Scene Management

Introduction

- Graphics cards can render a lot, and fast
  - But never as much or as fast as we'd like!
- Updating the game world can involve a lot of objects
  - Consider Dragonfly doing collision detection
- Intelligent scene management
  - Squeezes more graphics performance out of limited resources
  - Provides structures for more efficient world management

Motivation (1 of 2)

- Consider game with people, in a car, on a road
- People move around inside car, don't affect the position of car in world
- But car moving in world affects position of people in world
- If massive hand picks up road → affects location of car and people!
- Exists beyond positions, too
  - Consider animations or textures tied to skeletons
- To make movement/drawing more efficient, structure that supports such relationships → *Scene graphs*

Motivation (2 of 2)

- Consider Dragonfly 
- Drawing order of objects depends upon altitude, and ViewObjects drawn last
  - Can we group to make drawing more efficient?
- Collisions don't occur for SPECTRAL objects
  - Can we group to make collision detection more efficient?
- To make movement/drawing more efficient, structure that supports such relationships → *Scene graphs*

Outline

- Introduction (done)
- Scene graphs (next)
- Scene partitioning
- Visibility calculations
- Dragonfly SceneGraph

Scene Graphs

- Specification of object and attribute relationships
  - Spatial (where is it, i.e. position)
  - Hierarchical (relationship to other objects, e.g. inside)
  - Material properties (e.g. solidness)
- Easy to "attach" objects together
  - E.g. Riding in a vehicle
- Easy to query to get objects with same properties
  - E.g. All solid objects, all objects near (x, y)
- Implementation does not need to be objects in tree
  - Can use pointers (e.g. to textures, sprites) instead
- Logical and spatial relationships
  - Often goal is to make it easy to discard large swaths so do not need to render

→ *Spatial data structures* (next)

Spatial Data Structures

- Spatial data structures store data indexed by location
  - E.g. Store according to Position … 
  - Without graphics, used for queries like “Where is the nearest hotel?” or “Which stars are near enough to influence the sun?”
- Multitude of uses in computer games
  - *Visibility* - What can player see?
  - *Collision detection* - Did bullet just hit wall?
  - *Proximity queries* - Where is nearest health-pack?
- Can reduce “cost” with fast, approximate queries that eliminate most irrelevant objects quickly

→ Trees with containment property enable this
  - Cell of parent completely contains all cells of children
  - If query fails for cell, it will fail for all children
  - If query succeeds, try it for children
  - Cost? → Depends on object distribution, but roughly O(log *n*)

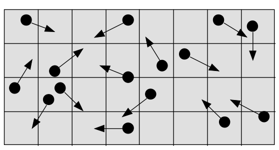
Spatial Data Structures

- For games, focus on spatial data structures that partition space into regions, or *cells*, of some type
  - Generally, cut up space with planes that separate regions
- Uniform Grids
  - Split space up into equal size cells
- Quad (or Oct) Trees
  - Recursively split space into 4 (or 8) equal-sized regions
  - Can do with sphere, too
- Binary-Space Partitioning (BSP) trees
  - Recursively divide space along single, arbitrary plane
- k-dimensional trees (k-d trees)
  - Recursively partition in k dimensions until termination condition (e.g. 1 object per cell)

(Example of each next)

Uniform Grid

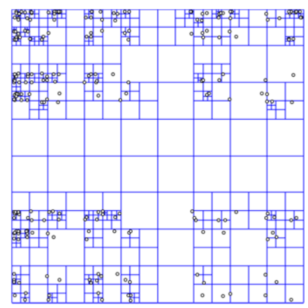
- Cells can be approximately size of view distance



- Only need consider objects in cell and neighbor
- Pro: Easy to find, compute
- Con: Not effective if many objects in one cell

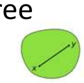
Quad Tree

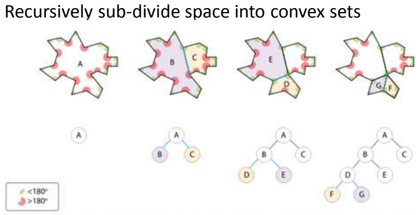
- Each node has exactly 4 children
- For 2-d space, subdivide into 4 regions
- Split until (max-1) objects in each cell
  - E.g. 1 object in each



Binary Space Partitioning (BSP) Tree

- Recursively sub-divide space into convex sets

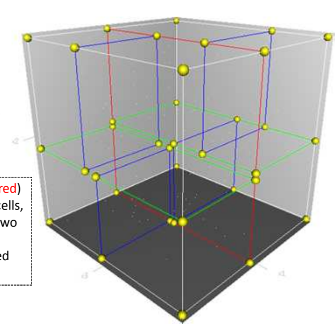




- For 3-d polygon scenes, can apply painter’s algorithm
  - Draw leaves of tree up (back polygons written first)
  - (Originally used in Doom before zbuffer to get fast rendering)
- Efficient to traverse, expensive to make so often done on static (not moving) geometry, pre-calculated
  - Can use z-buffer to merge dynamic objects with scene

K-D tree

- Instead of nodes being 2 dimensions (binary), nodes are k-dimensions



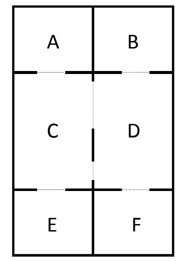
3-dimensional *k*-d tree. First split (red) cuts root cell (white) into two subcells, each of which is split (green) into two subcells. Finally, each is split (blue) into two sub-cells. Final eight called leaf cells.

Cell-Portal Structures

- Cell-Portal data structures dispense with hierarchy → just store neighbor information
  - Makes them graphs, not trees
- Cells described by bounding polygons
- Portals polygonal openings between cells
- Good for visibility culling algorithms, OK for collision detection and ray-casting
- Several ways to construct
  - By hand, as part of authoring process
  - Automatically, starting with BSP or k-d tree and extracting cells and portals
  - Explicitly, as part of automated modeling process

Cell-Portal Visibility

- Keep track of which cell viewer is in
- Enumerate all visible regions
- Preprocess to identify *potentially visible set* (PVS) for each cell

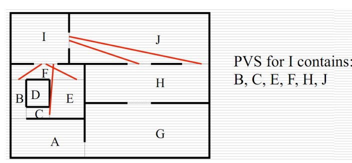


Potentially Visible Set (PVS)

- PVS: Set of cells/regions/objects/polygons that man be seen from particular cell
  - Want to identify objects that can be seen
  - Trade-off is memory consumption vs. accurate visibility
- Computed as pre-process
  - Easy for static objects (e.g. cells)
  - Need strategy to manage dynamic objects
- Used in various ways:
  - As only visibility computation - render everything in PVS for viewer's current cell
  - As first step - identify regions of interest, then apply more accurate run-time algorithms

Cell-to-Cell PVS

- Cell A in cell B's PVS if *stabbing line* from portal of B to portal of A
  - *Stabbing line* → line segment intersecting only portals
  - Neighbor cells are trivially in PVS



Putting It All Together

- The "best" solution often combination
  - Static things
    - E.g. quad-tree for terrain
    - E.g. cells and portals for interior structures
  - Dynamic things
    - E.g. quick reject using bounding spheres
- Balance between pre-computation and run-time computation

(See SceneGraph in Dragonfly)