Accelerated ray tracing

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CSE 557
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Reading

Required:

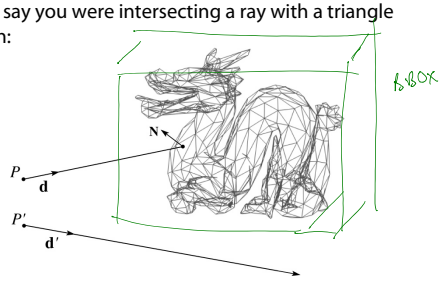
- Marschner and Shirley, Sections 12.3 (online handout)

Further reading:

- A. Glassner. An Introduction to Ray Tracing. Academic Press, 1989.

Faster ray-polyhedron intersection

Let's say you were intersecting a ray with a triangle mesh:



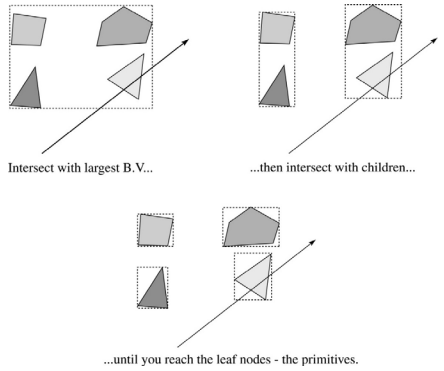
Straightforward method

- intersect the ray with each triangle
- return the intersection with the smallest t-value.

Q: How might you speed this up?

Bounding Volume Hierarchies (BVHs)

We can generalize the idea of bounding volume acceleration with **bounding volume hierarchies (BVHs)**.



Key: build balanced trees with *tight bounding volumes*.

Bounding Volume Hierarchies (BVHs)

How do you build a tree?

1. Bottom up: start with individual primitives and gradually cluster them into a tree.
2. Top down: start with one bounding volume around all the primitives and recursively split into two.

Recommendation: go with top down – easier to do, works well.

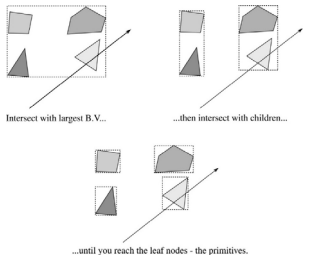
For top down, how to decide where to split?

Choose a splitting axis and then follow one of these heuristics:

- Find the median of the bounding box centers along the axis and split at that location
- Find the midpoint of the parent bounding box and split there
- Find the split that minimizes the Surface Area Heuristic (SAH) cost:

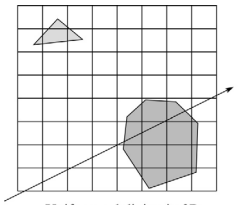
$$N_{left}\ \text{SurfaceArea}(V_{left}) + N_{right}\ \text{SurfaceArea}(V_{right})$$

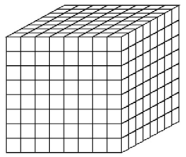
Then move on to the next axis and repeat.



Uniform spatial subdivision

Another approach is **uniform spatial subdivision**.


Uniform subdivion in 2D


Uniform subdivion in 3D

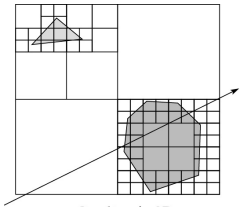
Idea:

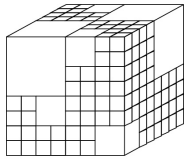
- Partition space into cells (voxels)
- Associate each primitive with the cells it overlaps
- Trace ray through voxel array using fast incremental arithmetic to step from cell to cell

Q: Given a 10^6 triangle football stadium with a 10^6 triangle teapot on one of the seats, would a single uniform spatial subdivision be a good idea?

Non-uniform spatial subdivision: octrees

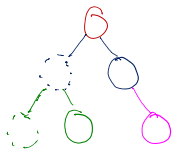
Another approach is **non-uniform spatial subdivision**.
One version of this is octrees:

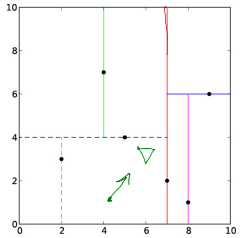

Quadtree in 2D


Octree in 3D

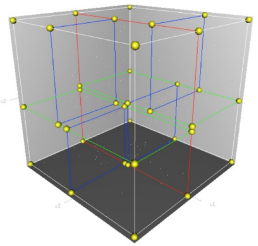
Non-uniform spatial subdivision: *k*-d trees

Another non-uniform subdivision is *k*-d (*k*–dimensional) trees:





k-d tree (*d* = 2)


k-d tree (*d* = 3)

If the planes can be non-axis aligned, then you get BSP (binary space partitioning) trees.

Various combinations of these ray intersections techniques are also possible.

[Image credits: Wikipedia.]