Irradiance Caching & Photon Mapping

Last Time?
- Rendering Equation
- Monte-Carlo Integration
- Monte Carlo Rendering
- Forward Ray Tracing
- Stratified Sampling

Today
- Irradiance Caching
- Photon Mapping
- Acceleration Data Structures
- 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

Questions?

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

Today

• Irradiance Caching
• Photon Mapping
• Acceleration Data Structures
• Ray Grammar
Readings for Today *(pick one)*


**Photon Mapping**

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

**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

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 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?

Comparison

- Path Tracing
  - 1000 paths/pixel
- Photon mapping

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Regular Grid

- Primitives that overlap multiple cells?
- Insert into multiple cells (use pointers)

For Each Cell Along a Ray

- Does the cell contain an intersection?
- Yes: return closest intersection
- No: continue to march along the ray
Regular Grid Discussion

• Advantages?
  – easy to construct
  – easy to traverse

• Disadvantages?
  – may be only sparsely filled
  – geometry may still be clumped

Adaptive Grids

• Subdivide until each cell contains no more than \( n \) elements, or maximum depth \( d \) is reached

Variations of Adaptive Grids

• When to split? When a cell contains “lots” of geometry, but has not yet reached the max tree depth
• Where to split?
  • Quadtree/Octree: split \textit{every} dimension in half, always axis aligned
  • kd-tree: choose \textit{one} dimension (often the largest dimension) and split it axis aligned (but not necessarily at the midpoint)
  • Binary Space Partition (BSP): choose a \textit{arbitrary} cut plane
• Which one is best? It depends…. Often they are all equally good!

Primitives in an Adaptive Grid

• Can live at intermediate levels, or be pushed to lowest level of grid

Adaptive Grid Discussion

• Advantages?
  – grid complexity matches geometric density

• Disadvantages?
  – more expensive to traverse (binary tree, lots of pointers)

Bounding Volume Hierarchy

• Find bounding box of objects
• Split objects into two groups
• Recurse
### Bounding Volume Hierarchy
- Find bounding box of objects
- Split objects into two groups
- Recurse

### Where to split objects?
- At midpoint  
  OR
- Sort, and put half of the objects on each side  
  OR
- Use modeling hierarchy

### Intersection with BVH
- Check sub-volume with closer intersection first

### Bounding Volume Hierarchy Discussion
- Advantages
  - easy to construct
  - easy to traverse
  - binary
- Disadvantages
  - may be difficult to choose a good split for a node
  - poor split may result in minimal spatial pruning

### Oriented Bounding Box (OBB)
- Generalization of the (axis-aligned) BVH

### Today
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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?

Readings for Friday 3/25 (pick one)

"Two Methods for the Display of High Contrast Images", Tumblin, Hodgins, & Guenter, ACM Transactions on Graphics 1999

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