Irradiance Caching & Photon Mapping

Raytracing & Epsilon

Image from Zachary Lynn

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

Monte-Carlo Ray Tracing vs. Path Tracing

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

Path Tracing is costly

Ray Tracing
- 2 bounces
- 5 glossy samples
- 5 shadow samples

How many rays cast per pixel?
1 main ray + 5 shadow rays + 5 glossy rays + 5x5 shadow rays + 5x5 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

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

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.


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?

Today

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Ray Grammar

- Classify local interaction:
  - \( E = \text{eye} \)
  - \( L = \text{light} \)
  - \( S = \text{perfect specular reflection or refraction} \)
  - \( G = \text{glossy scattering} \)
  - \( D = \text{diffuse scattering} \)

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?
Readings for Tuesday:

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