Implicit Surfaces, Collision Detection, & Volumetric Data Structures

Today

- Worksheet on Subdivision Surfaces
- Motivation: Collision Detection is Expensive
- Conservative Bounding Region
- Spatial Acceleration Data Structures
- Readings for Today
- Papers for Friday

Pop Worksheet!

Sketch the polygonal mesh after performing 2 iterations of
su).
If
sp

Traveler's Insurance, *Snowball*

Weta Digital, 2007

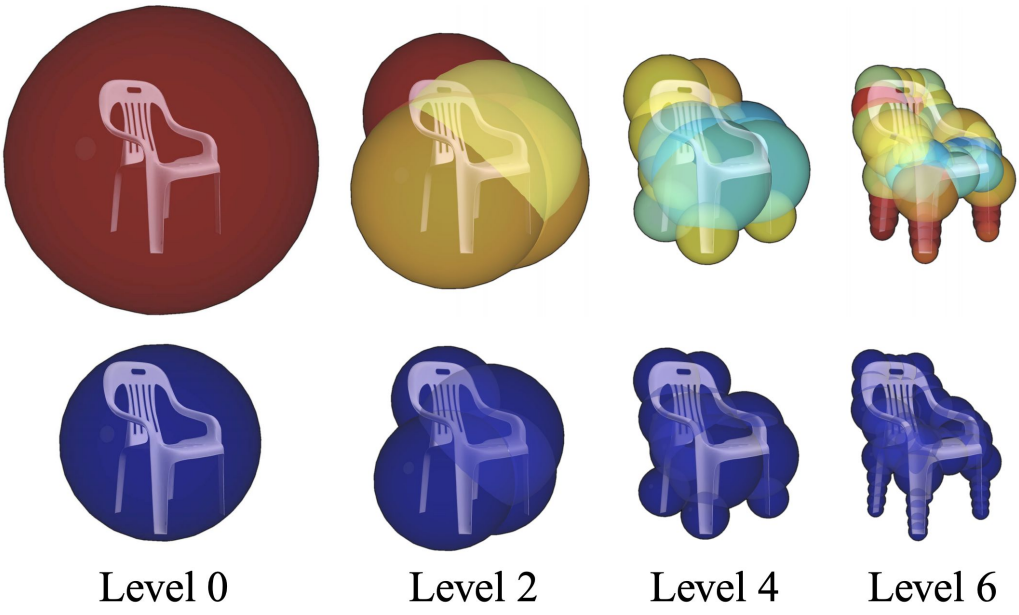
Traveler's Insurance, *Snowball*

Weta Digital, 2007

Katamari

BANDAI NAMCO Entertainment Inc., 2004-2018

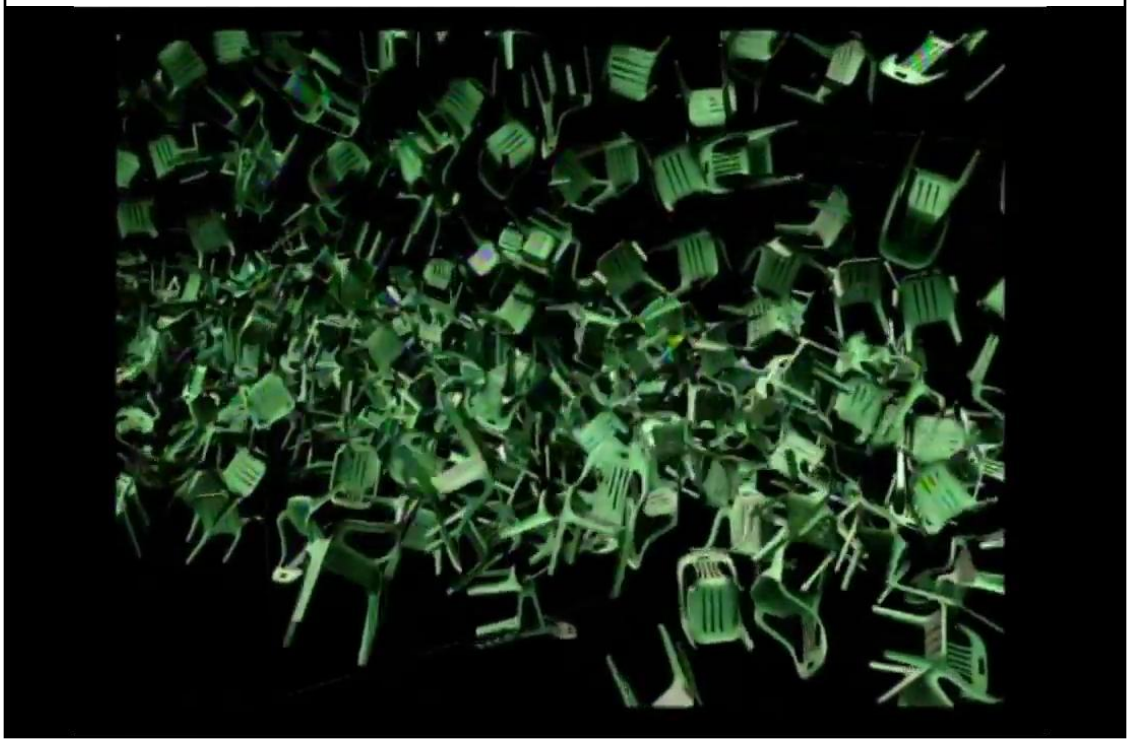
Output-Sensitive Collision Processing for Reduced-Coordinate Deformable Models



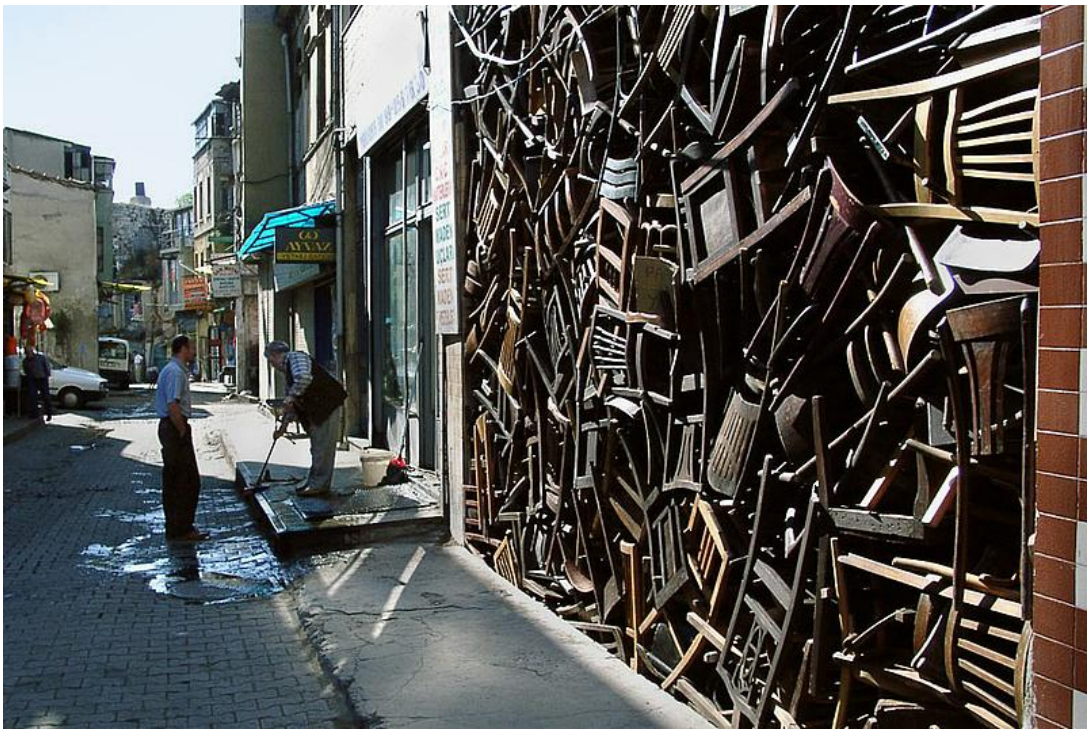
Level 0 Level 2 Level 4 Level 6

James, Pai, and Twigg, SIGGRAPH 2004

Output-Sensitive Collision Processing for Reduced-Coordinate Deformable Models

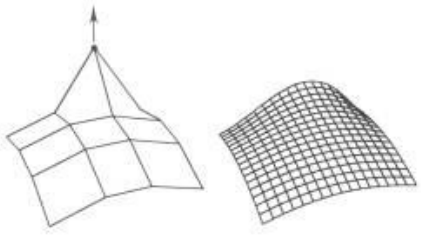


Untitled, 1550 chairs stacked, Doris Salcedo, 2003

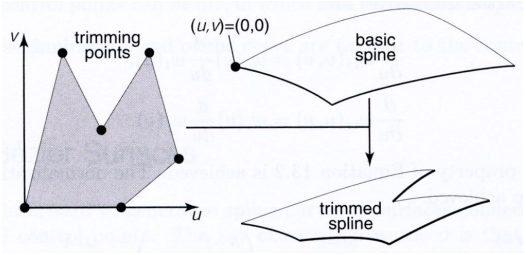


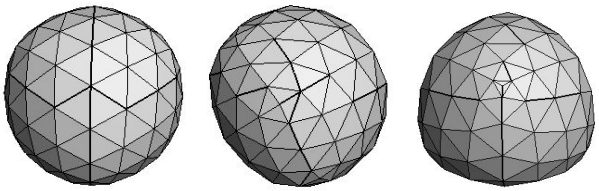
Untitled, 1550 chairs stacked, Doris Salcedo, 2003

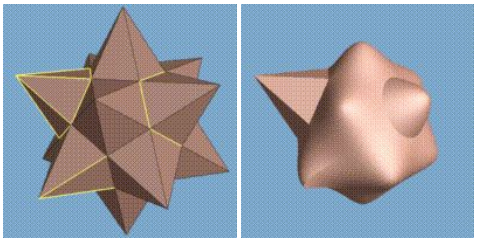
Last Time?



- Spline Surfaces
  - complex topology is challenging, requires trimming curves
- Subdivision Zoo
  - Doo-Sabin
  - Loop
  - Catmull-Clark
- Subdivision w/ Creases







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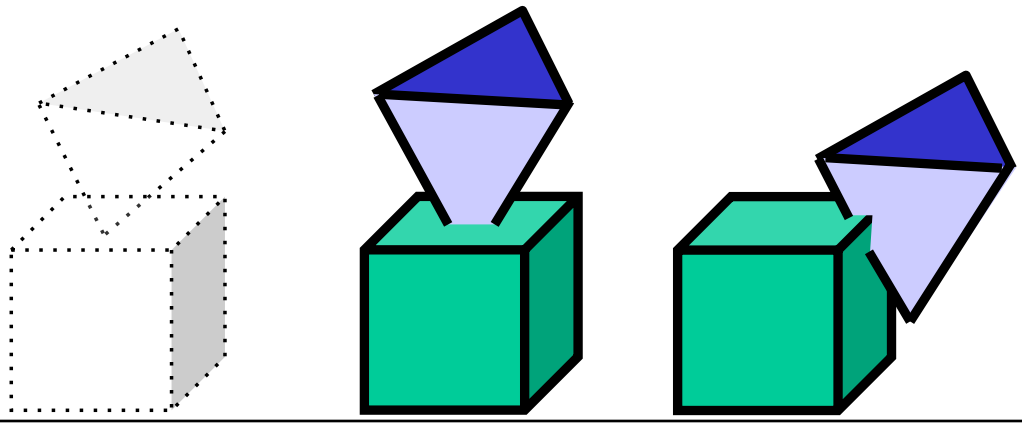
Collision Detection for Solids

- How to detect collision between 2 polyhedra?
- Need an inside/outside test
- Test if a vertex is inside the other polyhedron
- But treat also edge-edge intersection

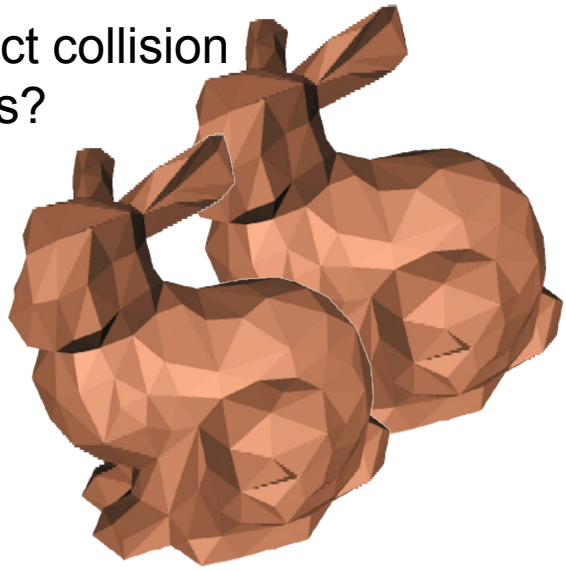


Cost of Detection?

- Test each edge with each face?

  $O(N^2)$

- How would you detect collision between two bunnies?
  - $O(N^2)$ is too expensive!
  - Let's use a spatial data structure



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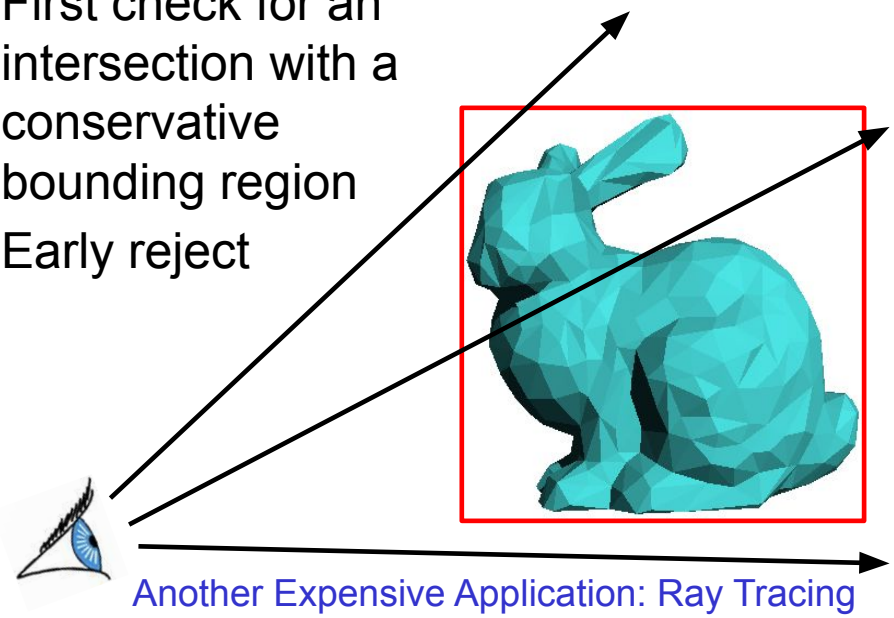
Conservative Bounding Region

- First check for an intersection with a conservative bounding region
- Early reject

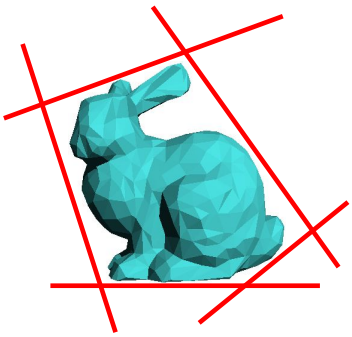


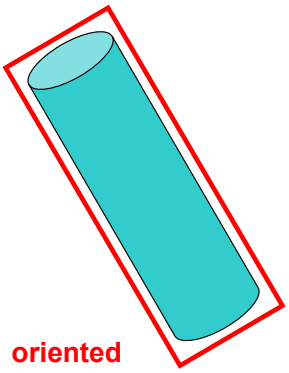
Another Expensive Application: Ray Tracing
Intersect object & ray… *more later this semester!!*

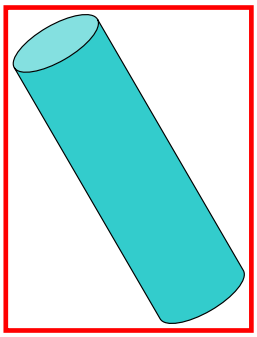
Conservative Bounding Regions

- tight → avoid false positives
- fast to intersect

- easy/fast/perfect construction (*less important*)

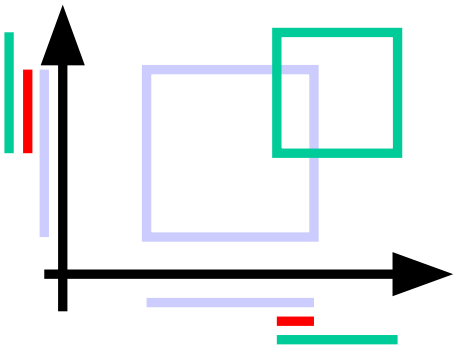


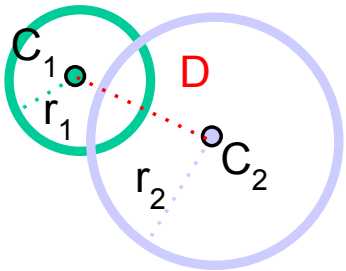




Overlap Test

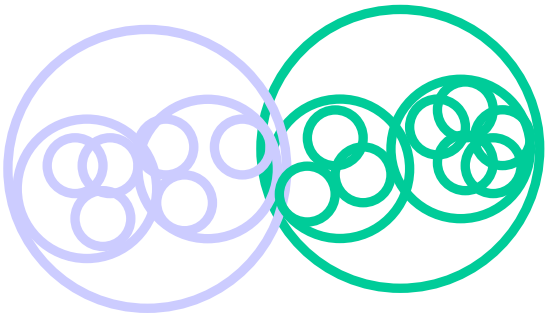
- Overlap between two axis-aligned boxes?
  - Check if the intervals along the 3 dimensions overlap
- Overlap test between two spheres?
  - $D(\text{center}_1, \text{center}_2) < r_1 + r_2$





General Collision Detection

- Put a hierarchy around your objects
- Use the fast overlap test recursively
- Handle exact case at the leaves (when necessary)
- More difficult for self-collision (e.g. cloth)
  - Because there is more overlap



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- Conservative Bounding Region
- Spatial Acceleration Data Structures
  - Fixed/Uniform/Regular Grid
  - Nested Grid
  - Octree
  - Binary Space Partition
  - K-d tree
  - Bounding Volume Hierarchy
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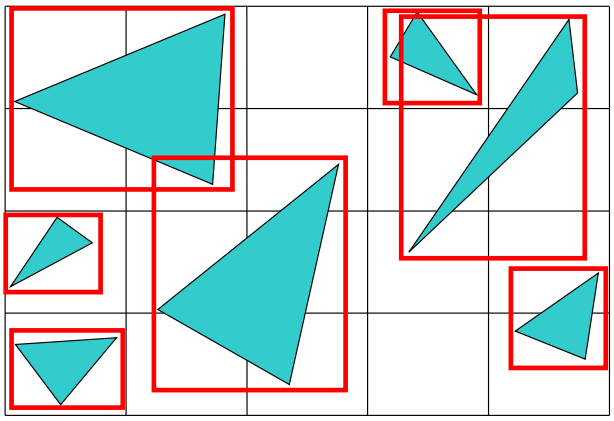
Fixed/Uniform/Regular Grid

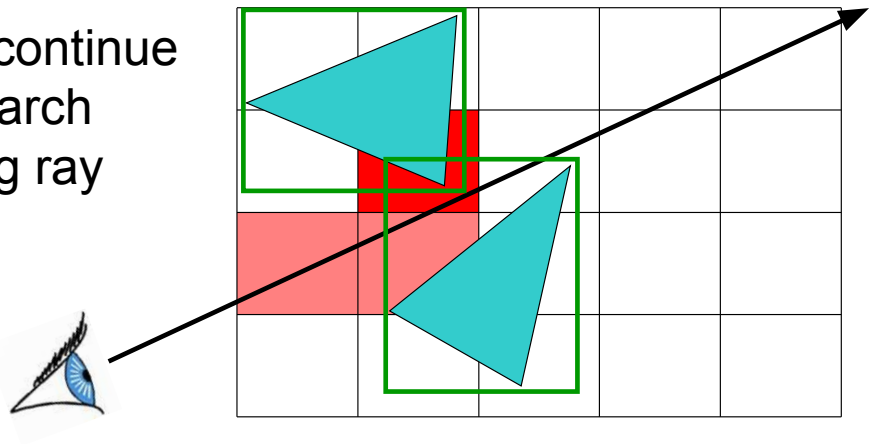
- Separate geometry into regions
- Reduces pairwise comparisons
- Primitives that overlap multiple cells?

  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 ray



Fixed/Uniform Grid Discussion

- Advantages?
  - easy to construct
  - easy to traverse
- Disadvantages?
  - may be only sparsely filled
  - geometry may still be clumped

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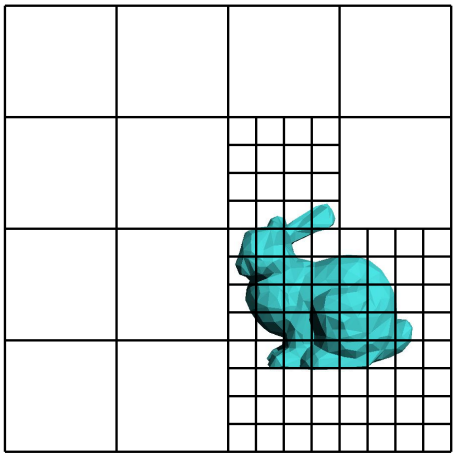
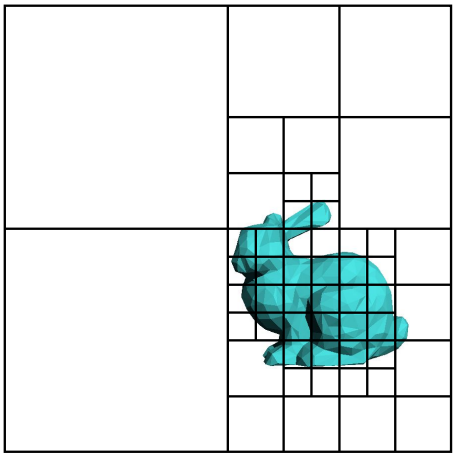
Adaptive Grids

- Subdivide until each cell contains no more than *n* elements, or maximum depth *d* is reached



Nested Grids



Octree/(Quadtree)

Adaptive Grids

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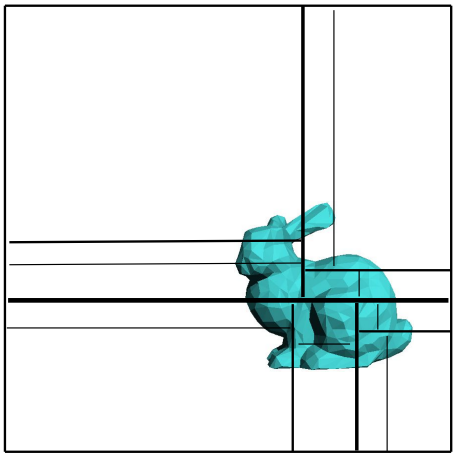
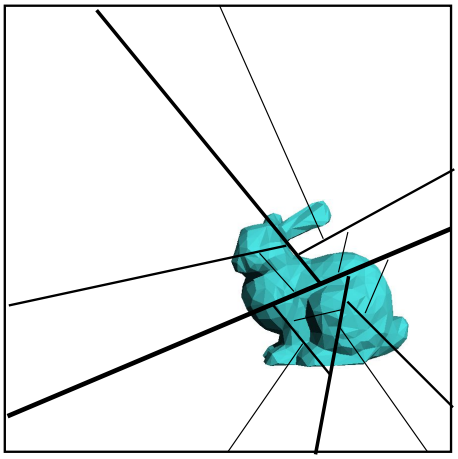


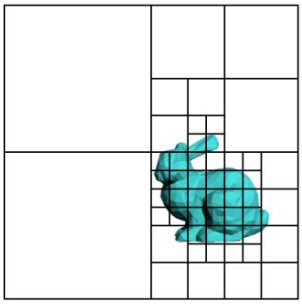
K-D Tree



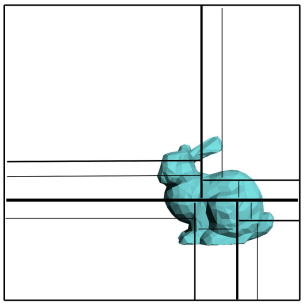
Binary Space Partition (BSP)

Variations of Adaptive Grids

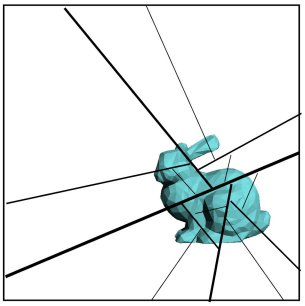
- **When to split?** When a cell contains "lots" of geometry, but has not yet reached the max tree depth
- **Where to split?**
  - Quadtree/Octree: split *every* dimension in half, always axis aligned
  - kd-tree: choose *one* dimension (often the largest dimension) and split it axis aligned (but not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



Quadtree/Octree



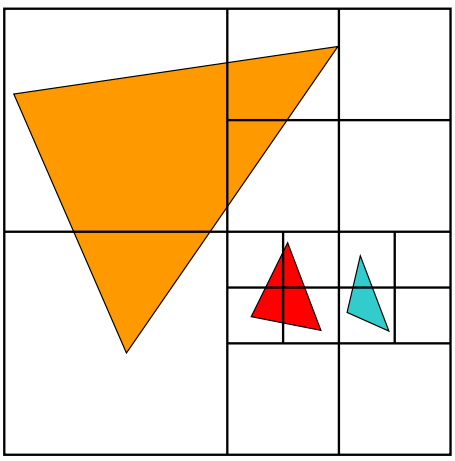
kd tree



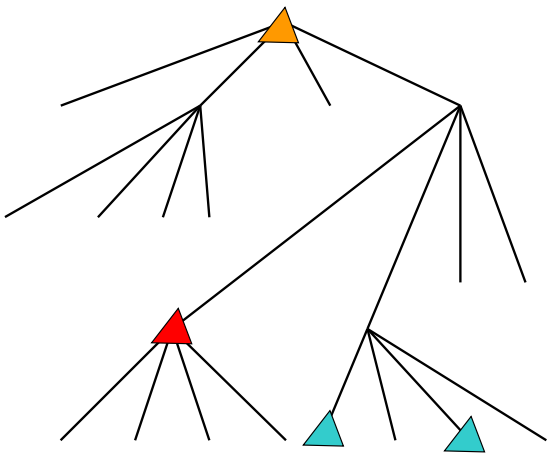
BSP Tree

Primitives in an Adaptive Grid

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

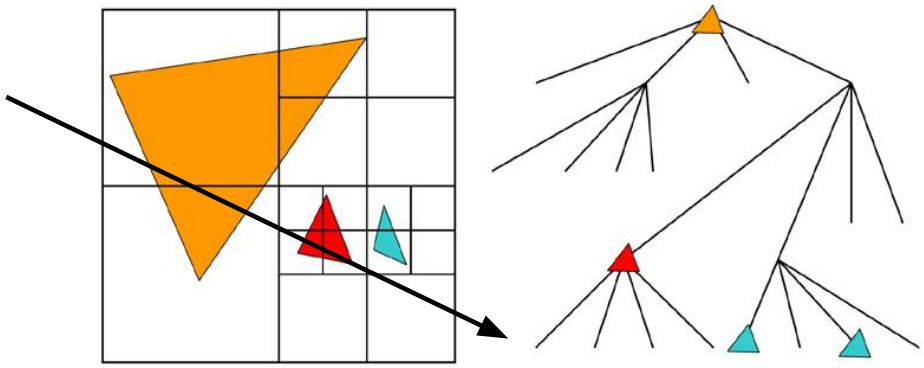


Octree/(Quadtree)



Adaptive Grid Discussion

- Advantages?
  - grid complexity matches geometric density
- Disadvantages?
  - more expensive to traverse (binary tree, lots of pointers)



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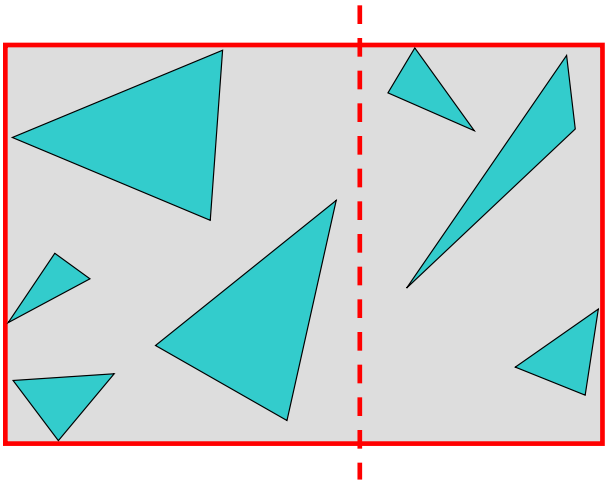
Bounding Volume Hierarchy

- Find bounding box of objects
- Split objects into two groups
- Recurse



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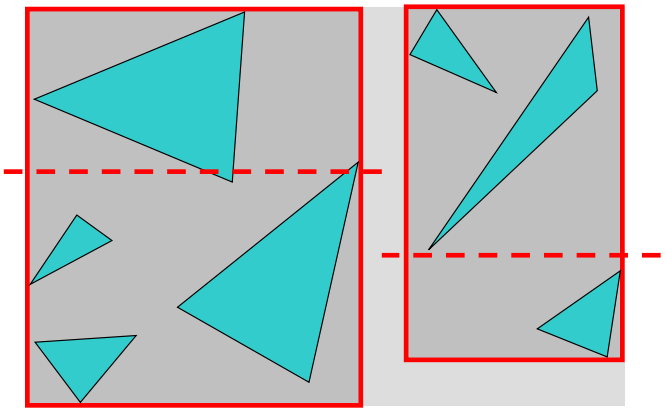
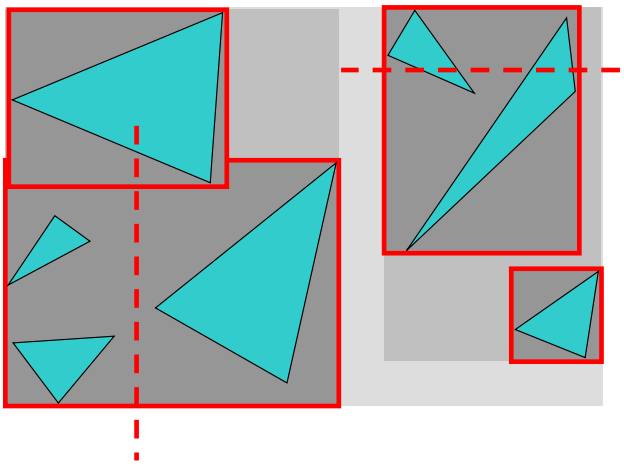
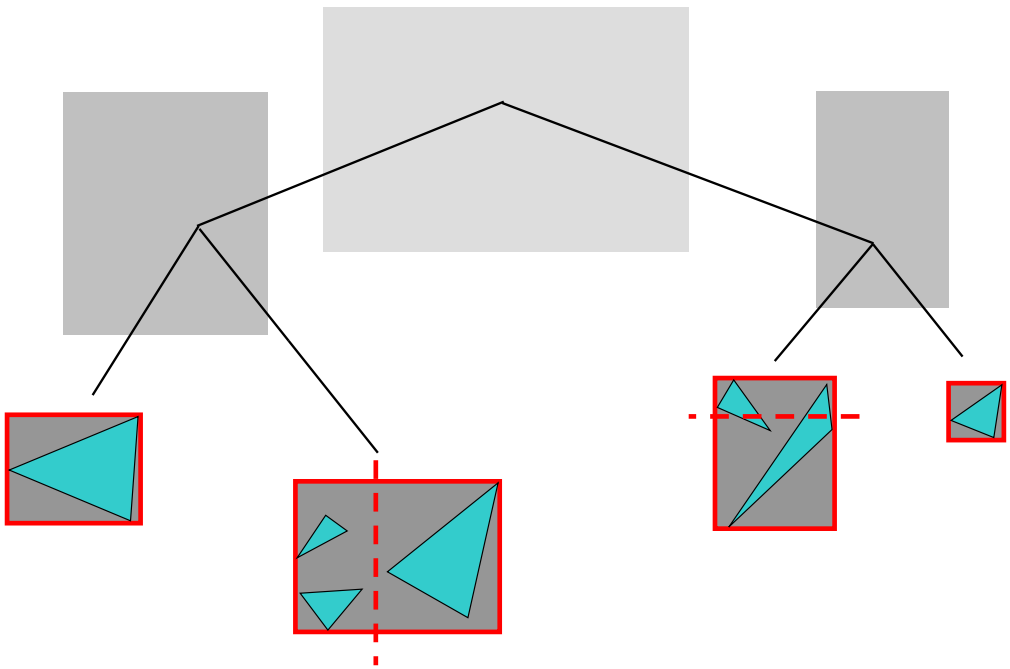


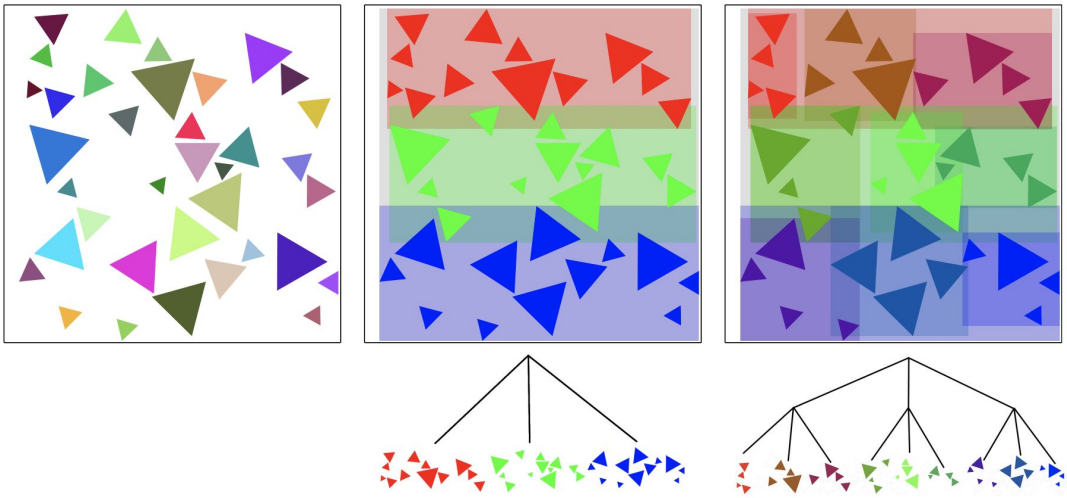
Where to split objects?

- At midpoint OR
- Sort, and put half of the objects on each side OR
- Use modeling hierarchy



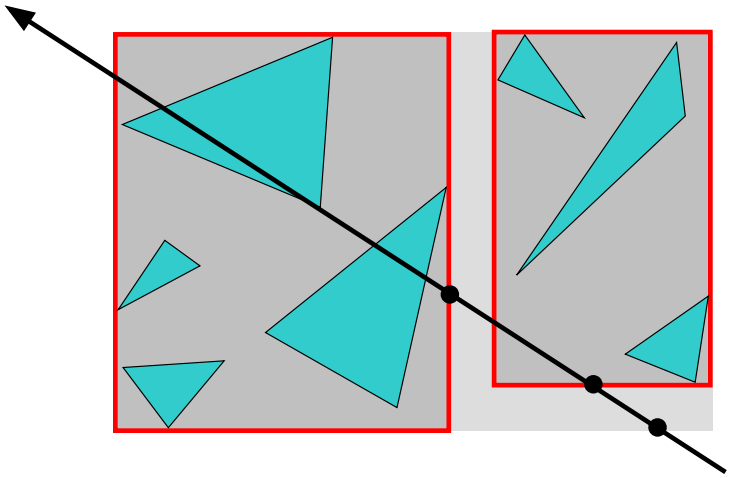


Data Structures Homework 8



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

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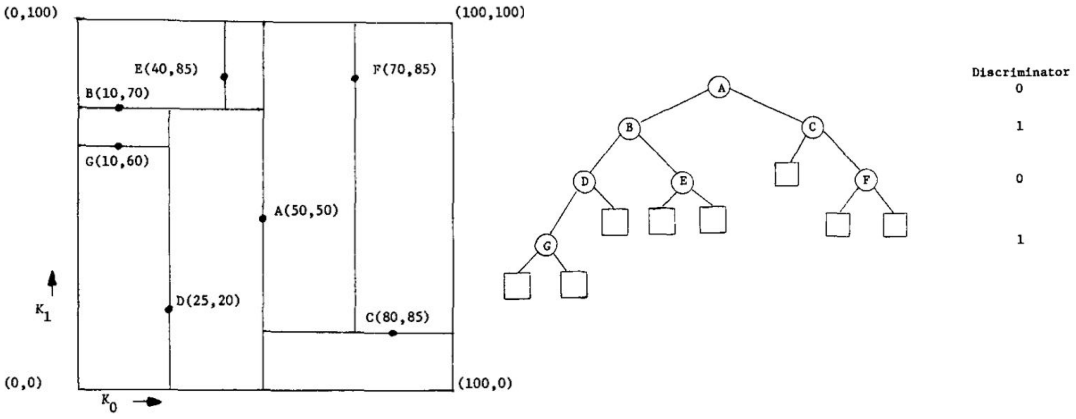
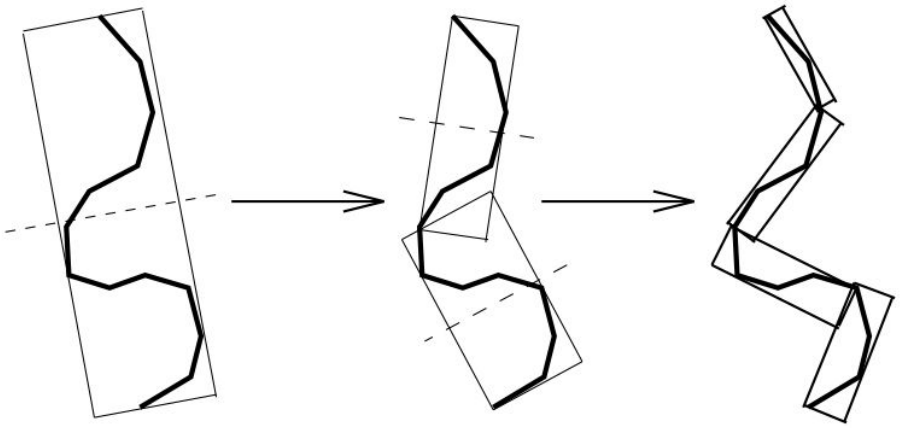
Reading for Today: *(pick one)*

"Multidimensional Binary Search Trees
Used for Associative Searching",
Bentley, Communications of the ACM, 1975



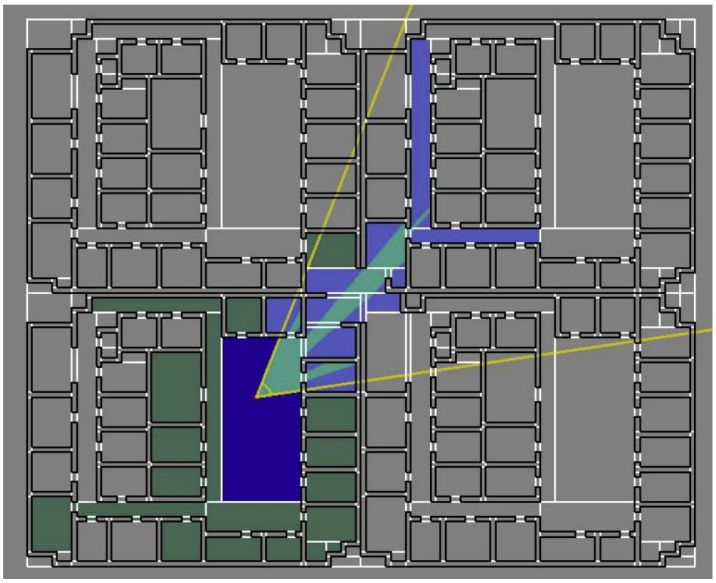
Reading for Today: *(pick one)*

“OBB-Tree: A Hierarchical Structure for Rapid Interference Detection”, Gottschalk, Lin, & Manocha, SIGGRAPH 1996.



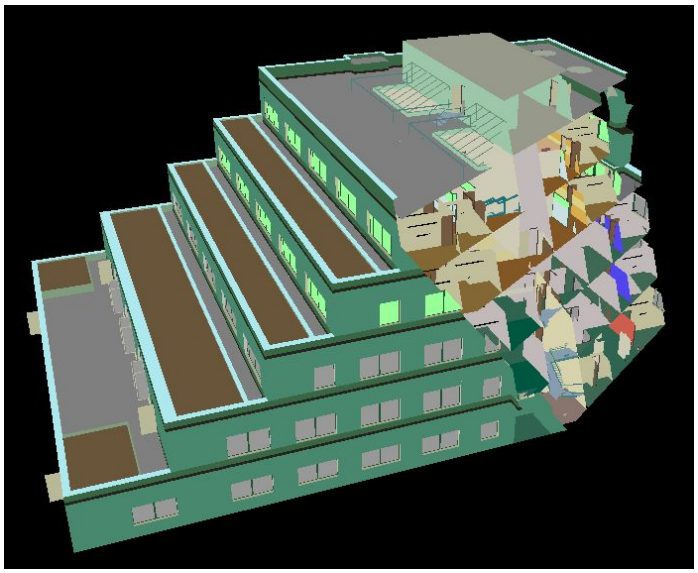
Reading for Today: *(pick one)*

"Visibility Preprocessing For Interactive Walkthroughs", Teller & Sequin, SIGGRAPH 1991.



Motivation: Architectural Walkthrough

- UC Berkeley's new Computer Science Building
- Pre-construction visualization
- Very large dataset!
- Interactive/ real-time camera motion!



Seth Teller, PhD thesis, 1992, Berkeley Soda Hall walkthrough

Seth Teller, PhD thesis, 1992, Berkeley Soda Hall walkthrough

- Performance requirement: Interactive vs real time
- Conservative visibility: overestimate of polygons that might be visible (neither “exact” nor “underestimate”)
- Input assumptions - parallel to x or y axis & integer grid coordinates
- subdivide space into ‘cells’ (rooms) & identify ‘portals’ between cells
- Portal sequences, sightlines, & stab tree
- Worst case quadratic storage not expected in typical architectural scenarios
- temporal coherence (re-use/cache recent computations)
- 3D is challenging, windows made of many small panes of glass challenges scalability

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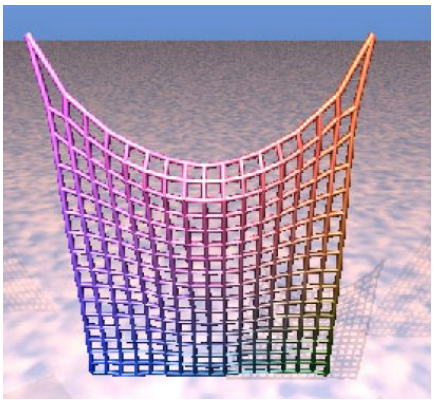
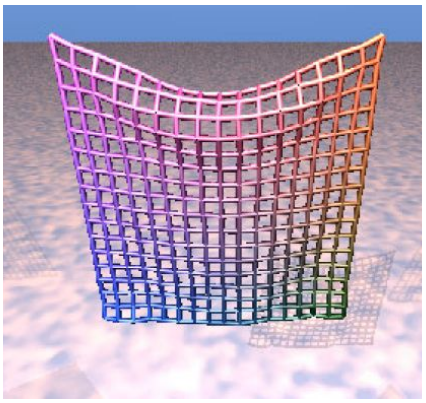
Reading for Next Time:

Everyone should read this
(simple cloth model used in HW2)

- "Deformation Constraints in a Mass-Spring Model to Describe Rigid Cloth Behavior", Provot, 1995.



Simple mass-spring system



Improved solution

Cloth in Practice (w/ Animation)

OPTIONAL READING FOR NEXT TIME

- Baraff, Witkin & Kass *Untangling Cloth* SIGGRAPH 2003