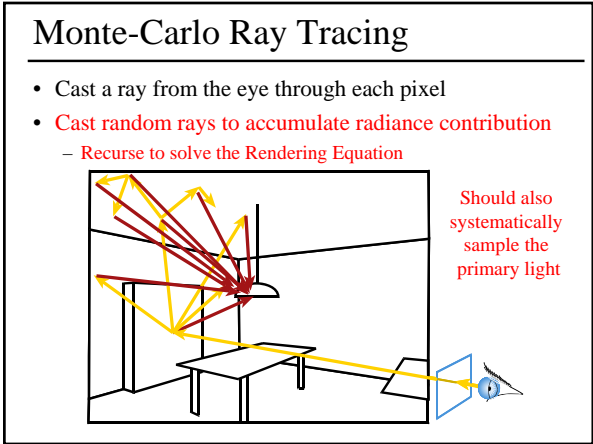
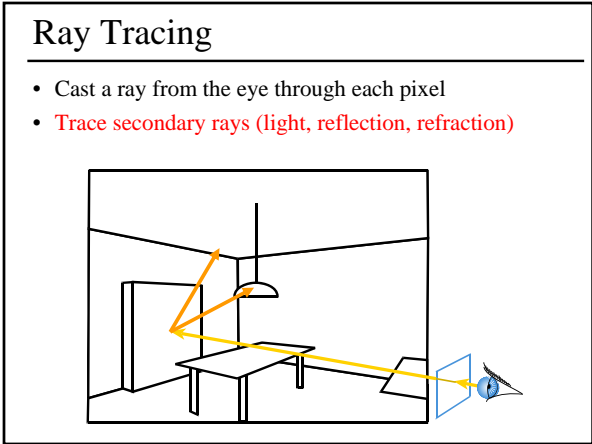
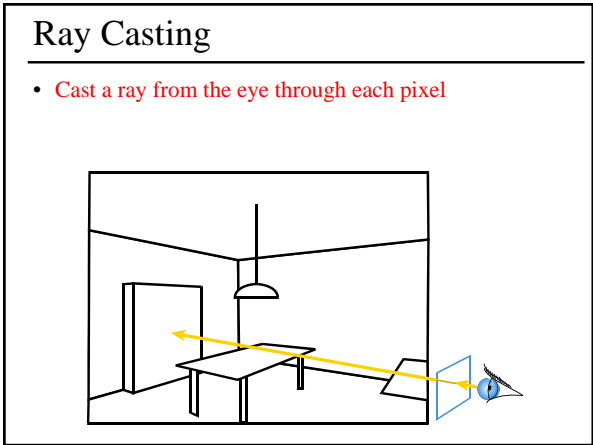


# Irradiance Caching & Photon Mapping

## Last Time?

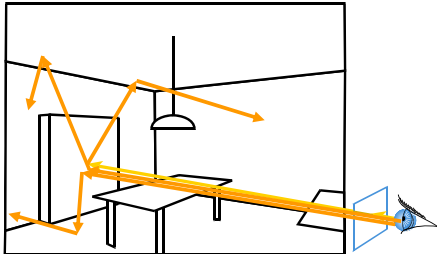
- What is a Pixel?
- Aliasing
- Fourier Analysis
- Sampling & Reconstruction
- Mip maps

- ## Today
- Ray Tracing Review
  - Irradiance Caching
  - Photon Mapping
  - Ray Grammar

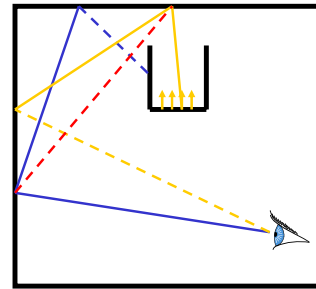


## Monte Carlo Path Tracing

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



## Challenging Indirect Lighting Scene



Backward  
path tracing

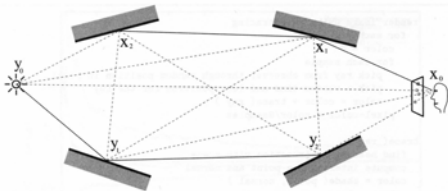
Forward  
path tracing

Bi-directional  
path tracing

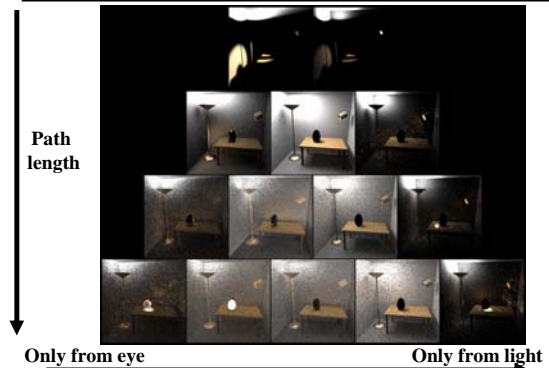
## Bi-directional Path Tracing

- Start from both eye and lights
- Create all compound paths
- Evaluate geometric/visibility term at connecting vertices:  $\cos \theta \cos \theta' / r^2$

[Veach & Guibas 94,  
Lafortune & Willems 93]



## Bi-directional Path Pyramid



## Questions?

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

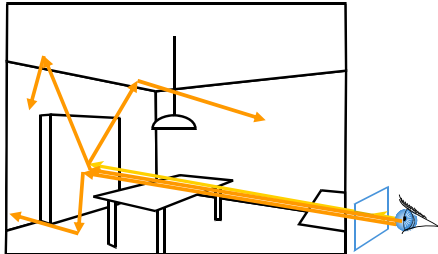


## Today

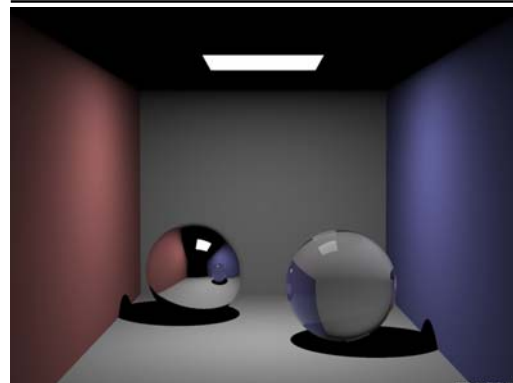
- Ray Tracing Review
- Irradiance Caching
- Photon Mapping
- Ray Grammar

### Path Tracing is costly

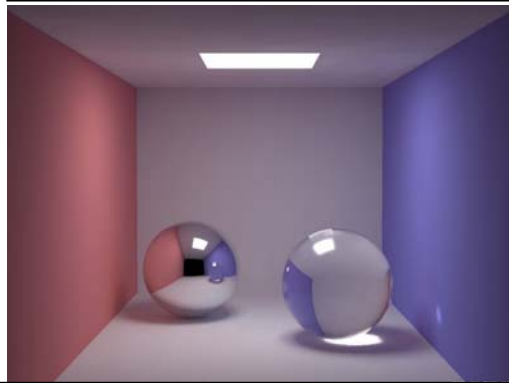
- Needs tons of rays per pixel



### Direct Illumination



### Global Illumination

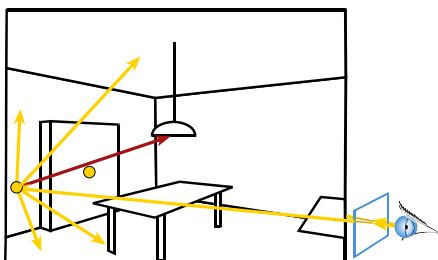


### Indirect Illumination: smooth



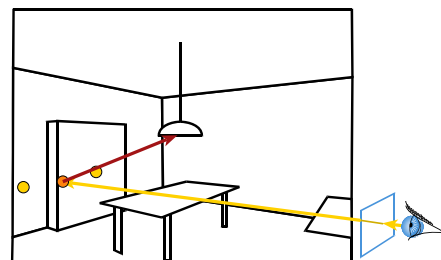
### Irradiance Cache

- The indirect illumination is smooth
- Store the indirect illumination

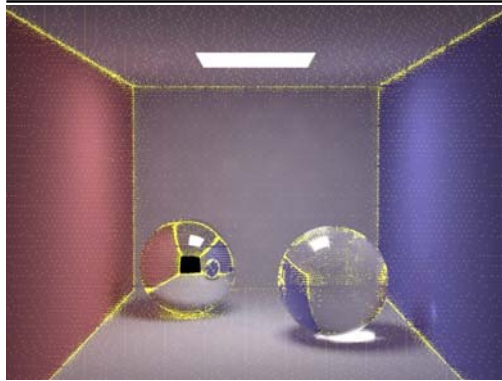


### Irradiance Cache

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



## Irradiance Cache



## Questions?



## Today

- Ray Tracing Review
- Irradiance Caching
- **Photon Mapping**
- Ray Grammar

## Reading for Today:

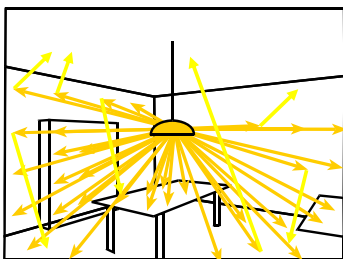
- *Global Illumination using Photon Maps*,  
Henrik Wann Jensen, Rendering Techniques 1996



- Post a comment or question on the LMS discussion by 10am on Tuesday 1/29

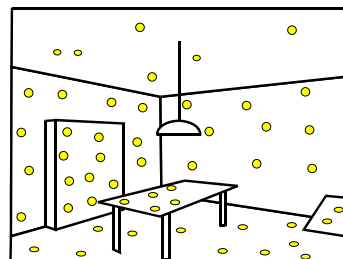
## Photon Mapping

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



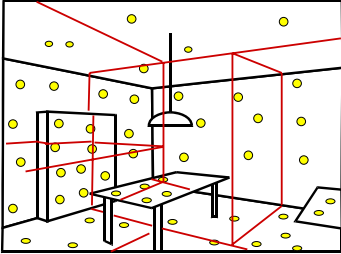
## Photon Mapping

- Store photons
  - position + light power + incoming direction



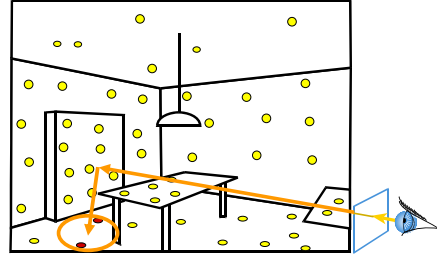
## Photon Map

- 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

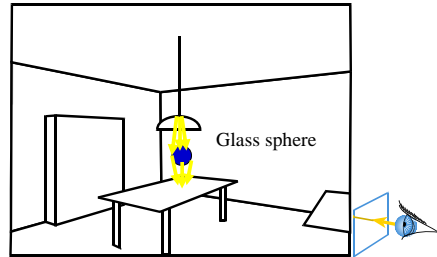


## Photon Map Results



## Photon Mapping - Caustics

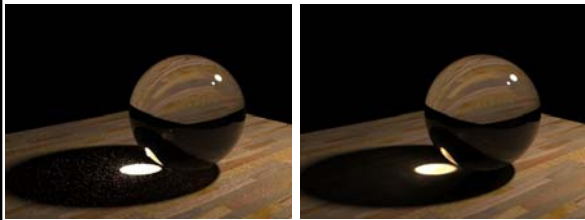
- Special photon map for specular reflection and refraction



## Comparison

Path Tracing  
1000 paths/pixel

Photon mapping



## Today

- Ray Tracing Review
- Irradiance Caching
- Photon Mapping
- **Ray Grammar**

## Ray Grammar

- Classify local interaction:

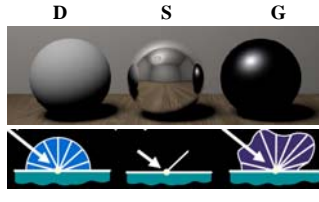
E = eye

L = light

S = perfect specular reflection or refraction

G = glossy scattering

D = diffuse scattering

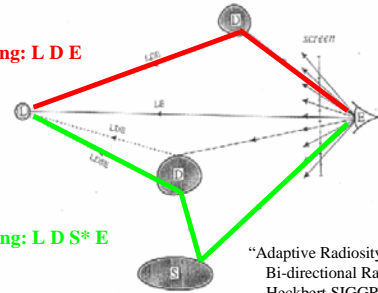


From Dutre et al.'s slides

## Classic Ray Casting/Tracing

Ray casting: **L D E**

Ray tracing: **L D S\* E**

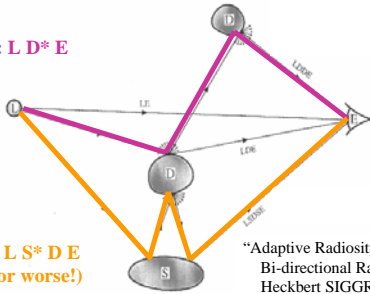


"Adaptive Radiosity Textures for Bi-directional Ray Tracing"  
Heckbert SIGGRAPH 1990

## Photon Tracing

Radiosity: **L D\* E**

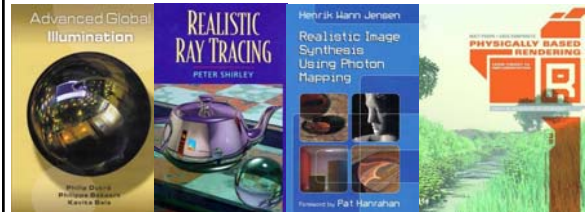
Caustics: **L S\* D E**  
(or worse!)



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

## Advanced Rendering References

- Eric Veach's PhD dissertation  
[http://graphics.stanford.edu/papers/veach\\_thesis/](http://graphics.stanford.edu/papers/veach_thesis/)



## Reading for Friday 4/4:

- "A Practical Model for Subsurface Light Transport", Jensen, Marschner, Levoy, & Hanrahan, SIGGRAPH 2001



- Post a comment or question on the LMS discussion by 10am on Tuesday 1/29