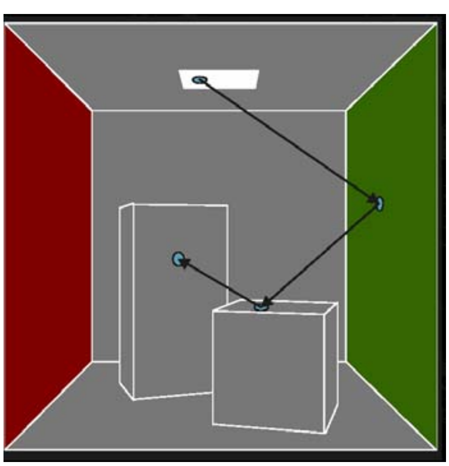
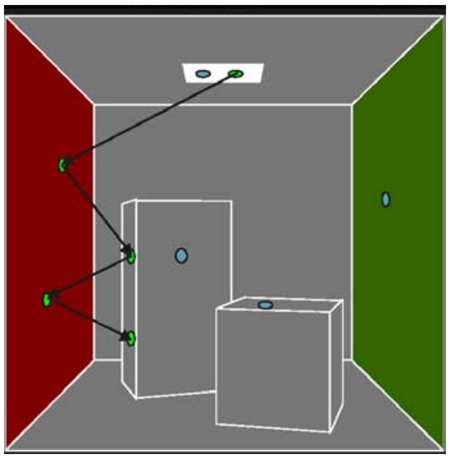
Photon Maps

Photon Tracing



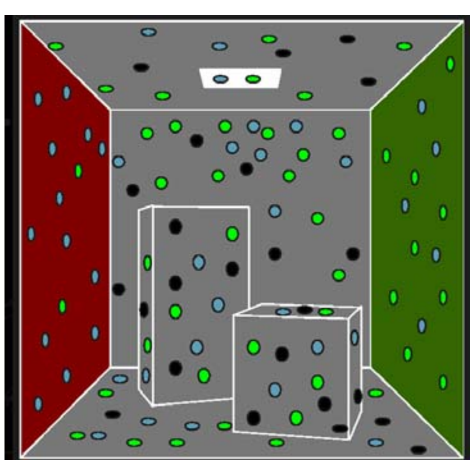
- Simulating light propagation by shooting photons from the light sources.

Photon Tracing



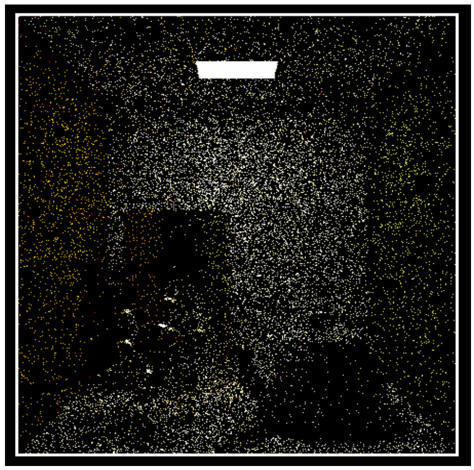
- Storing the incidences of photon's path.
- Implementing surface properties statistically.
- Russian Roulette.

Photon Tracing



- Photon maps keep:
  - Incidence point (in 3D).
  - The normal at that point.
  - Incidence direction.
  - Photons power.

Photon Map



Russian Rolette

- D – diffuse coefficient
- S – specular coefficient
- D + S <= 1
- Choose random number x [0,1]
- 0<= x <= D – diffuse reflection
- D < x <= S – specular reflection
- S < x <= 1 – absobrtion

Estimating Radiance

- The reflected radiance is given by:

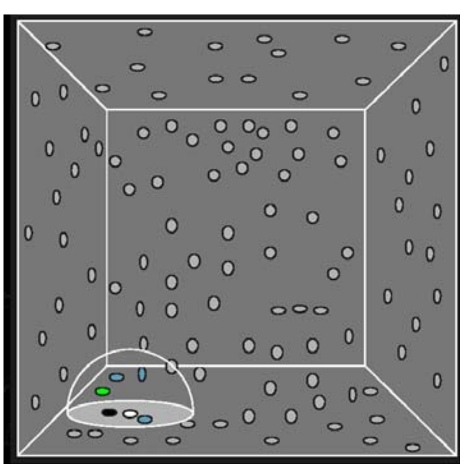
$$L(x,\vec{w}) = \int_{\Omega} f(w,\vec{w}',\vec{w}) L_i(x,\vec{w}')(\vec{n}_x,\vec{w}')d\vec{w}'$$

$$L_i(x,\vec{w}')(\vec{n}_x,\vec{w}') = \frac{\Phi_i(A)}{dA}$$

$$L(x,\vec{w}) \approx \sum_p f(x,\vec{w}'_p,\vec{w}) \frac{\Delta\Phi_p}{\Delta A}$$

- The last term has dA while we are tracing single photons and not fluxes.

Estimating Radiance



- Solution:
  - Look at a circle around x with radius r.
  - Add only photons from that are
  - dA = pi * r
- Or weighted sum (Gaussian kernel)

Building Photon Maps

- Caustic Maps: Cast rays from light source toward specular objects
  - Bias the sampling with "projection maps" that suggest good places to send rays
  - Stop when the ray hits a diffuse surface, and store the point, direction, intensity
  - When all the rays have been cast, build a kd-tree on the points
    - Only need tree for later look-up, so worth building a good tree
- Global Photon Map: Monte-Carlo Path tracing from lights
  - Deposit a photon at every surface hit
  - Use Russian Roulette to control cost and reduce bias

Producing the Image

- Use ray tracing to determine the visible points
- Radiance at a point is broken into several components:
  - One-bounce light from sources
  - Light reflected specularly from other points
  - Diffusely reflected caustics
  - Light reflected diffusely multiple times
- Each component is determined separately
  - Accurate method for directly seen light and "difficult" geometry
  - Approximate for diffusely reflected light (low weight)

Computing Contributions

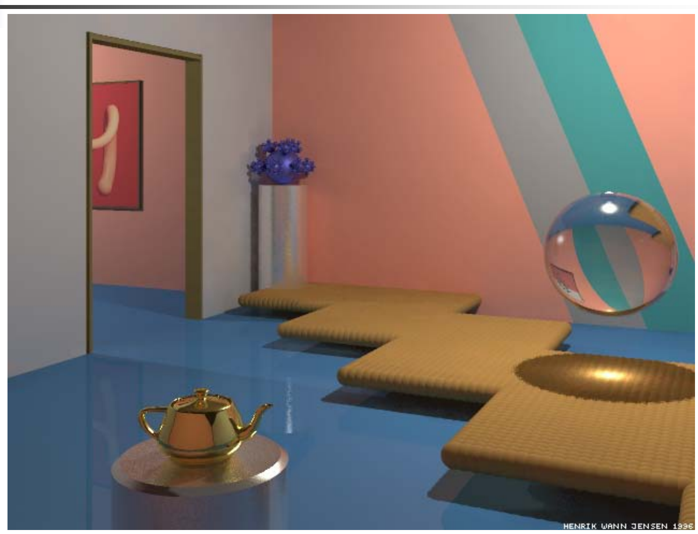
- Direct illumination:
  - Accurate: Photon map gives approx. shadow, cast ray if not certain
  - Approximate: Use diffuse photon map directly
- Specular reflection:
  - Distribution ray tracing with importance
- Caustics:
  - Use caustics photon map directly
- Soft indirect illumination:
  - Accurate: “Radiance” style estimate
  - Approximate: Global photon map

The “2 pass” algorithm

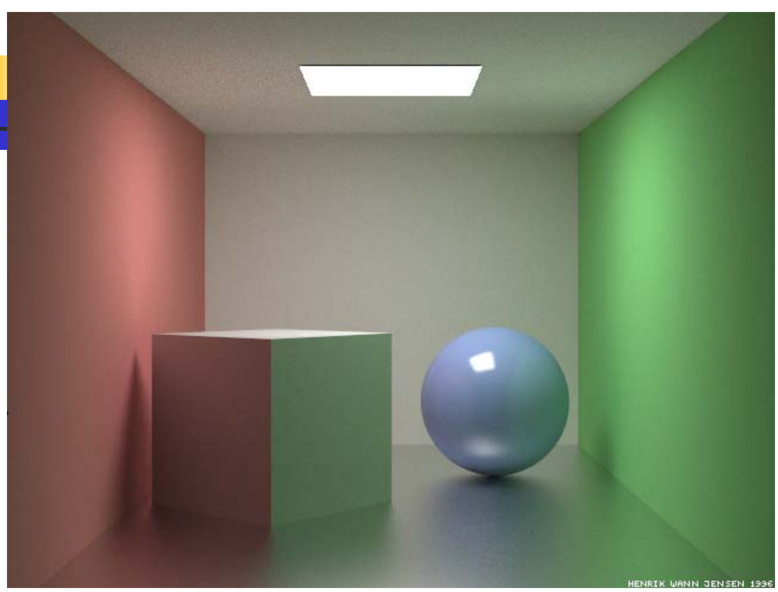
- Step I:
  - Building photon maps.
  - Contains: direct,indirect,caustics photons.
- Step II:
  - Rendering the scene using ray tracing.
  - Direct lighting – sending rays to light sources.
  - Specular – sending rays towards reflected direction.
  - Caustics – from PM.
  - Indirect – from PM.

Direct visualization of PM

"2 pass" Algorithm



Cornell box (PM): 2560x1920, 51 minutes



Cornell box (Rad): 5120x3840, 360 minutes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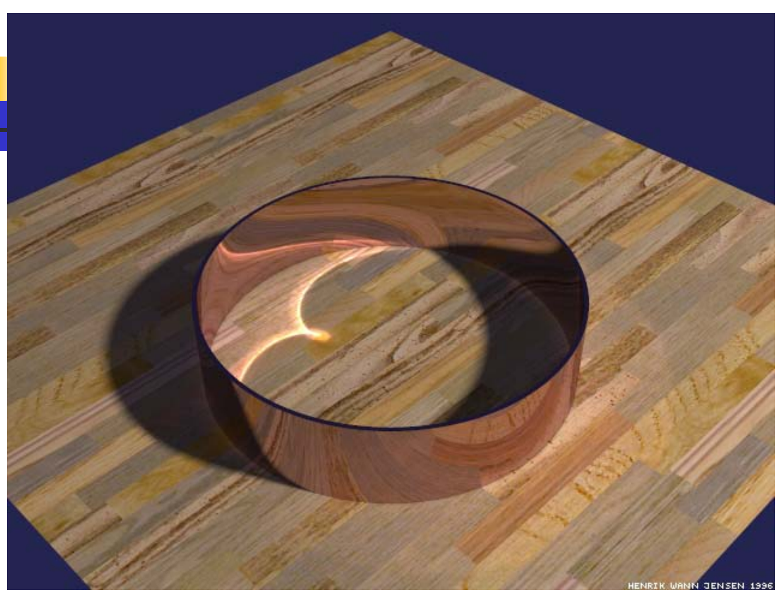
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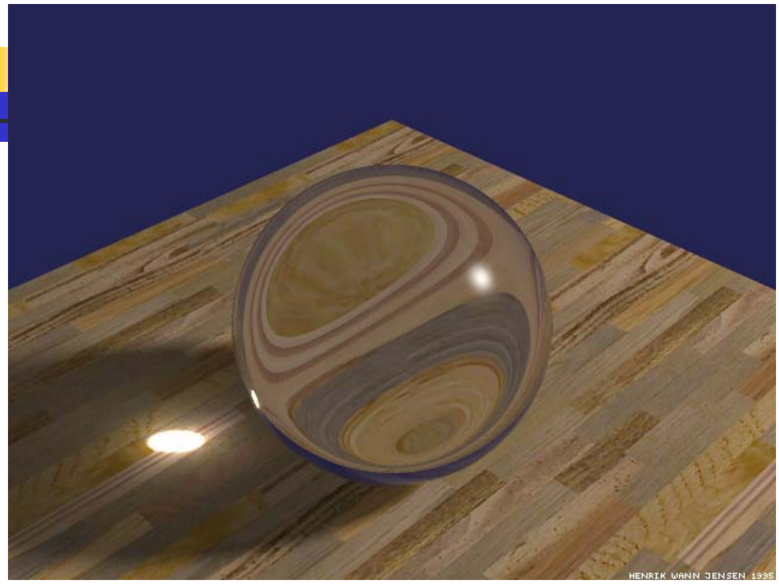
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