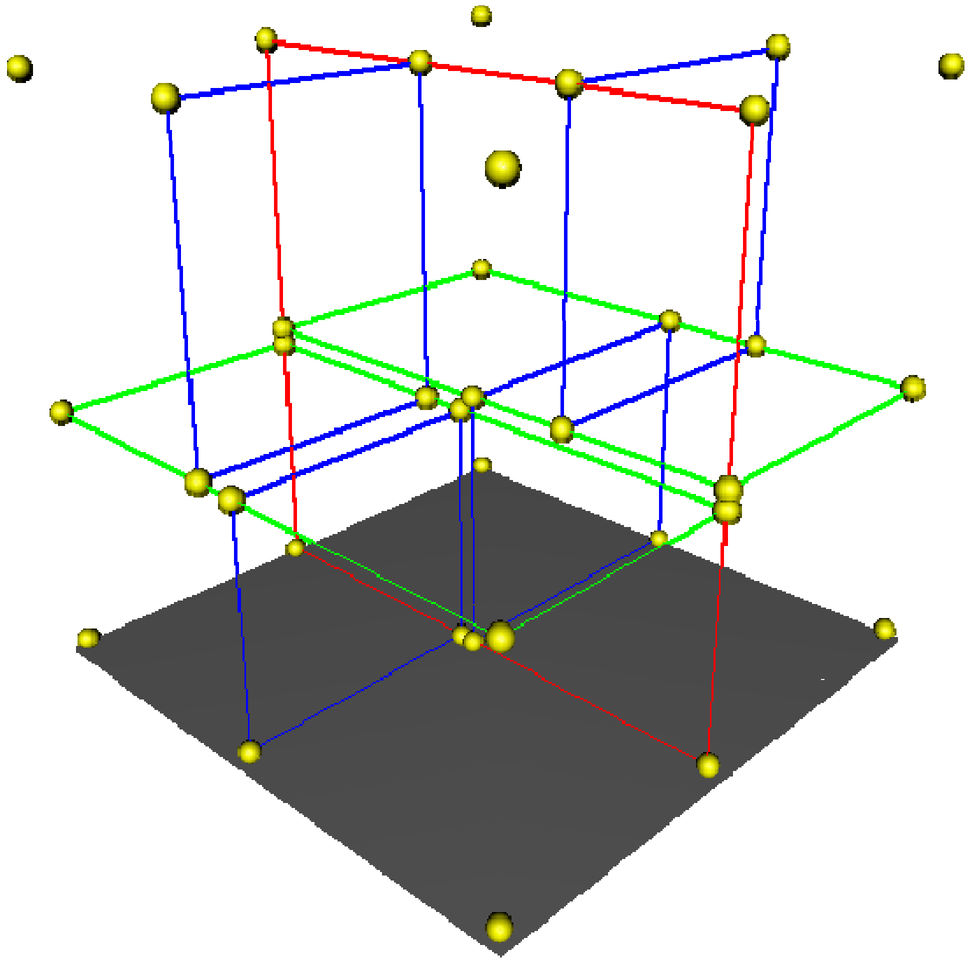
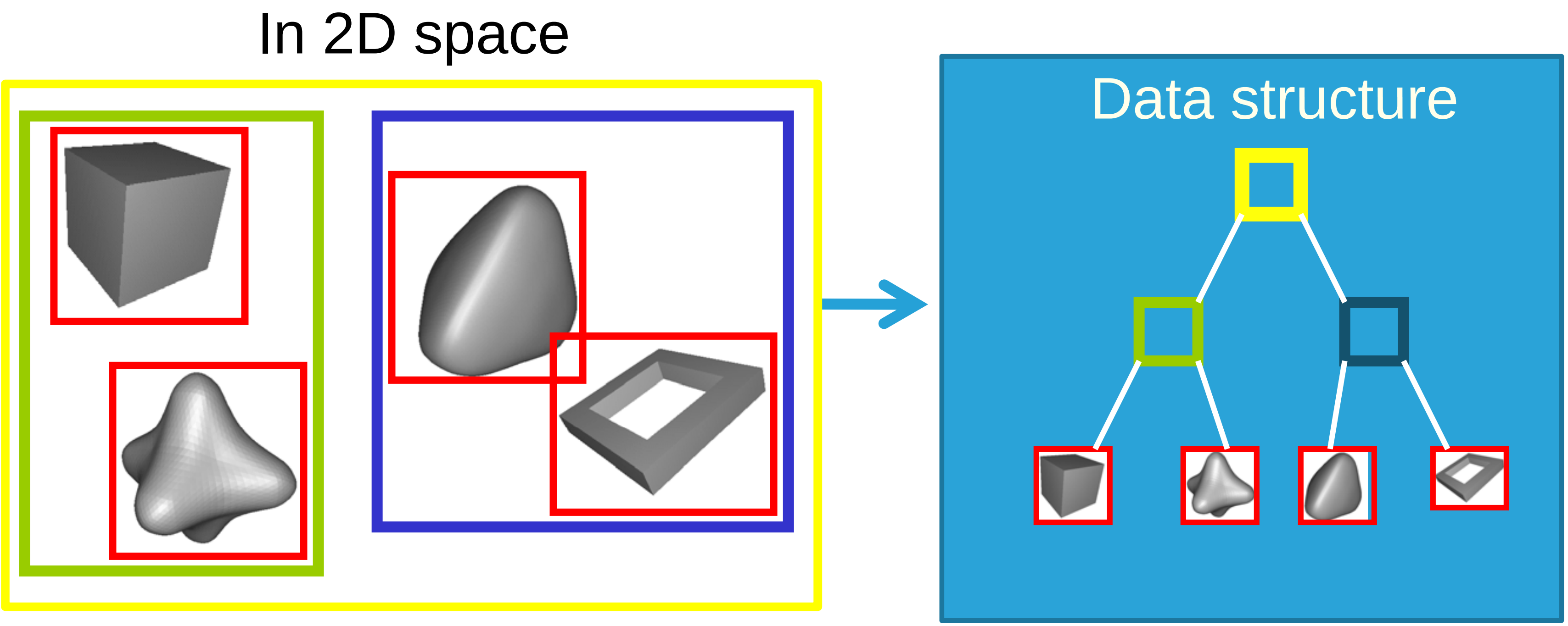
Spatial Data Structures



What is it?

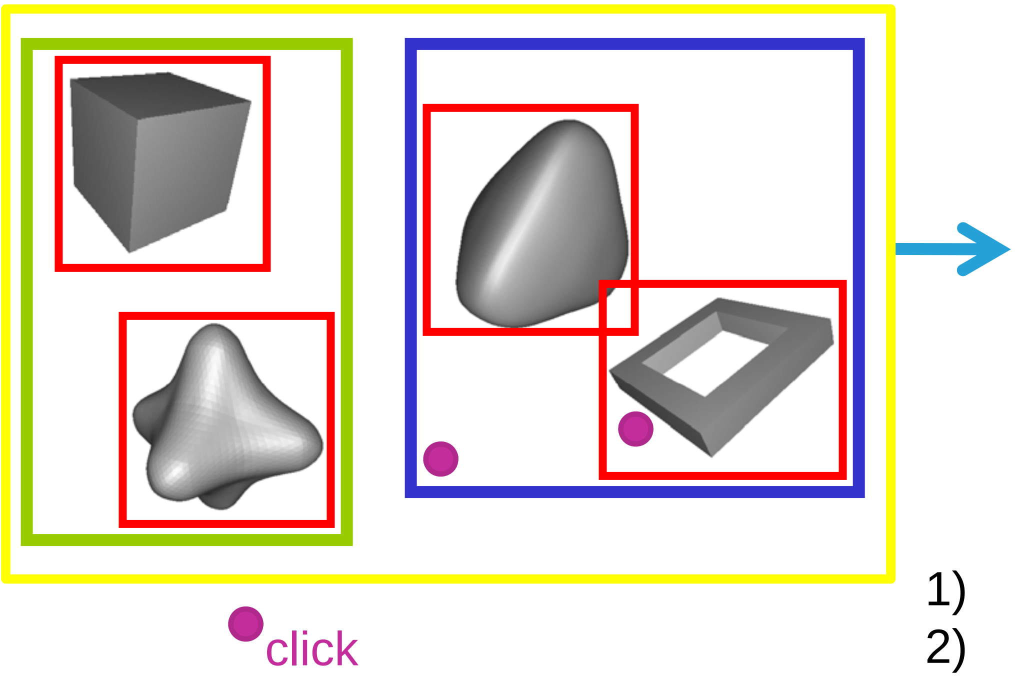
- Data structures that organize geometry in 2D,3D or higher dimensions
- Used for every search related problem
- Very important mathematical tool in CG:
  - Ray tracing/Photon mapping
  - Collision/Intersection
  - Culling
  - Data compression
  - Level of detail
- Goal is faster processing and searching

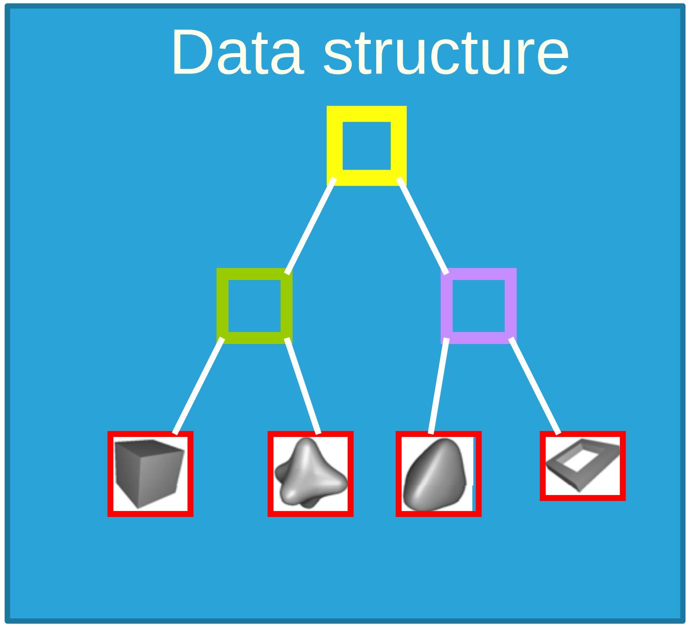
- Organize geometry in a hierarchy



Example

- Assume we click on screen, and want to find which object we clicked on



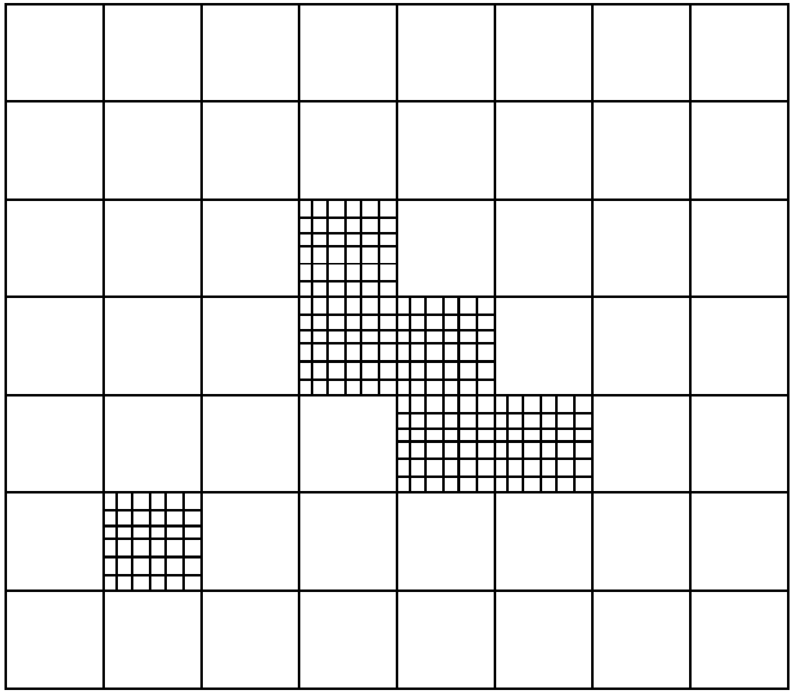


1) Test the root first
2) Descend recursively as needed
3) Terminate traversal when possible

In general: get O(log n) instead of O(n)

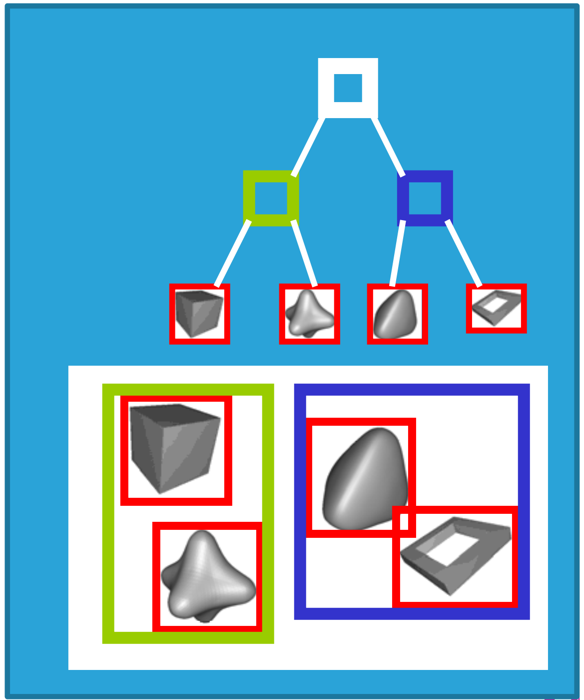
Grid

- Most simple data structure
- Regular subdivision
  - Directly addressable cells
  - Simple neighborhood finding in O(1)
- Problem:
  - Too few/many cells
  - ➢ Hierarchical grid
- Good for uniformly distributed problems



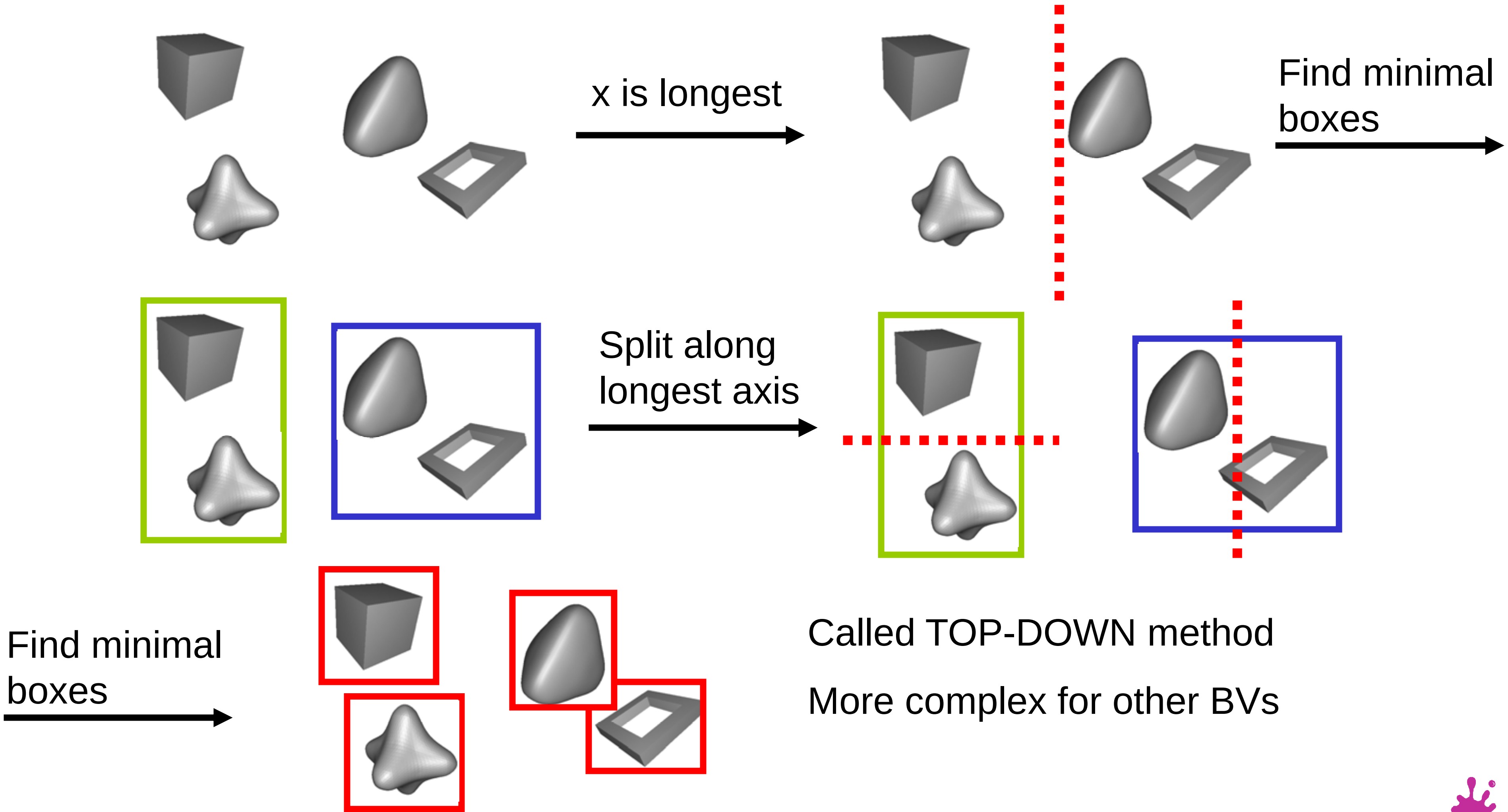
Bounding Volume Hierarchy (BVH)

- Most used structure in real-time graphics
- Most common bounding volumes (BVs):
  - Sphere
  - Boxes (AABB)
- BVs give information about maximum extend of an object
  - Encloses complete object
- Data structure is a k-ary tree
  - Leaves hold geometry
  - Internal nodes have at most k children
  - Internal nodes hold BVs that enclose all geometry in its subtree



How to create a BVH

- Find minimal box, then split along longest axis



Called TOP-DOWN method

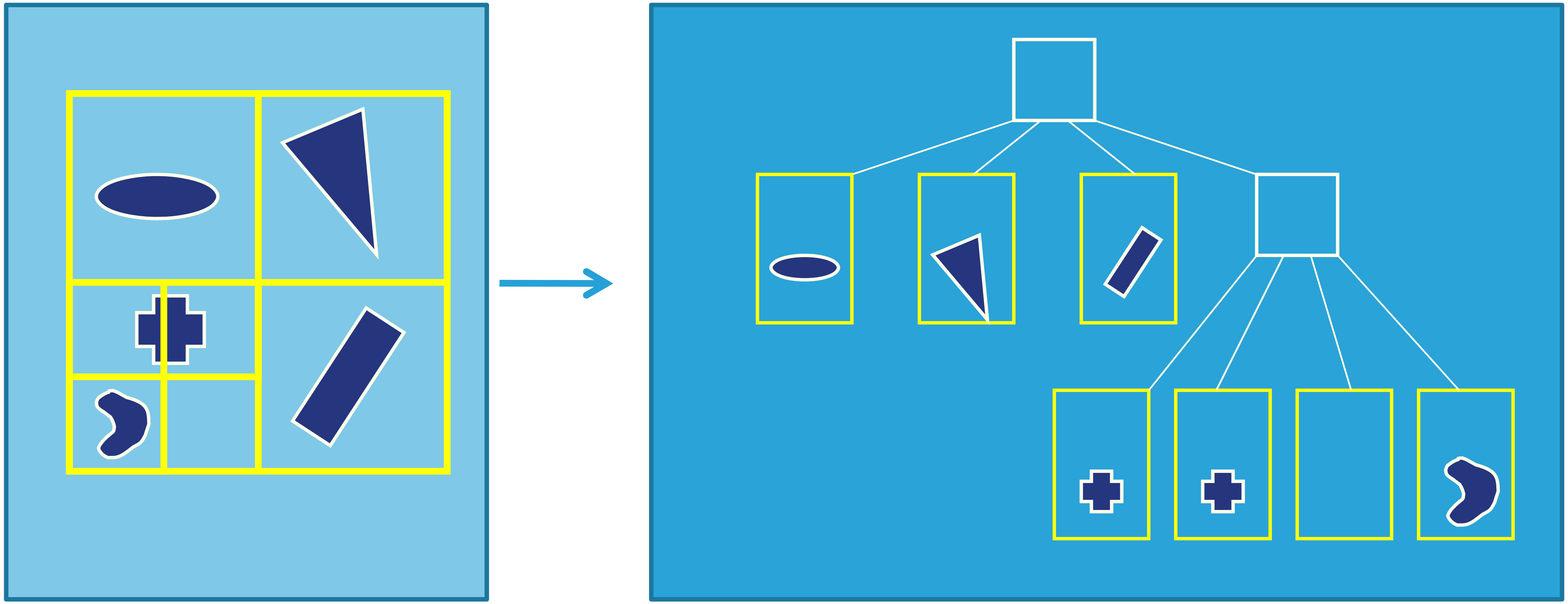
More complex for other BVs

Stopping Criteria for BVH

- We need to stop recursion when:
  - BV is empty
  - Only one primitive (e.g. Triangle, object) is inside Bounding Volume
  - $<n$ primitives is inside BV
  - Recursion level l has been reached

- Similar critera for other BSP trees

Octree (3D) Quadtree (2D)

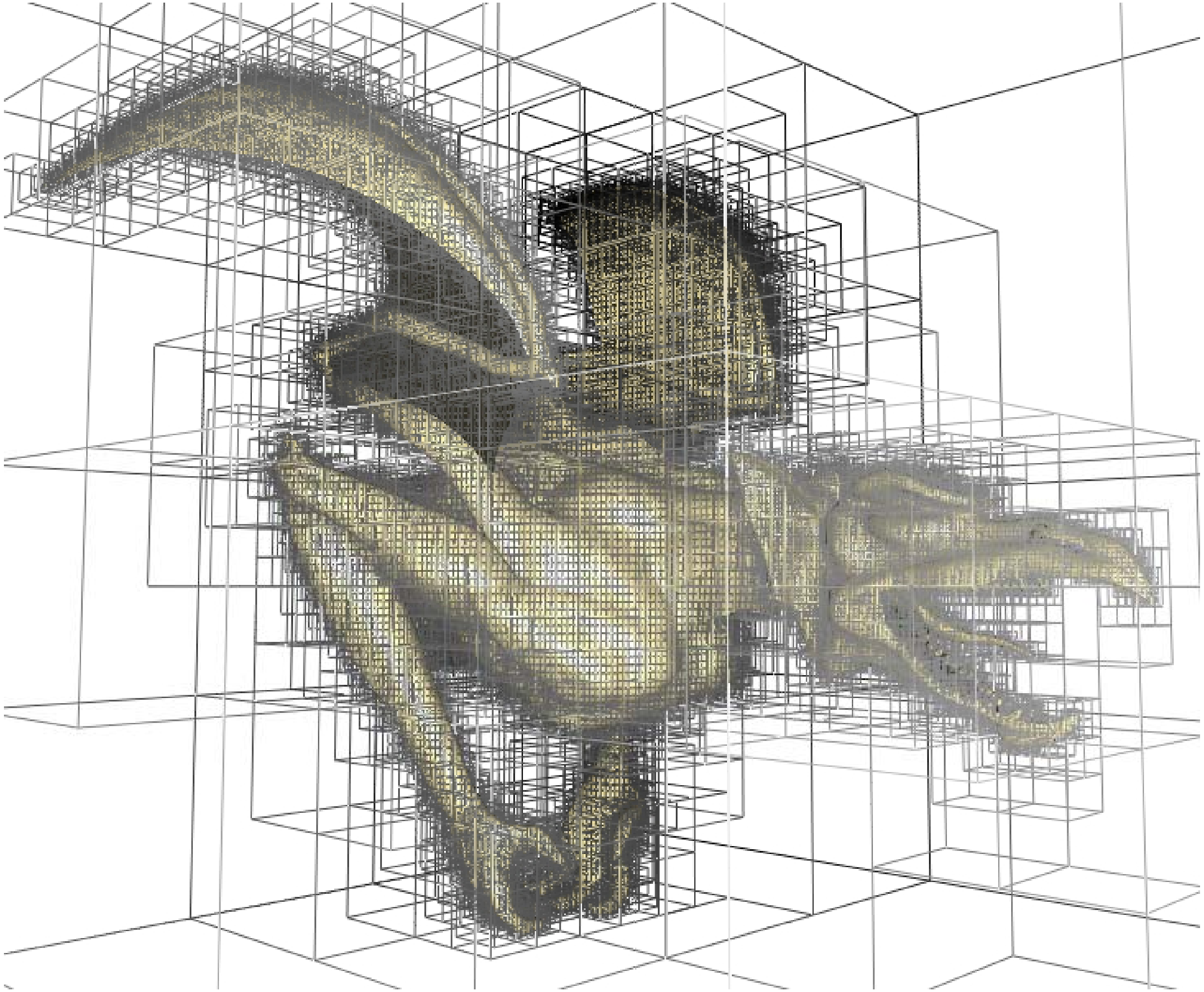


- Split at half the length axis aligned
  - Always 4 children
- In 3D each square becomes a box with 8 children

Octree (3D) Quadtree (2D)

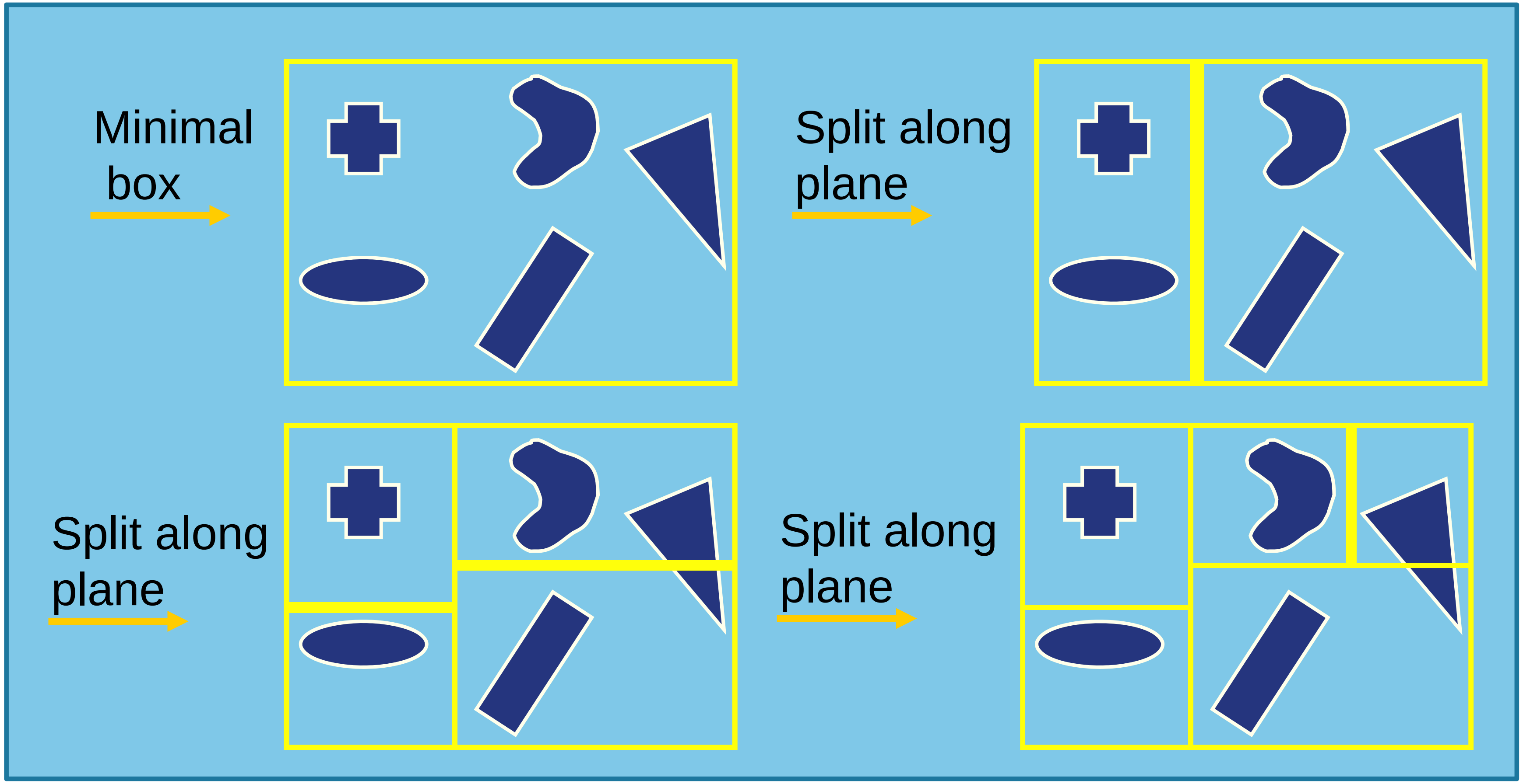
- Expensive to rebuild (all BSPs are)
- Easy to implement
  - No geometry analysis needed
  - Just test if something is in leaf
- Used to speed up
  - Culling, Raytracing,Picking
- **Loose octree**:
  - Each octant child of the octree actually overlaps it's siblings by a factor of 0.5
  - Guarantees that any thing that is half the size of the parent will fit completely into a child

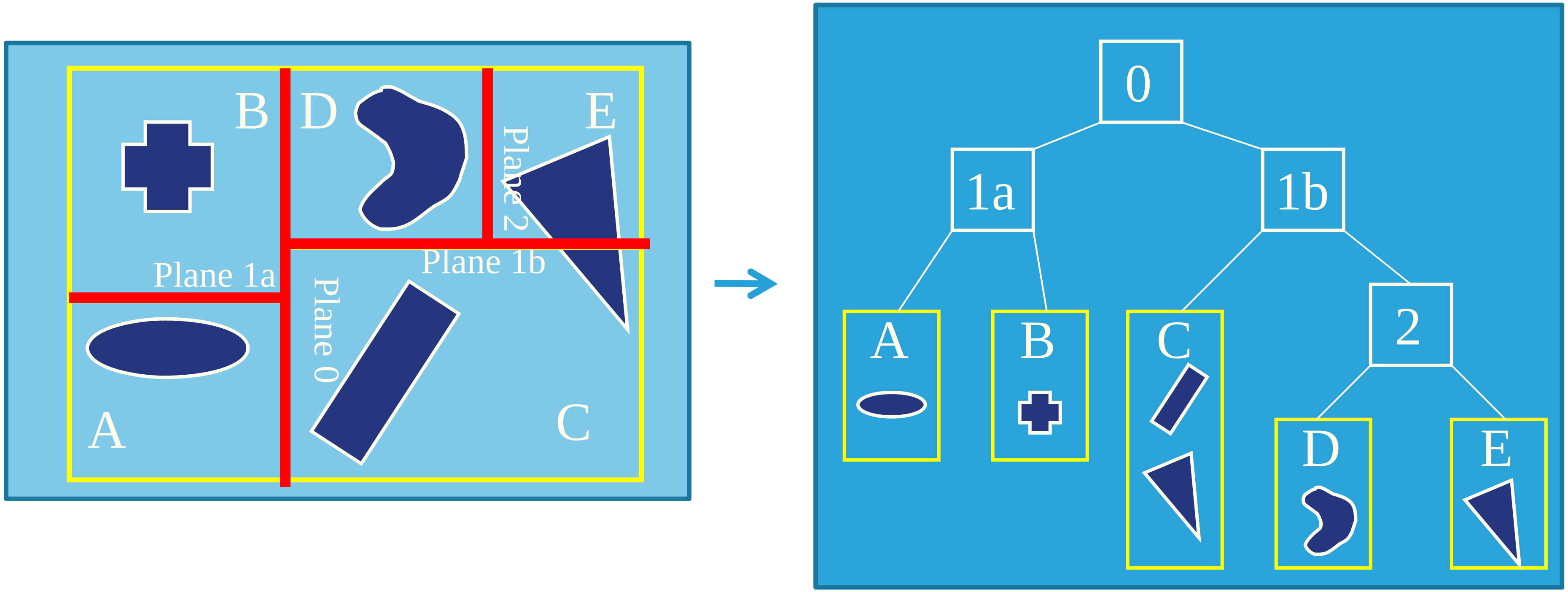
Octree (3D) Quadtree (2D)



Kd-tree

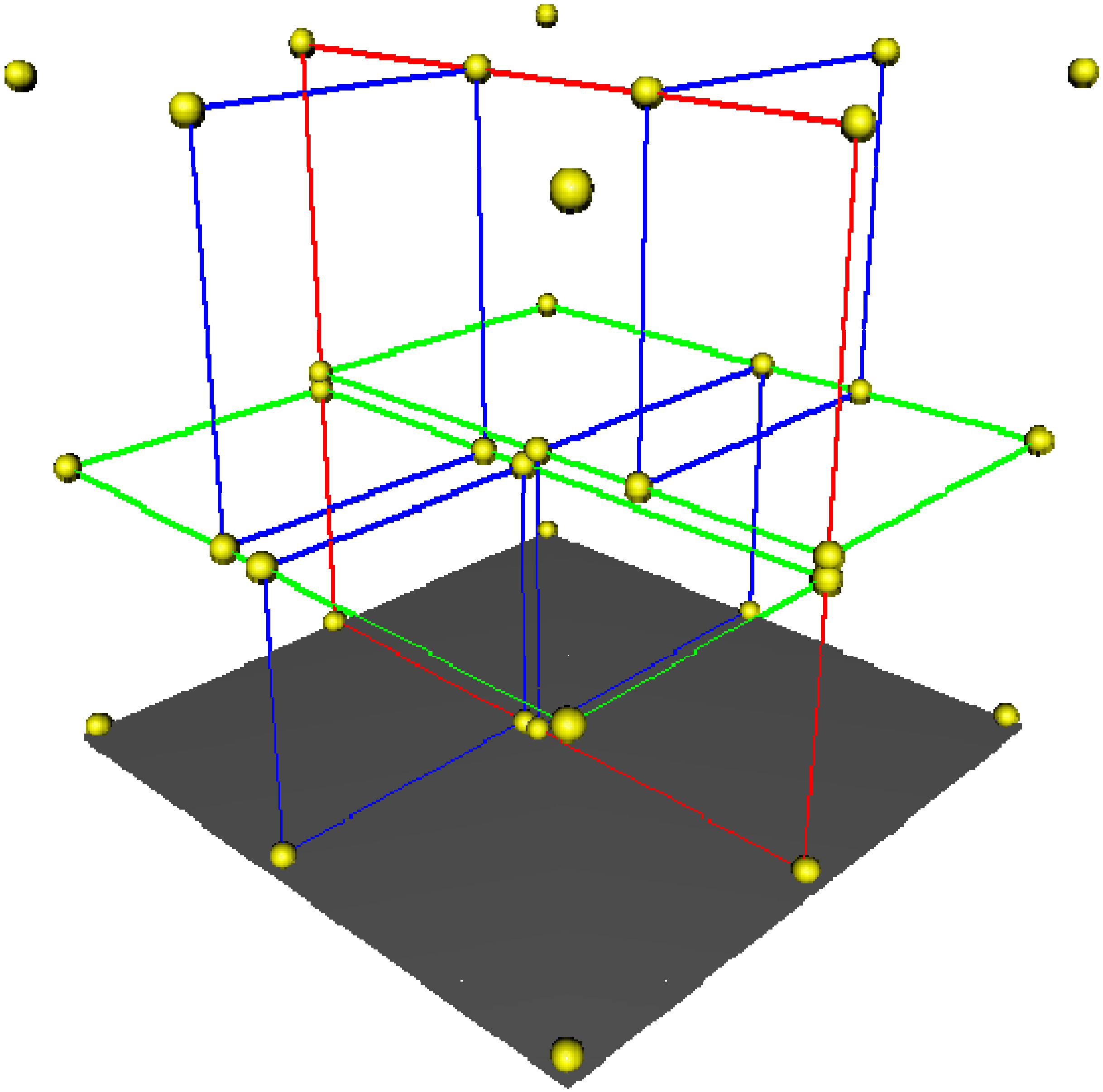
- Split along axis alinged planes/lines which results in minimum search time





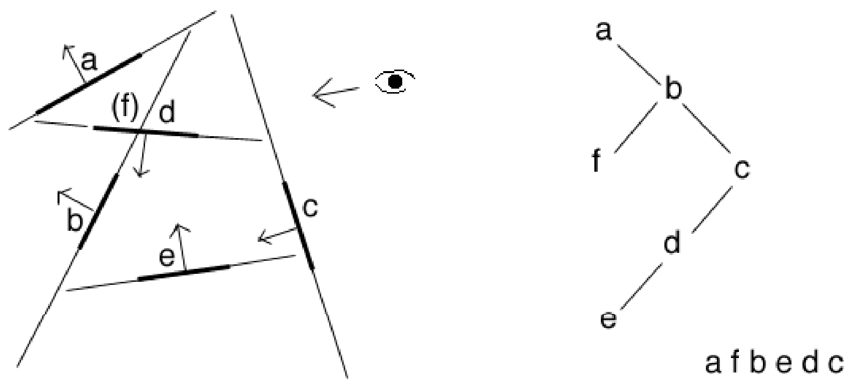
- Each internal node holds a divider plane
- Leafs hold geometry
- Problem: splitting criteria is complicated
  - Surface area heuristic (SAH) is best

Kd-tree



General BSP-Tree

- Same as kd-tree but without axis aligned splitting
  - Splitting criteria is even harder for general generation
  - Intersection calculations more expensive than kd-tree
- Usually used on a per triangle/quad splitting basis
  - Good for per triangle or quad collision detection



Scenegraphs

- BVH is used most often in real-time graphics
  - Simple to understand
  - Easy to implement
- But contains only geometric objects
- Scenegraph is and extended BVH with:
  - Lights
  - Transforms
  - Textures
  - …