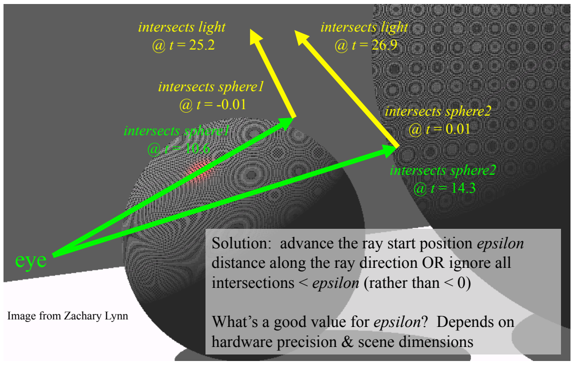
Irradiance Caching & Photon Mapping

Raytracing & Epsilon



Solution: advance the ray start position *epsilon* distance along the ray direction OR ignore all intersections < *epsilon* (rather than < 0)

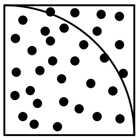
What's a good value for *epsilon*? Depends on hardware precision & scene dimensions

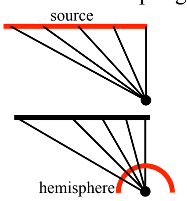
Image from Zachary Lynn

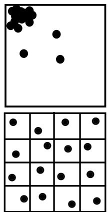
Last Time?

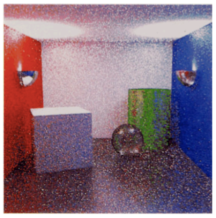
$L(x',\omega') = E(x',\omega') + \int \rho_{x'}(\omega,\omega')L(x,\omega)G(x,x')V(x,x')\,dA$

- Rendering Equation
- Monte-Carlo Integration
- Monte Carlo Rendering
- Forward Ray Tracing
- Stratified Sampling







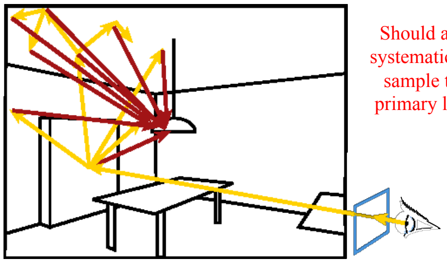


Today

- Monte-Carlo Ray Tracing vs. Path Tracing
- Irradiance Caching
- Photon Mapping
- Ray Grammar

Monte-Carlo Ray Tracing

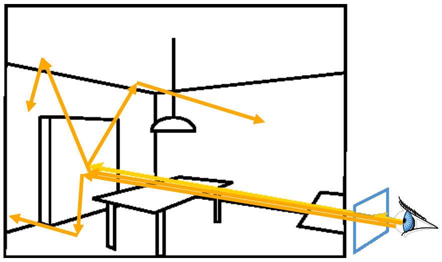
- Cast a ray from the eye through each pixel
- Cast random rays to accumulate radiance contribution
  - Recurse to solve the Rendering Equation



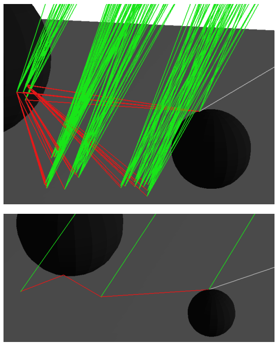
Should also systematically sample the primary light

Monte Carlo Path Tracing

- Trace only one secondary ray per recursion
- But send many primary rays per pixel (performs antialiasing as well)



Ray Tracing vs Path Tracing



2 bounces
5 glossy samples
5 shadow samples

How many rays cast per pixel?

1main ray + 5 shadow rays +
5 glossy rays + 5x5 shadow rays +
5*5 glossy rays + 5x5x5 shadow rays
= 186 rays

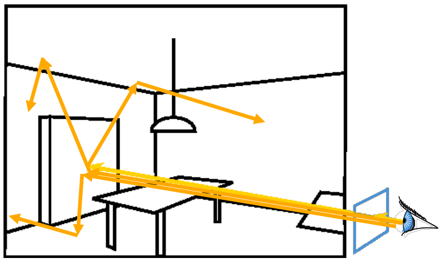
How many 3 bounce paths can we trace per pixel for the same cost?

186 rays / 8 ray casts per path
= ~23 paths

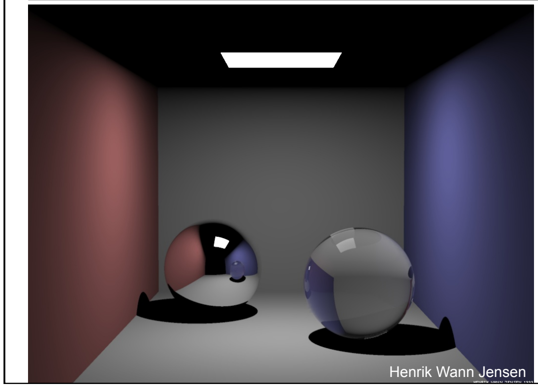
Which will probably have less error?

Path Tracing is costly

- Needs tons of rays per pixel

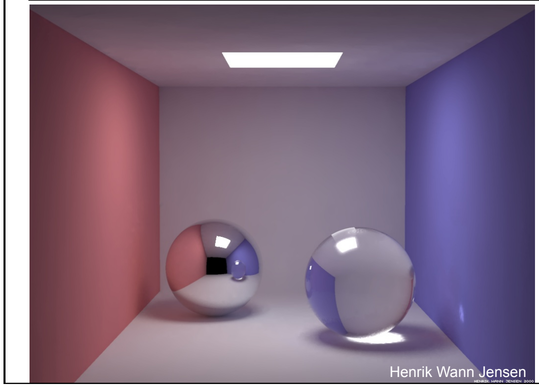


Direct Illumination



Henrik Wann Jensen

Global Illumination



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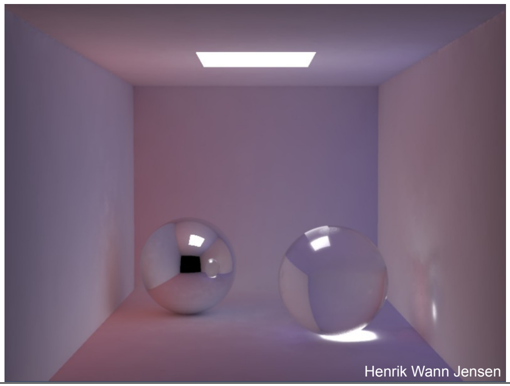
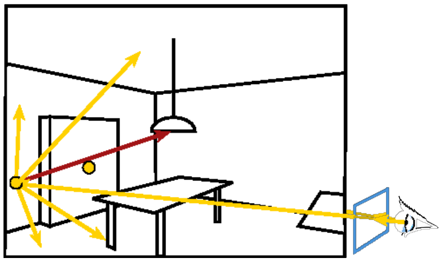
Indirect Illumination: smooth



Henrik Wann Jensen

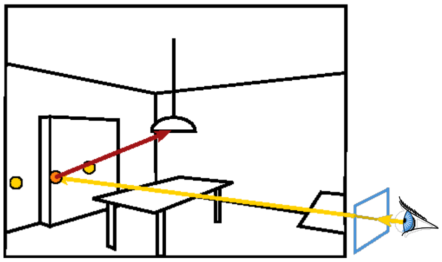
Irradiance Cache

- The indirect illumination is smooth
- Store the indirect illumination

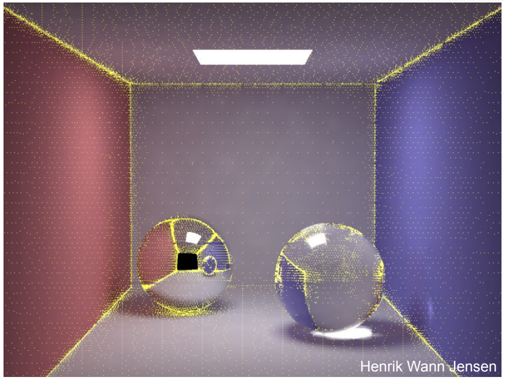


Irradiance Cache

- Interpolate nearby cached values
- But do full calculation for direct lighting

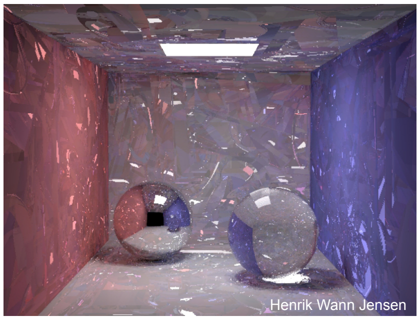


Irradiance Cache



Questions?

- Why do we need "good" random numbers?
  - With a fixed random sequence, we see the structure in the error

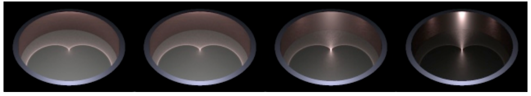


Today

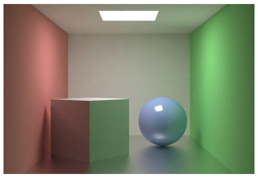
- Monte-Carlo Ray Tracing vs. Path Tracing
- Irradiance Caching
- Photon Mapping
- Ray Grammar

Readings for Today

- "Rendering Caustics on Non-Lambertian Surfaces", Henrik Wann Jensen, *Graphics Interface* 1996.

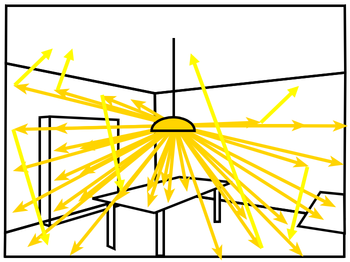


- "Global Illumination using Photon Maps", Henrik Wann Jensen, *Rendering Techniques* 1996.



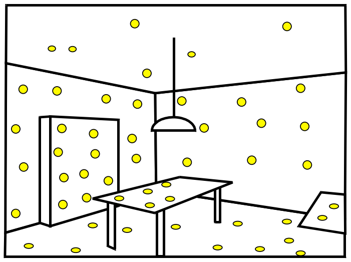
Photon Mapping

- Preprocess: cast rays from light sources
  - independent of viewpoint



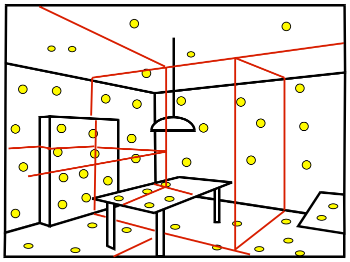
Photon Mapping

- Store photons
  - position + light power + incoming direction



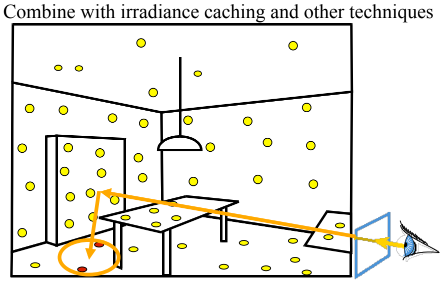
Photon Map

- Efficiently store photons for fast access
- Use hierarchical spatial structure (kd-tree)

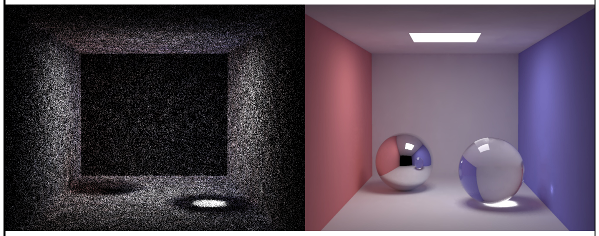


Rendering with Photon Map

- Cast primary rays
- For secondary rays
  - reconstruct irradiance using k closest photons
- Combine with irradiance caching and other techniques

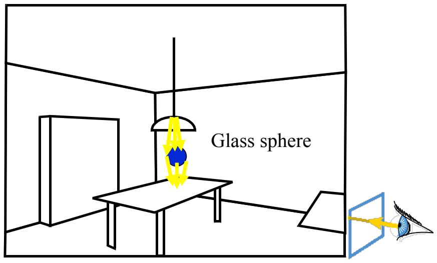


Photon Map Results



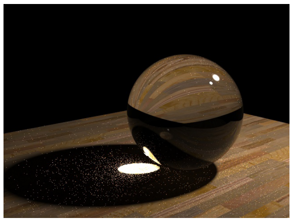
Photon Mapping - Caustics

- Special photon map for specular reflection and refraction

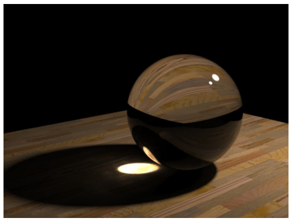


Comparison

Path Tracing
1000 paths/pixel

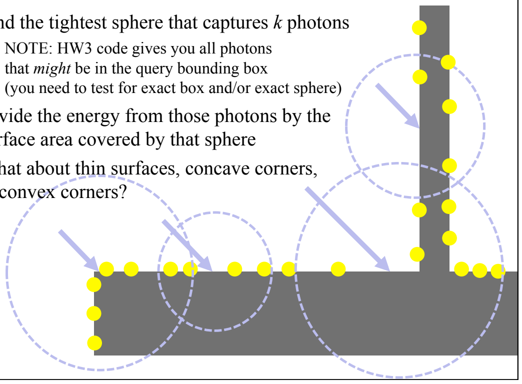


Photon mapping



Closest Photon Details

- Find the tightest sphere that captures *k* photons
  - NOTE: HW3 code gives you all photons that *might* be in the query bounding box (you need to test for exact box and/or exact sphere)
- Divide the energy from those photons by the surface area covered by that sphere
- What about thin surfaces, concave corners, & convex corners?



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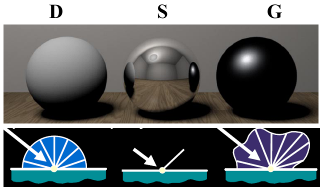
Ray Grammar

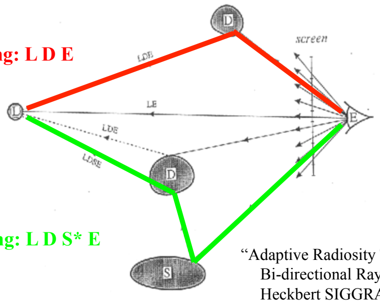
- Classify local interaction:
  - E = eye
  - L = light
  - S = perfect specular reflection or refraction
  - G = glossy scattering
  - D = diffuse scattering



From Dutre et al.'s slides

Classic Ray Casting/Tracing

Ray casting: L D E

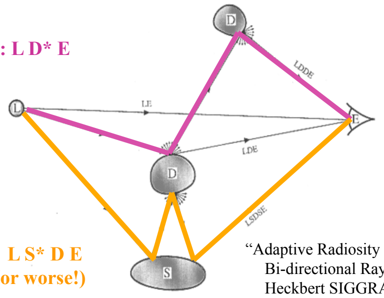


Ray tracing: L D S* E

"Adaptive Radiosity Textures for Bi-directional Ray Tracing" Heckbert SIGGRAPH 1990

Photon Tracing

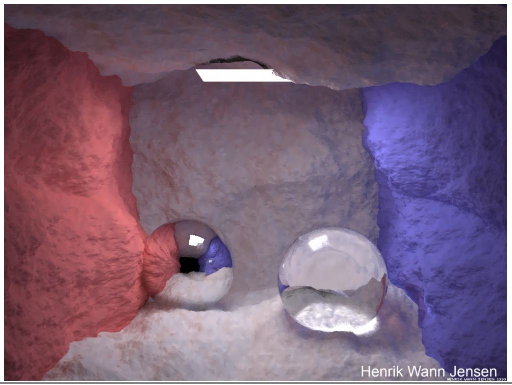
Radiosity: L D* E



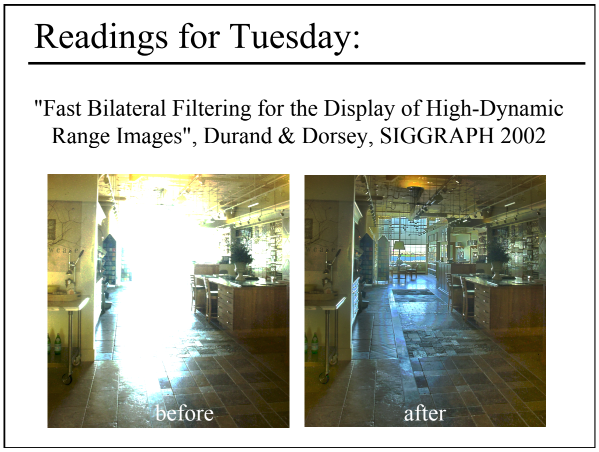
Caustics: L S* D E (or worse!)

"Adaptive Radiosity Textures for Bi-directional Ray Tracing" Heckbert SIGGRAPH 1990

Questions?



Henrik Wann Jensen



Readings for Tuesday:

"Fast Bilateral Filtering for the Display of High-Dynamic Range Images", Durand & Dorsey, SIGGRAPH 2002