Handles diffuse-to-diffuse

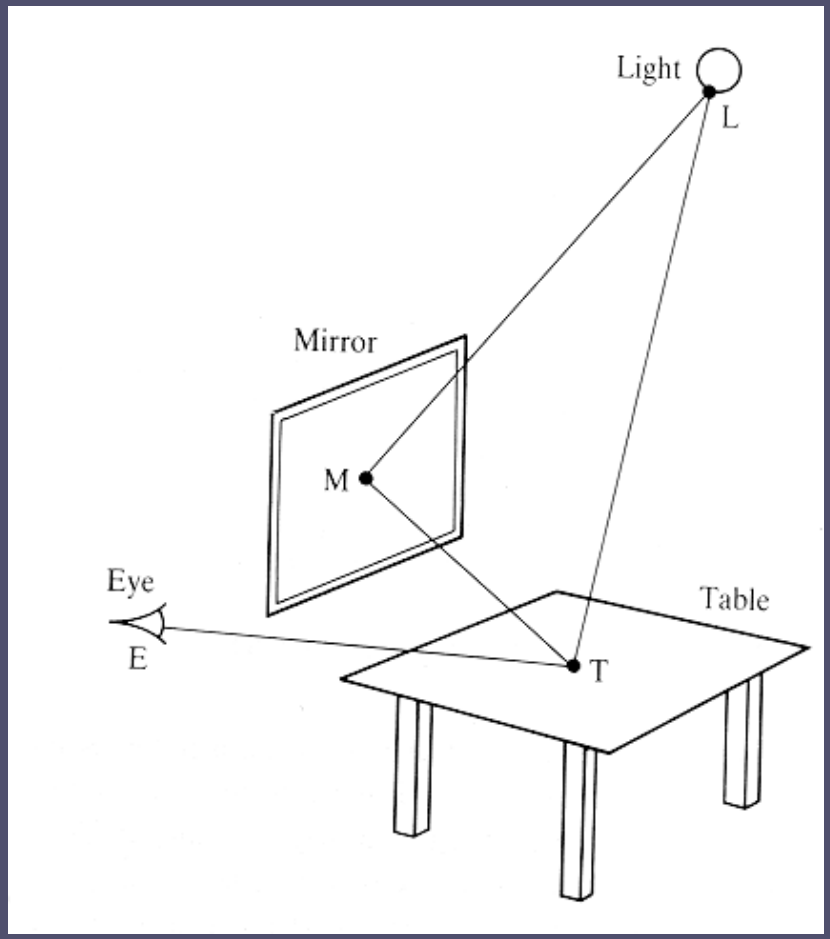


Problematic light transport chain



From Watt and Watt,
Advanced Animation and Rendering Techniques

Things easily missed: mirrors

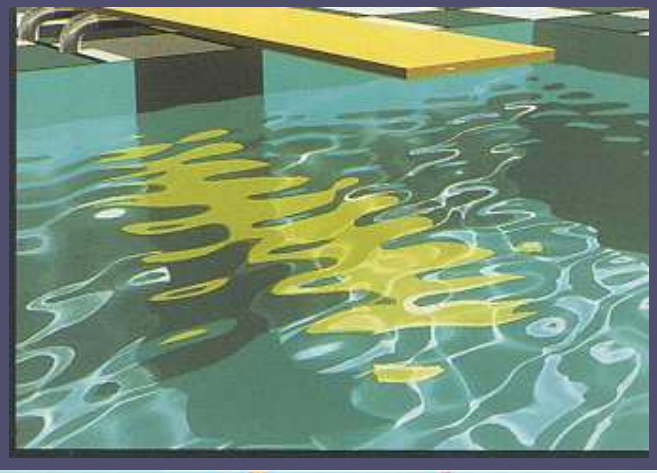


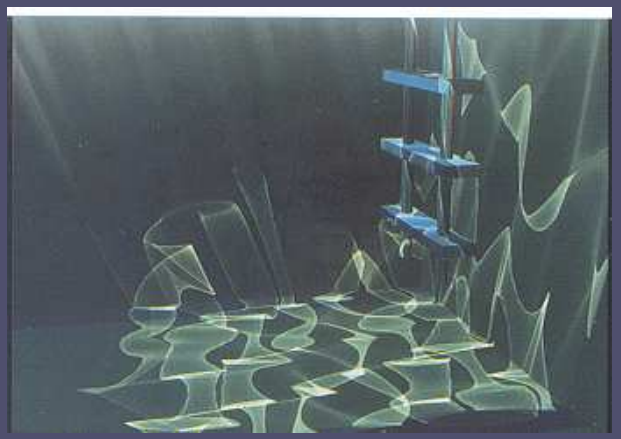
Specular-to-diffuse

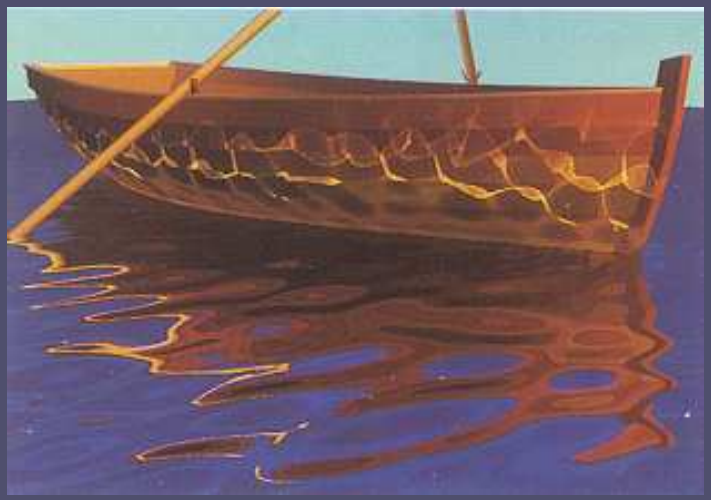
- **Ray tracing unlikely to discover illumination reflected off mirror onto table**

From Watt and Watt, *Advanced Animation and Rendering Techniques*

Things easily missed: caustics







Reflection and refraction by curved surfaces causes intense focusing of light

From Watt and Watt, *Advanced Animation and Rendering Techniques*

Backward ray tracing

Trace lots of rays from light sources to see where they go

- Store illumination maps with diffuse surfaces
- Easier to “follow the light” than to “find the light”
- Gets expensive! (in the general case)

Can be made efficient for special cases

Path Tracing

Similar to distribution ray tracing

Applies Monte Carlo sampling to estimate integral

Traces a single path for each eye ray (only a single ray spawned at each surface intersection)

Two-Pass Radiosity/Ray Tracing

First pass: radiosity

- Compute extended form factors and diffuse illumination

Second pass: ray tracing

- Perform standard ray tracing
- Diffuse component of illumination radiosity solution rather than just local illumination

Note: still doesn't handle light reflected specularly and later diffusely

Two-Pass Examples

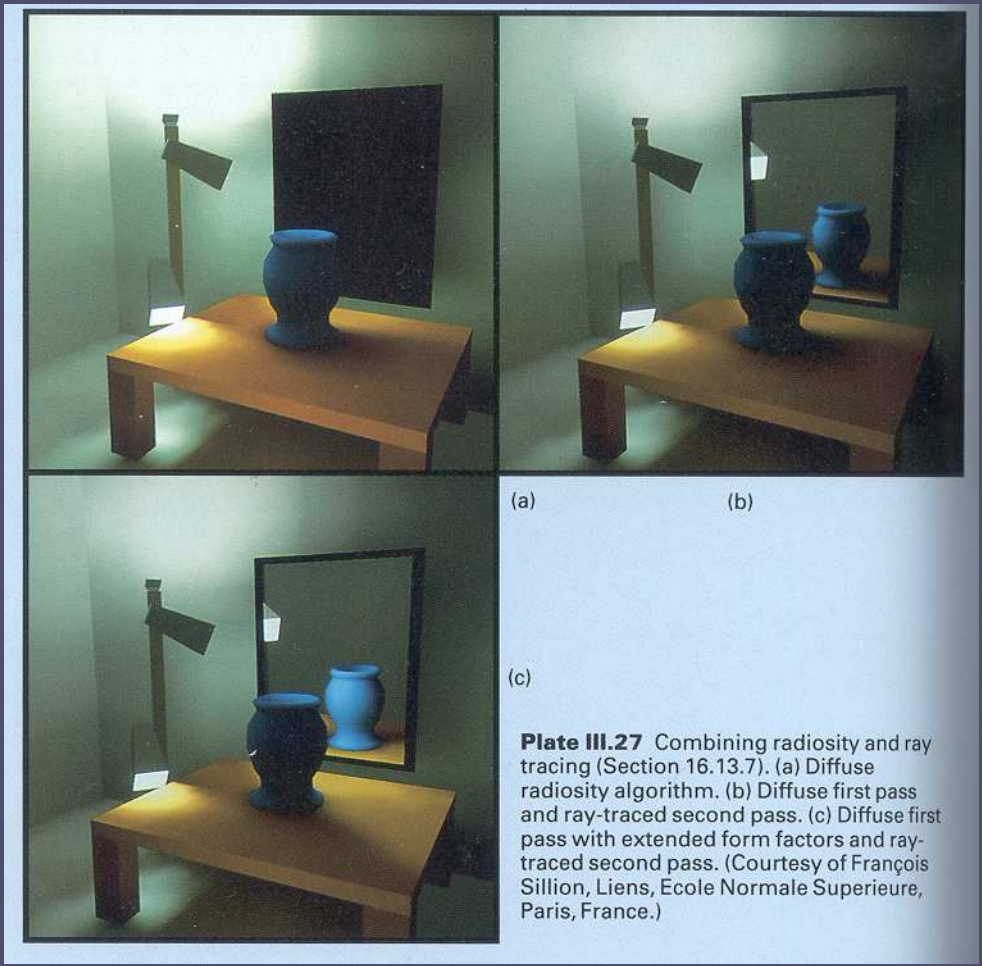


Plate III.27 Combining radiosity and ray tracing (Section 16.13.7). (a) Diffuse radiosity algorithm. (b) Diffuse first pass and ray-traced second pass. (c) Diffuse first pass with extended form factors and ray-traced second pass. (Courtesy of François Sillion, Liens, Ecole Normale Superieure, Paris, France.)

From Foley, van Dam, et al., *Computer Graphics: Principles and Practice*