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
Sketch the polygonal mesh after performing 2 iterations of subdivision (Loop/Butterfly, Catmull-Clark, and Doo-Sabin). If necessary, pre-process the mesh to allow use of the specified method.
Traveler's Insurance, Snowball

Weta Digital, 2007

Katamari

BANDAI NAMCO Entertainment Inc., 2004-2018
Output-Sensitive Collision Processing for Reduced-Coordinate Deformable Models

James, Pai, and Twigg, SIGGRAPH 2004

Output-Sensitive Collision Processing for Reduced-Coordinate Deformable Models
**Untitled**, 1550 chairs stacked, Doris Salcedo, 2003

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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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  – Fixed/Uniform/Regular Grid
  – Nested Grid
  – Octree
  – Binary Space Partition
  – K-d tree
  – Bounding Volume Hierarchy

• Readings for Today
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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

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

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!*

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)

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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

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Reading for Today: *(pick one)*

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

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Reading for Today: *(pick one)*

Reading for Today: *(pick one)*


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
• 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)

Simple mass-spring system  Improved solution
Cloth in Practice (w/ Animation)

OPTIONAL READING FOR NEXT TIME

- Baraff, Witkin & Kass
  Untangling Cloth
  SIGGRAPH 2003