VU Rendering SS 2014
186.101

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Unit 06 – Spatial Acceleration Structures
Scope

Rendering pipeline

3D Scene → Light Simulation → 2D Raster Image → 2D Display
Scope

Rendering pipeline

3D Scene ➔ Light Simulation ➔ 2D Raster Image ➔ 2D Display

Efficiency of ray shooting
Generally, Monte-Carlo methods use ray shooting to sample the integrand of the rendering equation.

Computing the closest intersection with the scene is equivalent to computing the local visibility.

This is very expensive for a large amount of scene objects.
Solution

- **Naive approach:**
  Intersect ray with all objects to determine the closest intersection ($O(n)$ for $n$ objects)

- **Better approach:**
  Reorganize the objects into a spatial hierarchy to skip large parts of the scene ($o(n)$ for $n$ objects)
Spatial hierarchies

- **k-d tree**
  Subdivide space and store the objects in overlapping nodes

- **Bounding Volume Hierarchy (BVH)**
  Group objects recursively into a tree structure
Spatial hierarchies

- **k-d tree**
  + Faster traversal on the CPU
  - Larger amount of nodes (and duplicate references)

- **Bounding Volume Hierarchy (BVH)**
  + Faster traversal on the GPU
  + Easier to update (for dynamic scenes)
  + Every object only in one tree leaf
  - Spatial overlap of nodes
Object grouping can be done in many ways – optimality is usually scene dependent but heuristics exist.

**Surface area heuristic (SAH)**

\[
SAH = C_{inner} \sum_I \frac{A_n}{A_{root}} + C_{leaf} \sum_L T_n \frac{A_n}{A_{root}}
\]

- \(I \ldots\) inner nodes,
- \(L \ldots\) leaf nodes,
- \(A_n \ldots\) surface area node \(n\),
- \(A_{root} \ldots\) surface area of its root
Constructing the tree with the minimal SAH cost is expensive → usually approximations are used.

This leads to a quality/speed trade-off:

Comparison of different BVH construction methods. From [1].
Literature

Textbooks
- PBRT chapter 4
- C. Ericson, *Real-Time Collision Detection*, 2005

Papers
- Z. Wu et al., SAH KD-Tree construction on GPU, HPG 2011
- T. Karras, *Maximizing Parallelism in the Construction of BVHs, Octrees and k-d Trees*, HPG 2012
- M. Doyle et al., *A Hardware Unit for Fast SAH-optimised BVH Construction*, Siggraph 2013
Questions?