Scene Management

Introduction

- Graphics cards can render a lot, and fast
  - But never as much or as fast as we'd like!
- Intelligent scene management squeezes more graphics performance out of limited resources
  - Scene graphs
  - Scene partitioning
  - Visibility calculations
  - Level of detail control

Outline

- Scene Graphs

Motivation for Scene Graphs

- Consider game with people, in a car, on a road
- People move around the car, don't affect the position of car
- But car moving affects position of people
- 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*

Scene Graphs

- Specification of object and attribute relationships
  - Spatial
  - Hierarchical
  - Material properties
- Easy to "attach" objects together
  - E.g. Riding in a vehicle
- Implementation does not need to be objects in tree
  - Can use pointers (e.g. to textures, sprites) instead
- Logical and possibly 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*)

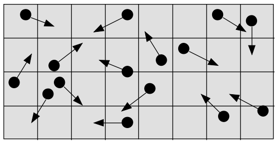
Spatial Data Structures

- 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 sized / number of cells
- Quad (or Oct) Trees
  - Recursively split space into 4 (or 8) equal-sized regions
  - Can do with a sphere, too
- Binary-Space Partitioning (BSP) trees
  - Recursively divide space along a 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)

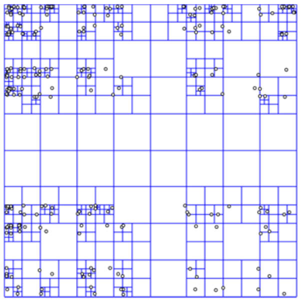
Uniform Grid

- 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

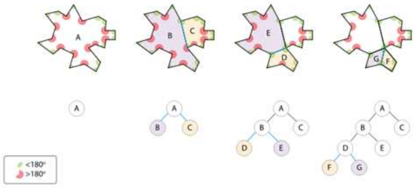
Quad Tree



- 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

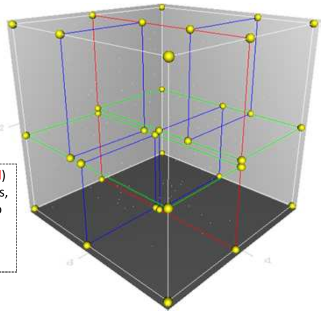
- Recursively sub-divide space into convex sets



- 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)

K-D tree

- Instead of 2 dimensions (binary) can use k-dimensions



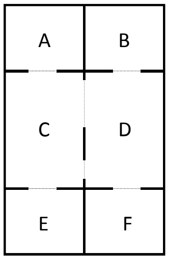
3-dimensional *k*-d tree. First split (red) cuts root cell (white) into two subcells, each of which is split (green) into two subcells. Finally, each is split (blue) into two sub-cells. Final eight called leaf cells.

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

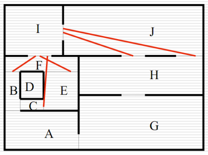


Potentially Visible Set (PVS)

- 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

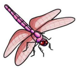


PVS for I contains:
B, C, E, F, H, J

Putting it All Together

- The "best" solution will be a 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

Group Exercise (1)

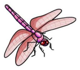


- Assume you want to SceneManager for Dragonfly
- Support: Altitude

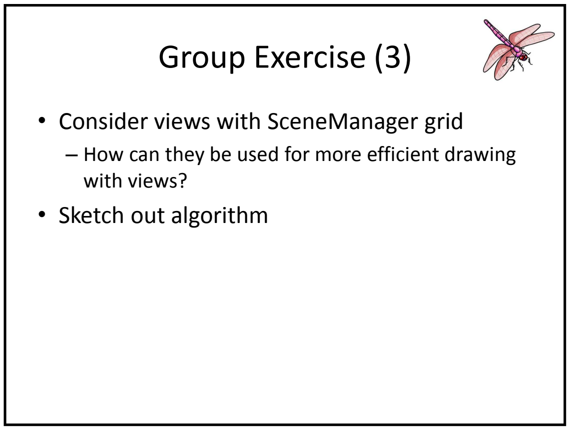
```
for alt = -MAX_ALTITUDE to MAX_ALTITUDE
    // iterate through all objects
    if (p_temp_go -> getAltitude() == alt)
      // draw
```

  - Keep current levels, but have more efficient data structure
- Design SceneManager
  - Attributes (data structures)?
  - Methods?
- What existing code need refactoring?

Group Exercise (2)



- Consider additional Scene Management functionality
  - More efficient collision detection
- Consider simple first (list), then advanced (grid)
- To support, what is needed …
  - Attributes (data structures)?
  - Methods?
- What existing code need refactoring?



Group Exercise (3)

- Consider views with SceneManager grid
  - How can they be used for more efficient drawing with views?
- Sketch out algorithm