University of British Columbia
CPSC 314 Computer Graphics
Jan-Apr 2007

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Picking II, Collision and Accelleration

Week 10, Fri Mar 23

http://www.ugrad.cs.ubc.ca/~cs314/Vjan2007

News

- showing up for your project grading slot is **not** optional
  - 2% penalty for noshows
- signing up for your project grading slot is **not** optional
  - 2% penalty for nosignups within two days of due date
  - your responsibility to sign up for slot
    - not ours to hunt you down if you chose to skip class on signup day
- we do make best effort to accomodate change requests via email to grader for that project

News

- project 4 proposals due today 3pm
  - handin cs314 proj3.prop
  - or on paper in box

- proposal: your chance to get feedback from me
  - don’t wait to hear back from me to get started
    - you’ll hear from me soon if I see something dubious
  - not a contract, can change as you go

Midterm 2: Wed Mar 26

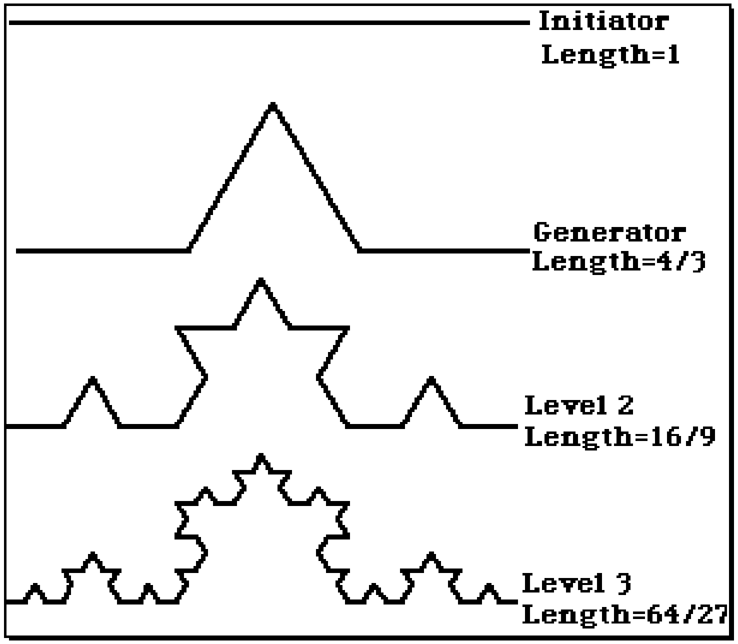
- covering through Homework 3 material
  - MT1: transformations, some viewing
  - MT2 emphasis
    - some viewing
    - projections
    - color
    - rasterization
    - lighting/shading
    - advanced rendering (incl raytracing)
- graded H3 + solutions out Monday

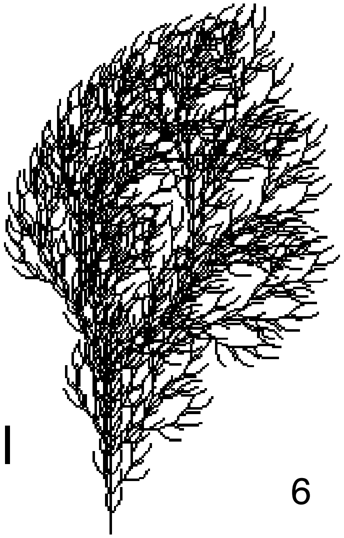
Midterm 2: Wed Mar 26

- closed book
- allowed to have
  - calculator
  - one side of 8.5”x11” paper, handwritten
    - write your name on it
    - turn it in with exam, you’ll get it back
- have ID out and face up

Review: Language-Based Generation

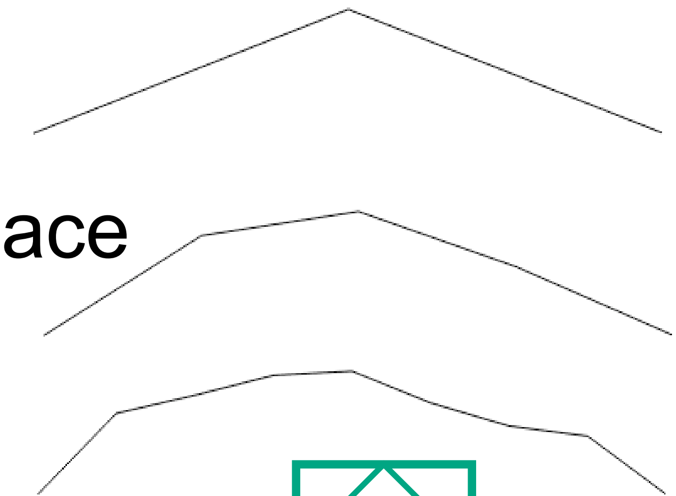
- L-Systems
  - F: forward, R: right, L: left
  - Koch snowflake:
    F = FLFRRFLF
  - Mariano's Bush:
    F=FF-[-F+F+F]+[+F-F-F]
    - angle 16



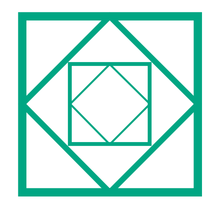


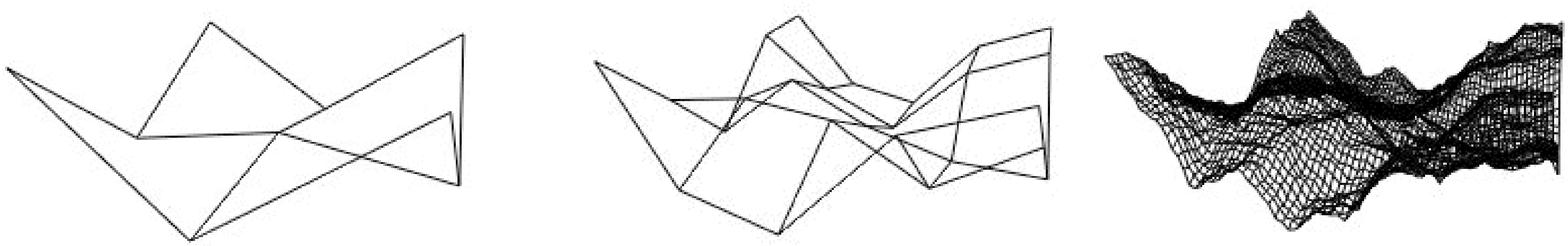
http://spanky.triumf.ca/www/fractint/lsys/plants.html

Review: Fractal Terrain



- 1D: midpoint displacement
  - divide in half, randomly displace
  - scale variance by half
- 2D: diamond-square
  - generate new value at midpoint
  - average corner values + random displacement
    - scale variance by half each time

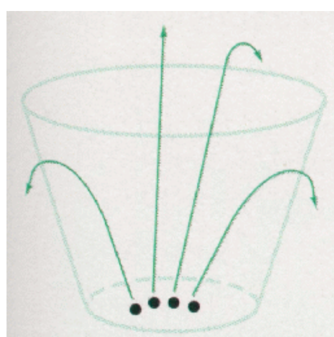


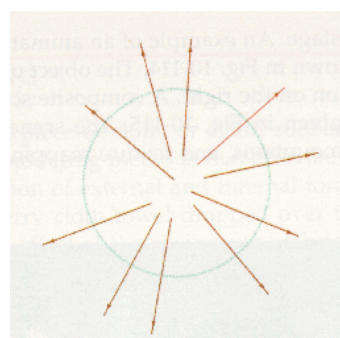


http://www.gameprogrammer.com/fractal.html

Review: Particle Systems

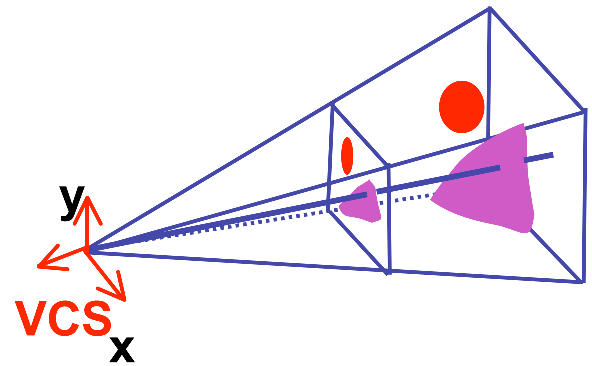
- changeable/fluid stuff
  - fire, steam, smoke, water, grass, hair, dust, waterfalls, fireworks, explosions, flocks
- life cycle
  - generation, dynamics, death
- rendering tricks
  - avoid hidden surface computations



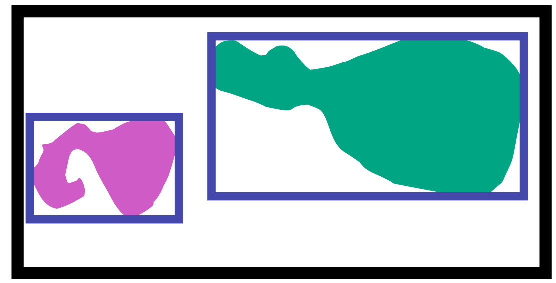


Review: Picking Methods

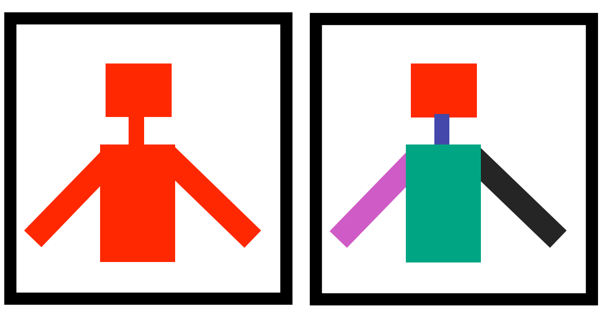
- manual ray intersection

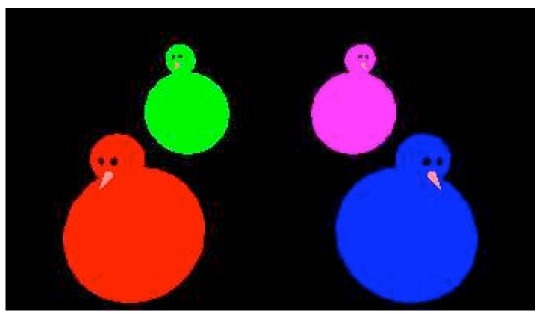


- bounding extents



- backbuffer coding





Picking II

Select/Hit

- use small region around cursor for viewport
- assign per-object integer keys (names)
- redraw in special mode
- store hit list of objects in region
- examine hit list

- OpenGL support

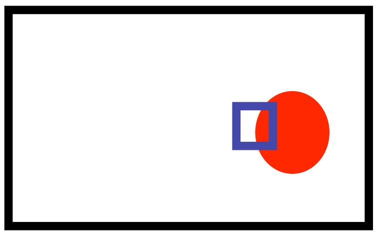
Viewport

- small rectangle around cursor
  - change coord sys so fills viewport

- why rectangle instead of point?
  - people aren't great at positioning mouse
    - Fitts' Law: time to acquire a target is function of the distance to and size of the target
  - allow several pixels of slop

Viewport

- nontrivial to compute
  - invert viewport matrix, set up new orthogonal projection
- simple utility command
  - gluPickMatrix(x,y,w,h,viewport)
    - x,y: cursor point
    - w,h: sensitivity/slop (in pixels)
  - push old setup first, so can pop it later



Render Modes

- glRenderMode(mode)
  - GL_RENDER: normal color buffer
    - default
  - GL_SELECT: selection mode for picking
  - (GL_FEEDBACK: report objects drawn)

Name Stack

- again, "names" are just integers

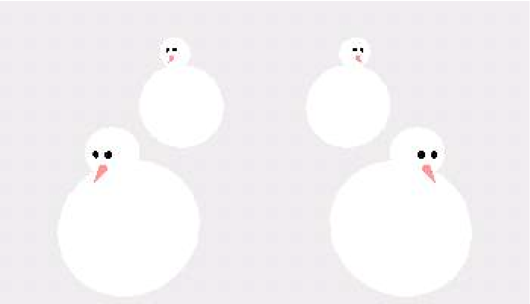
  glInitNames()
- flat list

  glLoadName(name)
- or hierarchy supported by stack

  glPushName(name), glPopName
  - can have multiple names per object

Hierarchical Names Example

```
for(int i = 0; i < 2; i++) {
  glPushName(i);
  for(int j = 0; j < 2; j++) {
    glPushMatrix();
    glPushName(j);
    glTranslatef(i*10.0,0,j * 10.0);
      glPushName(HEAD);
      glCallList(snowManHeadDL);
      glLoadName(BODY);
      glCallList(snowManBodyDL);
      glPopName();
    glPopName();
    glPopMatrix();
  }
  glPopName();
}
```



http://www.lighthouse3d.com/opengl/picking/

Hit List

- glSelectBuffer(buffersize, *buffer)
  - where to store hit list data
- on hit, copy entire contents of name stack to output buffer.
- hit record
  - number of names on stack
  - minimum and minimum depth of object vertices
    - depth lies in the z-buffer range [0,1]
    - multiplied by 2^32 -1 then rounded to nearest int

Integrated vs. Separate Pick Function

- integrate: use same function to draw and pick
  - simpler to code
  - name stack commands ignored in render mode
- separate: customize functions for each
  - potentially more efficient
  - can avoid drawing unpickable objects

Select/Hit

- advantages
  - faster
    - OpenGL support means hardware acceleration
    - avoid shading overhead
  - flexible precision
    - size of region controllable
  - flexible architecture
    - custom code possible, e.g. guaranteed frame rate
- disadvantages
  - more complex

Hybrid Picking

- select/hit approach: fast, coarse
  - object-level granularity
- manual ray intersection: slow, precise
  - exact intersection point
- hybrid: both speed and precision
  - use select/hit to find object
  - then intersect ray with that object

OpenGL Precision Picking Hints

- gluUnproject
  - transform window coordinates to object coordinates given current projection and modelview matrices
  - use to create ray into scene from cursor location
  - call gluUnProject twice with same (x,y) mouse location
    - z = near: (x,y,0)
    - z = far: (x,y,1)
    - subtract near result from far result to get direction vector for ray
- use this ray for line/polygon intersection

Picking and P4

- you must implement true 3D picking!
  - you will not get credit if you just use 2D information

Collision/Acceleration

Collision Detection

- do objects collide/intersect?
  - static, dynamic
- picking is simple special case of general collision detection problem
  - check if ray cast from cursor position collides with any object in scene
  - simple shooting
    - projectile arrives instantly, zero travel time
- better: projectile and target move over time
  - see if collides with object during trajectory

Collision Detection Applications

- determining if player hit wall/floor/obstacle
  - terrain following (floor), maze games (walls)
  - stop them walking through it
- determining if projectile has hit target
- determining if player has hit target
  - punch/kick (desired), car crash (not desired)
- detecting points at which behavior should change
  - car in the air returning to the ground
- cleaning up animation
  - making sure a motion-captured character's feet do not pass through the floor
- simulating motion
  - physics, or cloth, or something else

From Simple to Complex

- boundary check
  - perimeter of world vs. viewpoint or objects
    - 2D/3D absolute coordinates for bounds
    - simple point in space for viewpoint/objects
- set of fixed barriers
  - walls in maze game
    - 2D/3D absolute coordinate system
- set of moveable objects
  - one object against set of items
    - missile vs. several tanks
  - multiple objects against each other
    - punching game: arms and legs of players
    - room of bouncing balls

Naive General Collision Detection

- for each object ***i*** containing polygons ***p***
  - test for intersection with object ***j*** containing polygons ***q***
- for polyhedral objects, test if object ***i*** penetrates surface of ***j***
  - test if vertices of ***i*** straddle polygon ***q*** of ***j***
    - if straddle, then test intersection of polygon ***q*** with polygon ***p*** of object ***i***
- very expensive! $O(n^2)$

Fundamental Design Principles

- *fast simple tests first*, eliminate many potential collisions
  - test bounding volumes before testing individual triangles
- exploit *locality*, eliminate many potential collisions
  - use cell structures to avoid considering distant objects
- use as much *information* as possible about geometry
  - spheres have special properties that speed collision testing
- exploit *coherence* between successive tests
  - things don’t typically change much between two frames

Example: Player-Wall Collisions

- first person games must prevent the player from walking through walls and other obstacles
- most general case: player and walls are polygonal meshes
- each frame, player moves along path not known in advance
  - assume piecewise linear: straight steps on each frame
  - assume player's motion could be fast

Stupid Algorithm

- on each step, do a general mesh-to-mesh intersection test to find out if the player intersects the wall
- if they do, refuse to allow the player to move
- problems with this approach? how can we improve:
  - in response?
  - in speed?

Collision Response

- frustrating to just stop
  - for player motions, often best thing to do is move player tangentially to obstacle
- do recursively to ensure all collisions caught
  - find time and place of collision
  - adjust velocity of player
  - repeat with new velocity, start time, start position (reduced time interval)
- handling multiple contacts at same time
  - find a direction that is tangential to all contacts

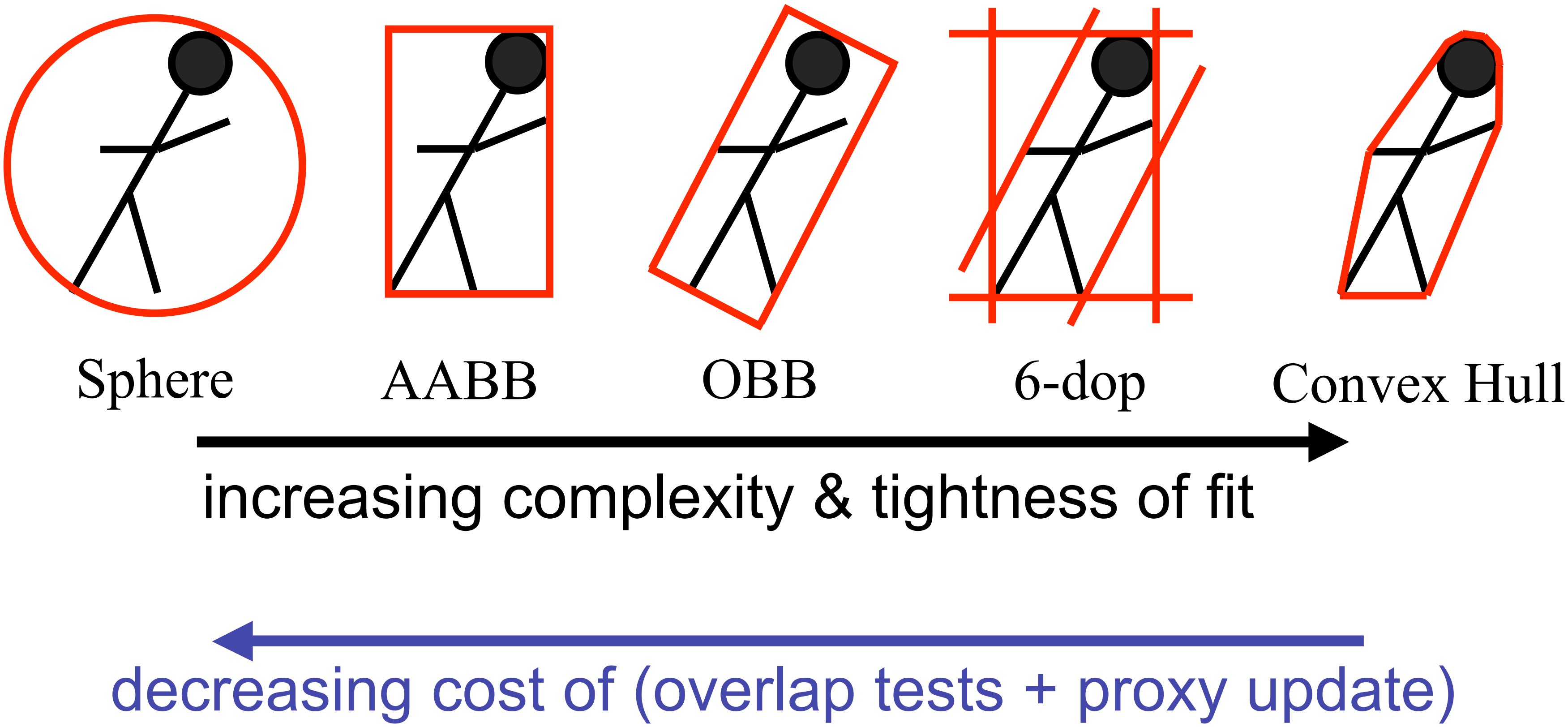
Accelerating Collision Detection

- two kinds of approaches (many others also)
  - collision proxies / bounding volumes
  - spatial data structures to localize
- used for both 2D and 3D
- used to accelerate many things, not just collision detection
  - raytracing
  - culling geometry before using standard rendering pipeline

Collision Proxies

- proxy: something that takes place of real object
  - cheaper than general mesh-mesh intersections
- collision proxy (bounding volume) is piece of geometry used to represent complex object for purposes of finding collision
  - if proxy collides, object is said to collide
  - collision points mapped back onto original object
- good proxy: cheap to compute collisions for, tight fit to the real geometry
- common proxies: sphere, cylinder, box, ellipsoid
  - consider: fat player, thin player, rocket, car …

Trade-off in Choosing Proxies



- AABB: axis aligned bounding box
- OBB: oriented bounding box, arbitrary alignment
- k-dops – shapes bounded by planes at fixed orientations
  - discrete orientation polytope

Pair Reduction

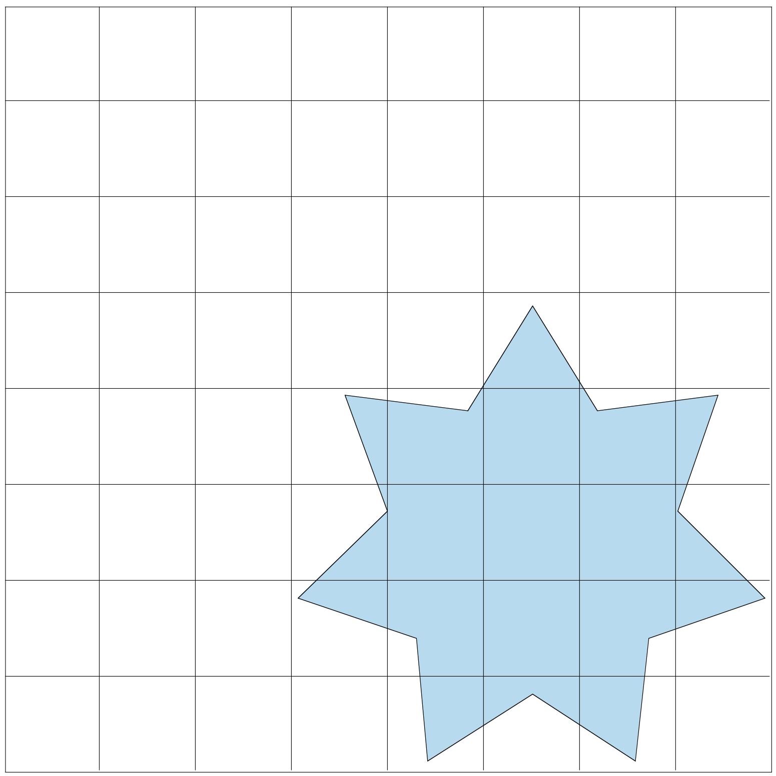
- want proxy for any moving object requiring collision detection
- before pair of objects tested in any detail, quickly test if proxies intersect
- when lots of moving objects, even this quick bounding sphere test can take too long: N^2 times if there are N objects
- reducing this N^2 problem is called *pair reduction*
- pair testing isn't a big issue until N>50 or so…

Spatial Data Structures

- can only hit something that is close
- spatial data structures tell you what is close to object
  - uniform grid, octrees, kd-trees, BSP trees
  - bounding volume hierarchies
    - OBB trees
  - for player-wall problem, typically use same spatial data structure as for rendering
    - BSP trees most common

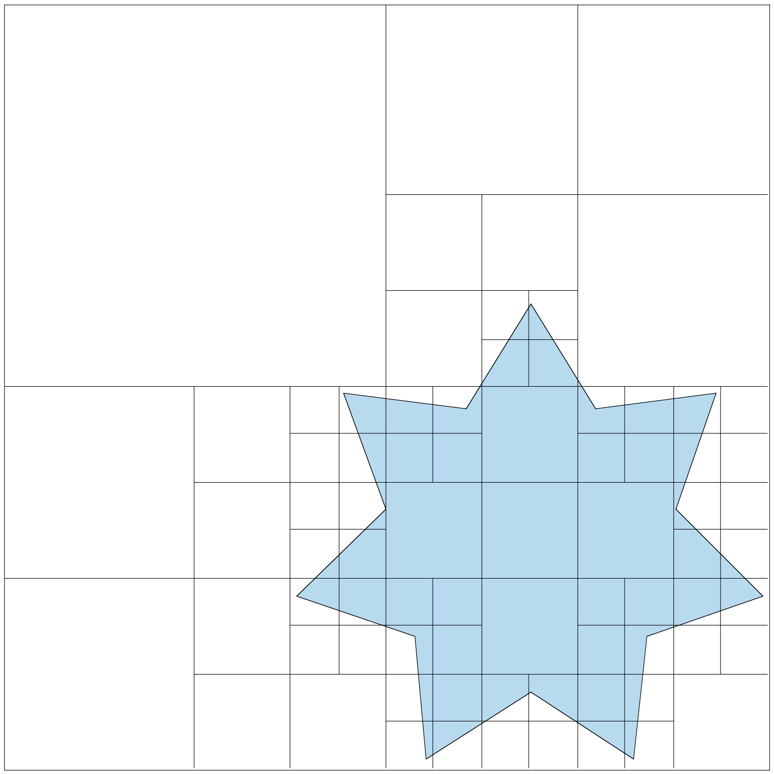
Uniform Grids

- axis-aligned
- divide space uniformly



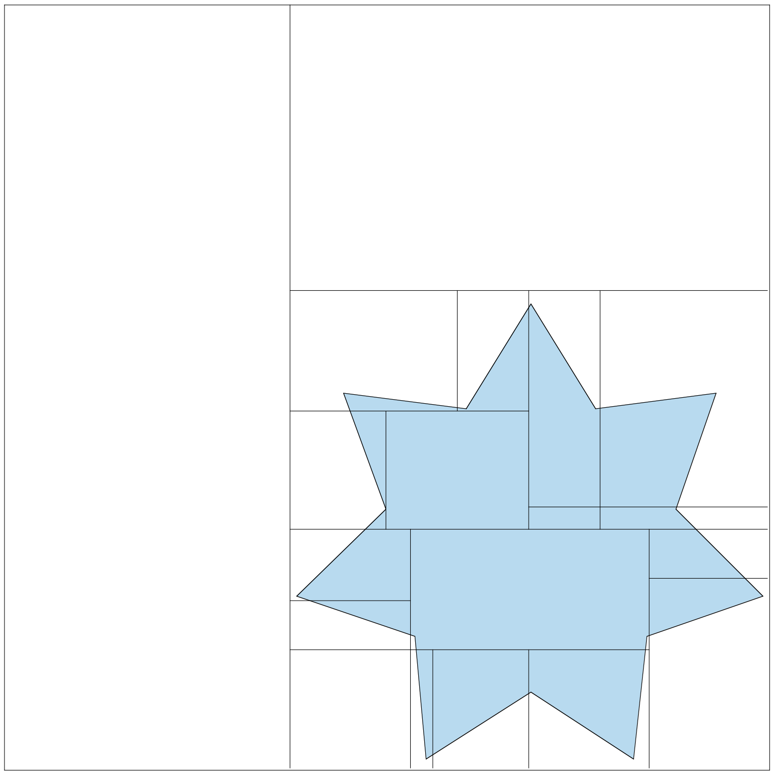
Quadtrees/Octrees

- axis-aligned
- subdivide until no points in cell



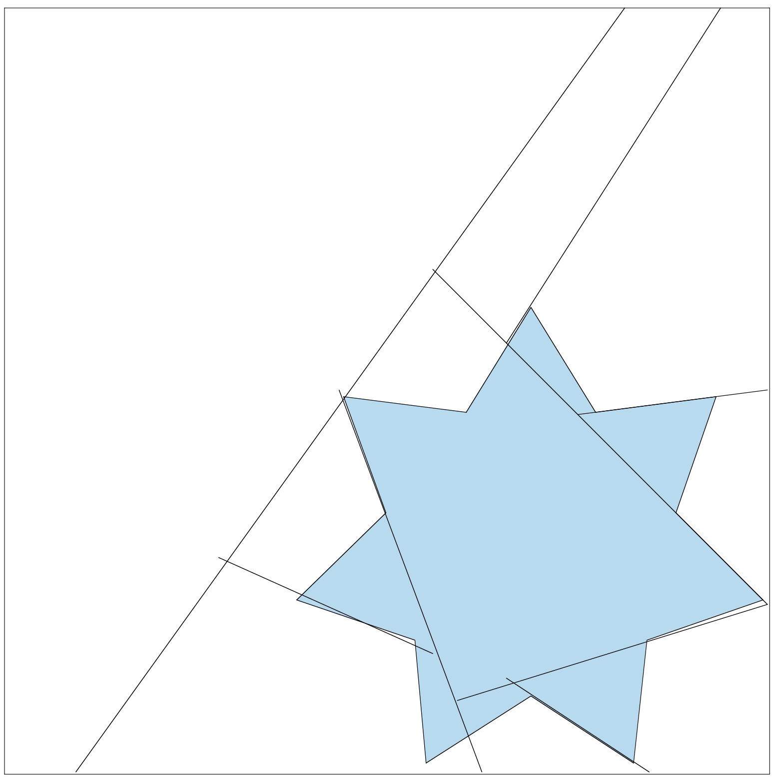
KD Trees

- axis-aligned
- subdivide in alternating dimensions

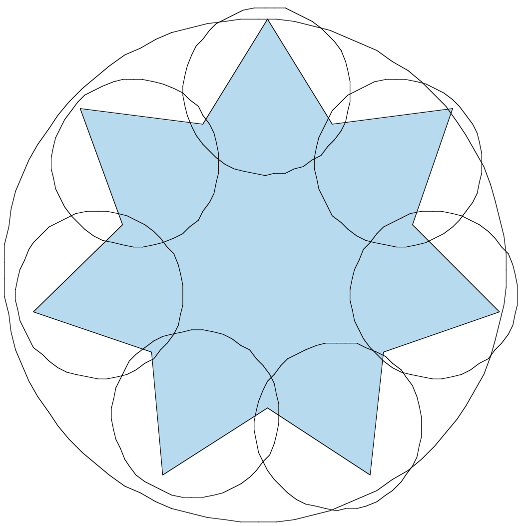


BSP Trees

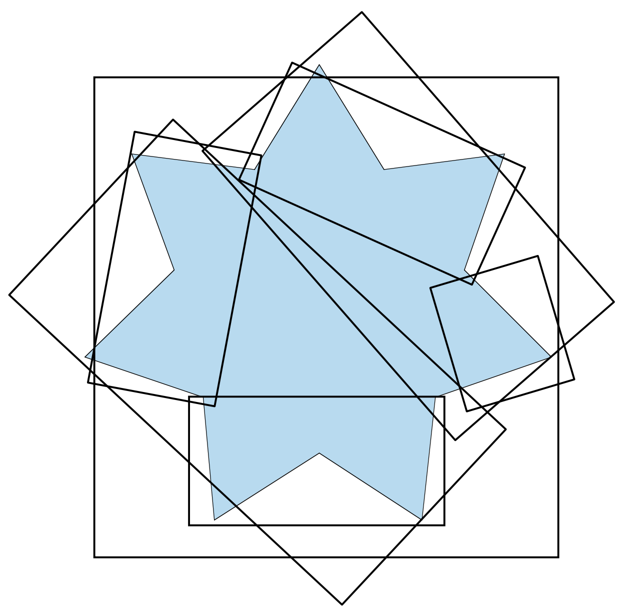
- planes at arbitrary orientation



Bounding Volume Hierarchies



OBB Trees



Related Reading

- Real-Time Rendering
  - Tomas Moller and Eric Haines
  - on reserve in CICSR reading room

Acknowledgement

- slides borrow heavily from
  - Stephen Chenney, (UWisc CS679)
  - http://www.cs.wisc.edu/~schenney/courses/cs679-f2003/lectures/cs679-22.ppt
- slides borrow lightly from
  - Steve Rotenberg, (UCSD CSE169)
  - http://graphics.ucsd.edu/courses/cse169_w05/CSE169_17.ppt