University of British Columbia
CPSC 314 Computer Graphics
Jan-Apr 2010

Tamara Munzner

Procedural II, Collision

Week 10, Fri Mar 26

http://www.ugrad.cs.ubc.ca/~cs314/Vjan2010

News

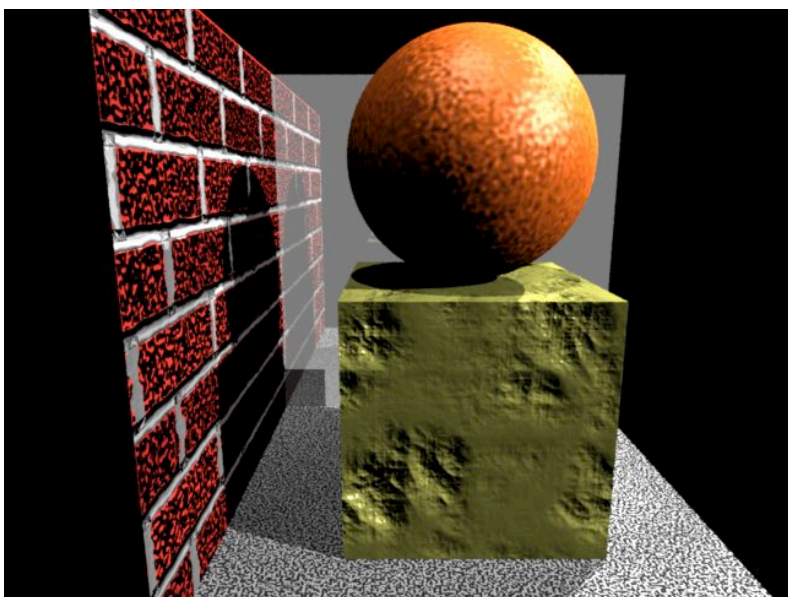
- Today office hours slight shift
  - Kai 2:30-5
  - my office hours cancelled, I'm sick and will lurch home right after teaching
- Thu 10-11 lab moved, now Thu 1-2 rest of term
- signup sheet for P3 grading for last time today
  - or send email to dingkai AT cs
    - by 48 hours after the due date or you'll lose marks
- P3 due today 5pm

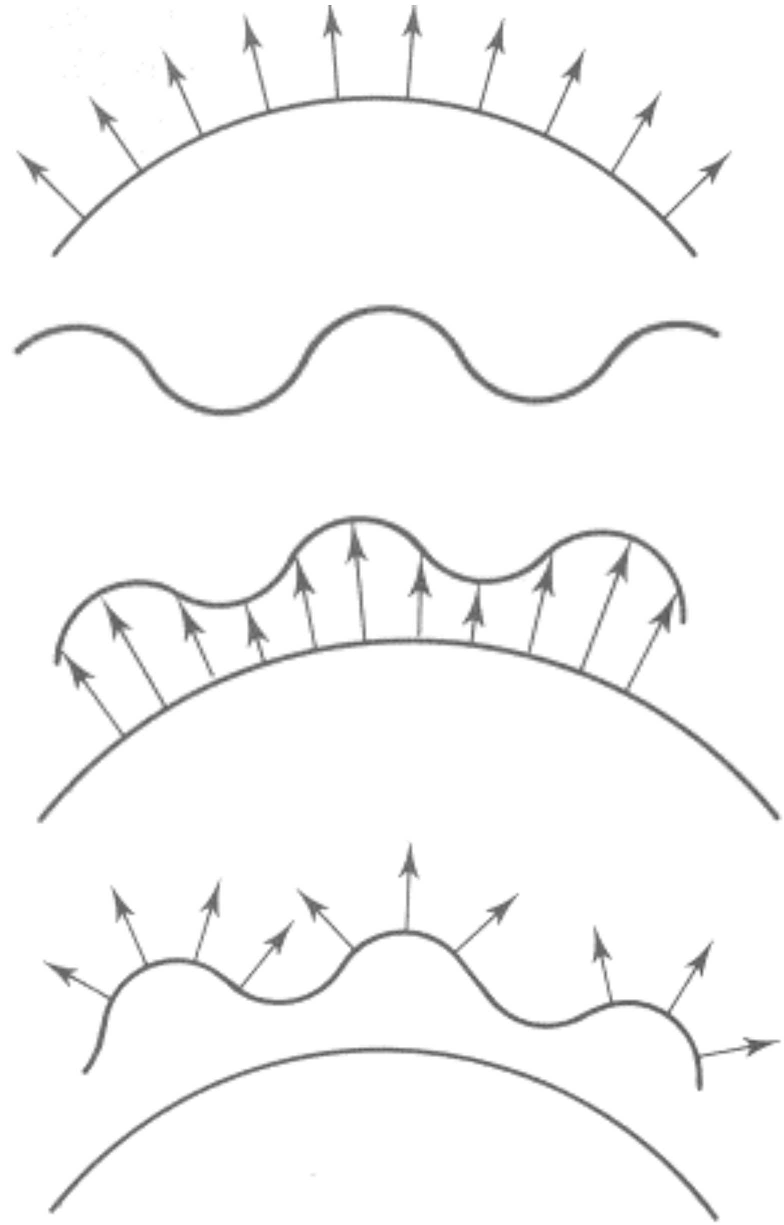
Readings

- Procedural:
  - FCG Sect 17.6 Procedural Techniques
  - 17.7 Groups of Objects
  - (16.6, 16.7 2nd ed)
- Collision:
  - FCG Sect 12.3 Spatial Data Structures
  - (10.9 2nd edition)

Review: Bump Mapping: Normals As Texture

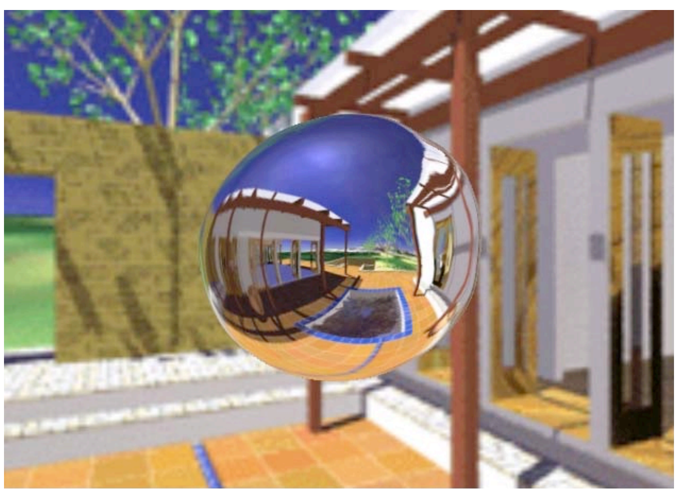
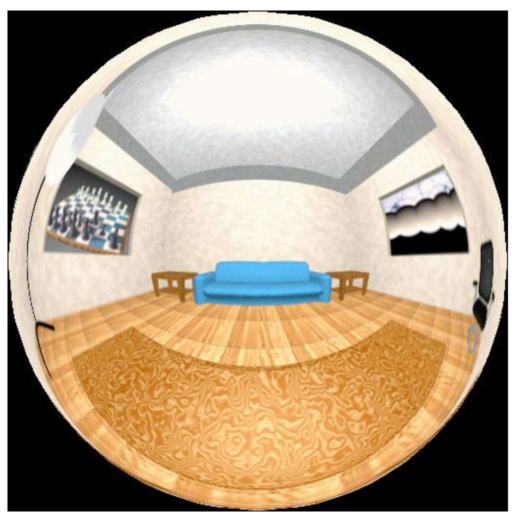
- create illusion of complex geometry model
- control shape effect by locally perturbing surface normal





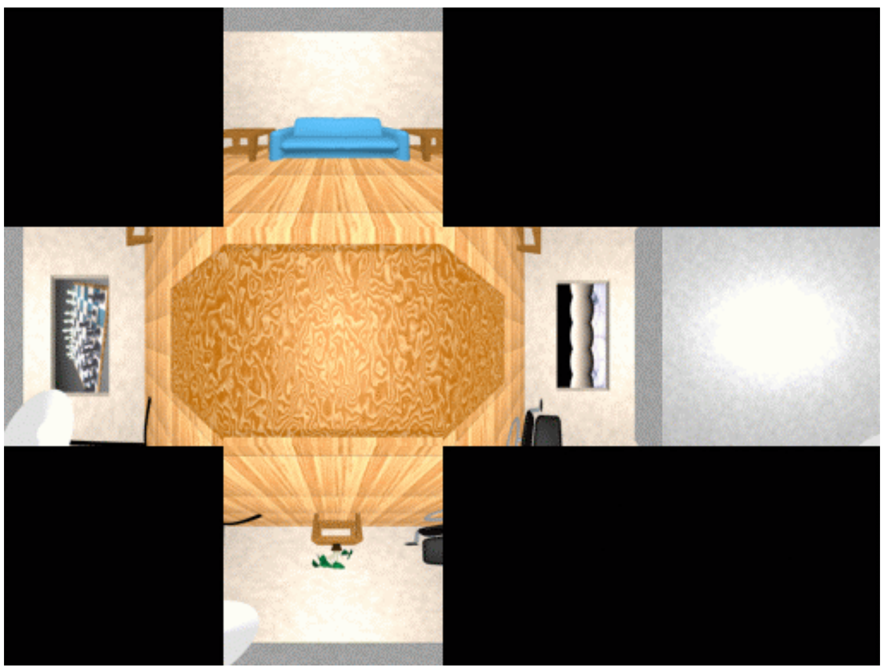
Review: Environment Mapping

- cheap way to achieve reflective effect
  - generate image of surrounding
  - map to object as texture
- sphere mapping: texture is distorted fisheye view
  - point camera at mirrored sphere
  - use spherical texture coordinates

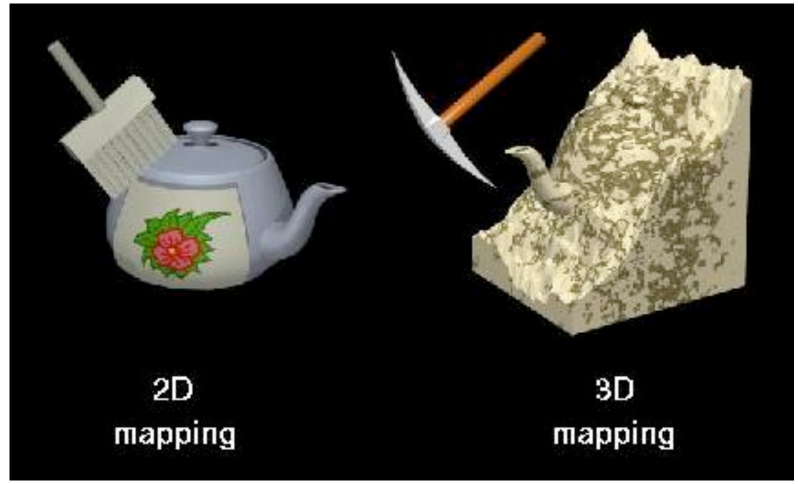

Review: Cube Environment Mapping

- 6 planar textures, sides of cube
  - point camera outwards to 6 faces
    - use largest magnitude of vector to pick face
    - other two coordinates for (s,t) texel location



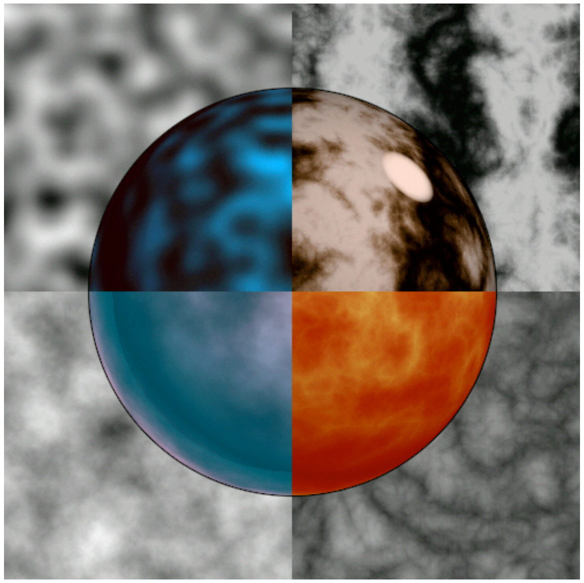
Review: Volumetric Texture

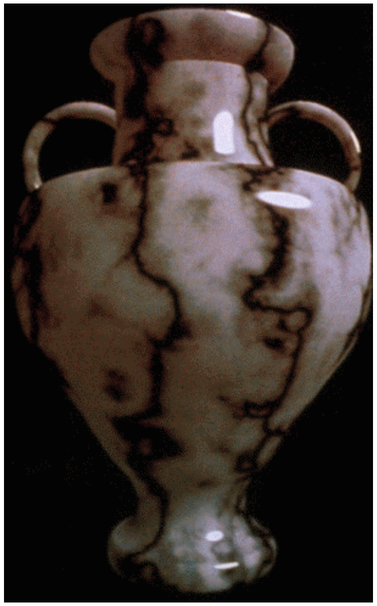
- define texture pattern over 3D domain - 3D space containing the object
  - texture function can be digitized or procedural
  - for each point on object compute texture from point location in space
- 3D function $\rho(x,y,z)$

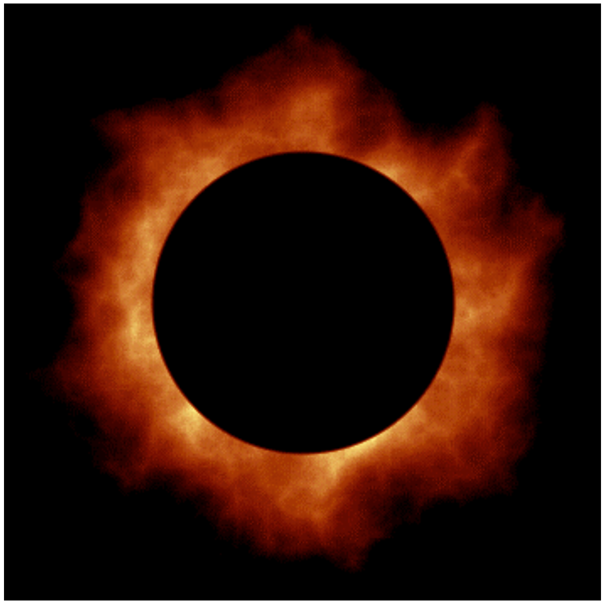


Review: Perlin Noise: Procedural Textures

```
function marble(point)
 x = point.x + turbulence(point);
 return marble_color(sin(x))
```

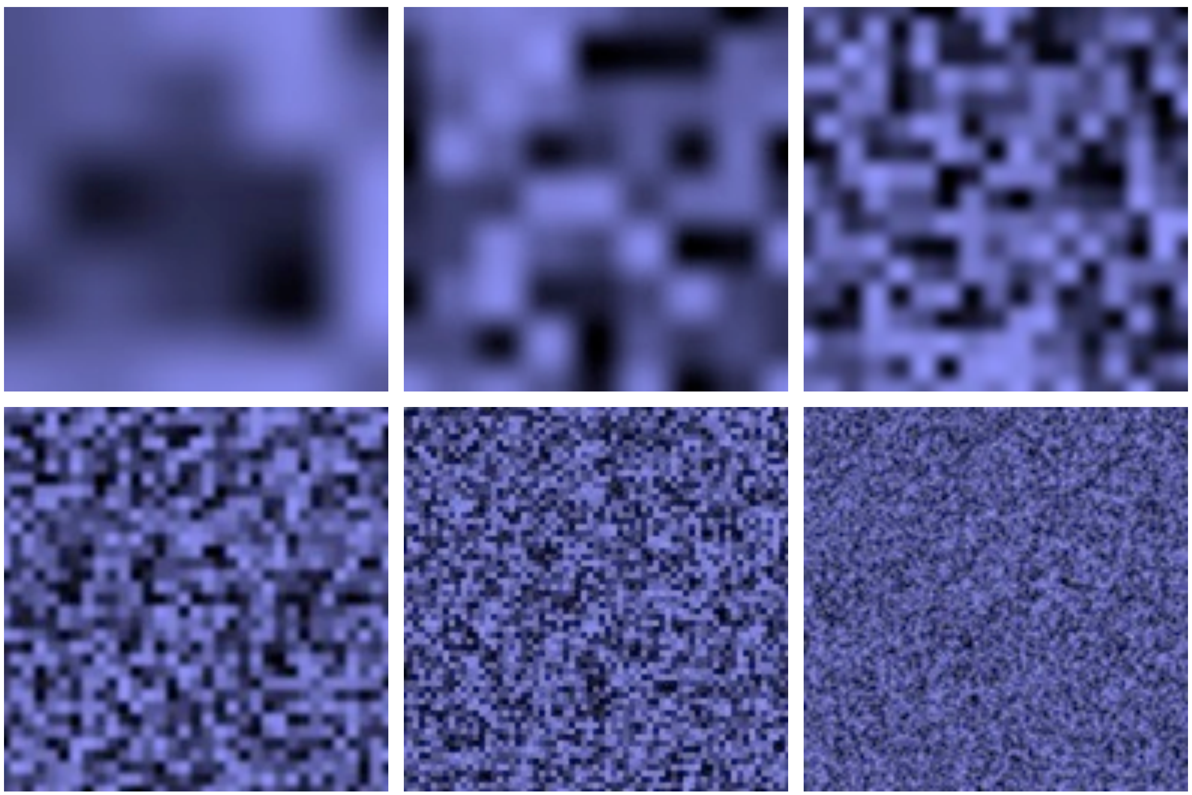


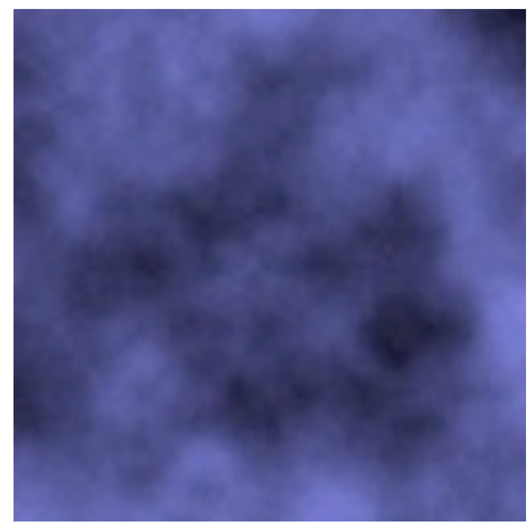




Review: Perlin Noise

- coherency: smooth not abrupt changes
- turbulence: multiple feature sizes





Review: Generating Coherent Noise

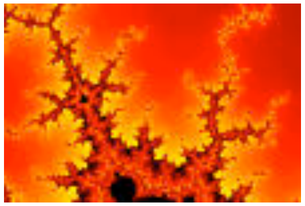
- just three main ideas
  - nice interpolation
  - use vector offsets to make grid irregular
  - optimization
    - sneaky use of 1D arrays instead of 2D/3D one

Review: Procedural Modeling

- textures, geometry
  - nonprocedural: explicitly stored in memory
- procedural approach
  - compute something on the fly
    - not load from disk
  - often less memory cost
  - visual richness
    - adaptable precision
- noise, fractals, particle systems

Fractal Landscapes

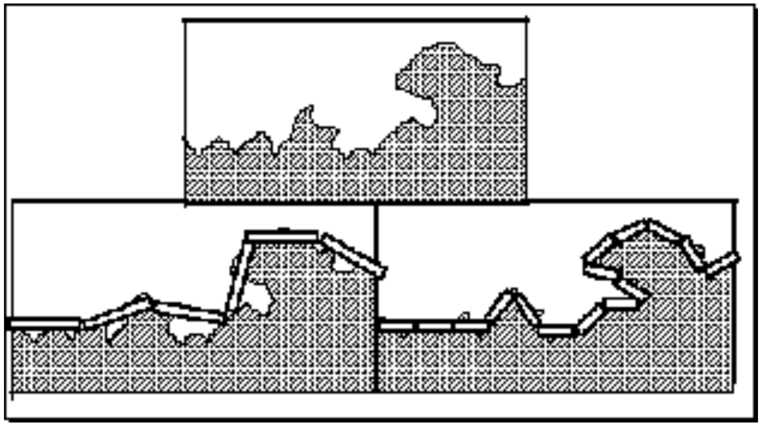
- fractals: not just for "showing math"
  - triangle subdivision
  - vertex displacement
  - recursive until termination condition



http://www.fractal-landscapes.co.uk/images.html

Self-Similarity

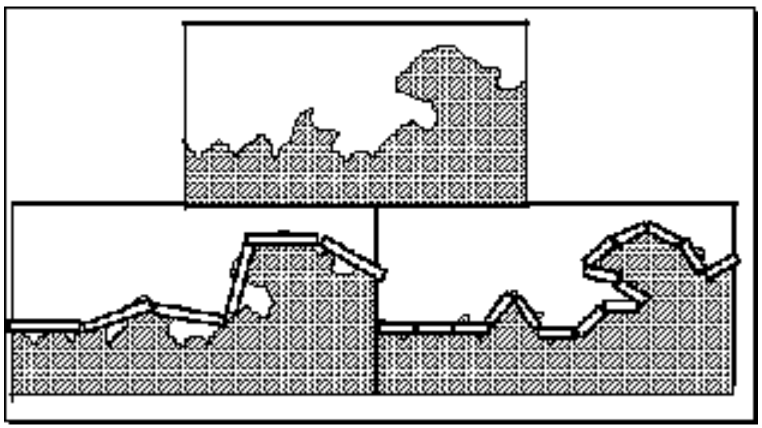
- infinite nesting of structure on all scales



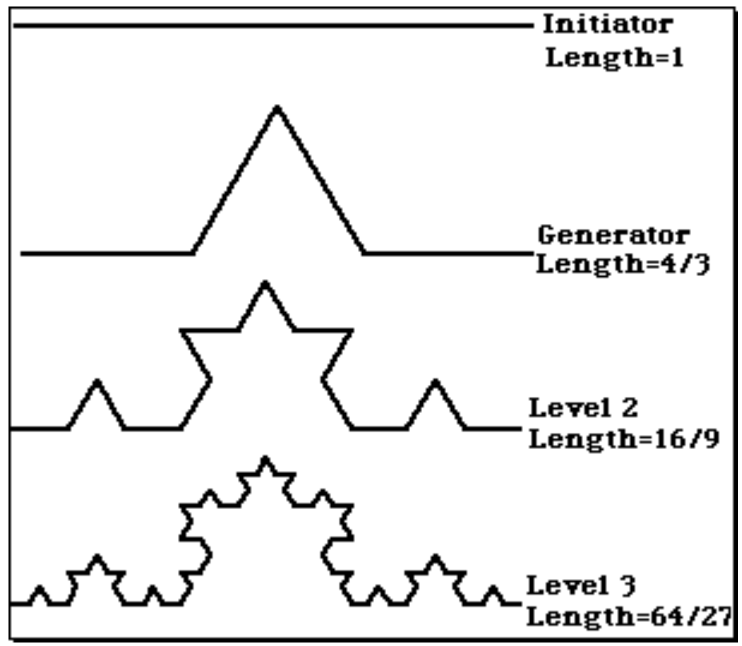
Fractal Dimension

- $D = \log(N)/\log(r)$
  N = measure, r = subdivision scale
  - Hausdorff dimension: noninteger

coastline of Britain



Koch snowflake

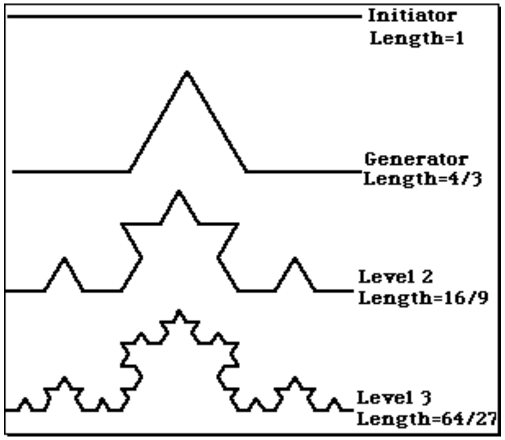


$D = \log(N)/\log(r)$ $D = \log(4)/\log(3) = 1.26$

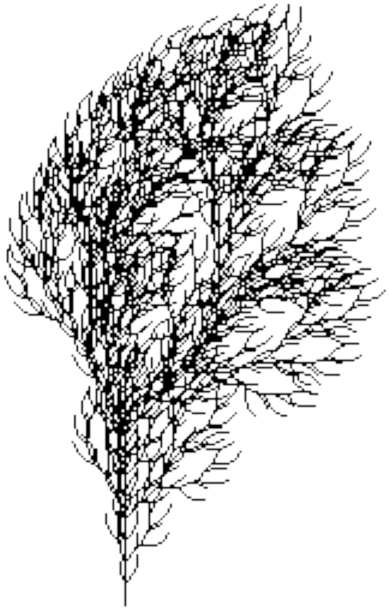
http://www.vanderbilt.edu/AnS/psychology/cogsci/chaos/workshop/Fractals.html

Language-Based Generation

- L-Systems: after Lindenmayer
  - Koch snowflake: F :- FLFRRFLF
    - F: forward, R: right, L: left



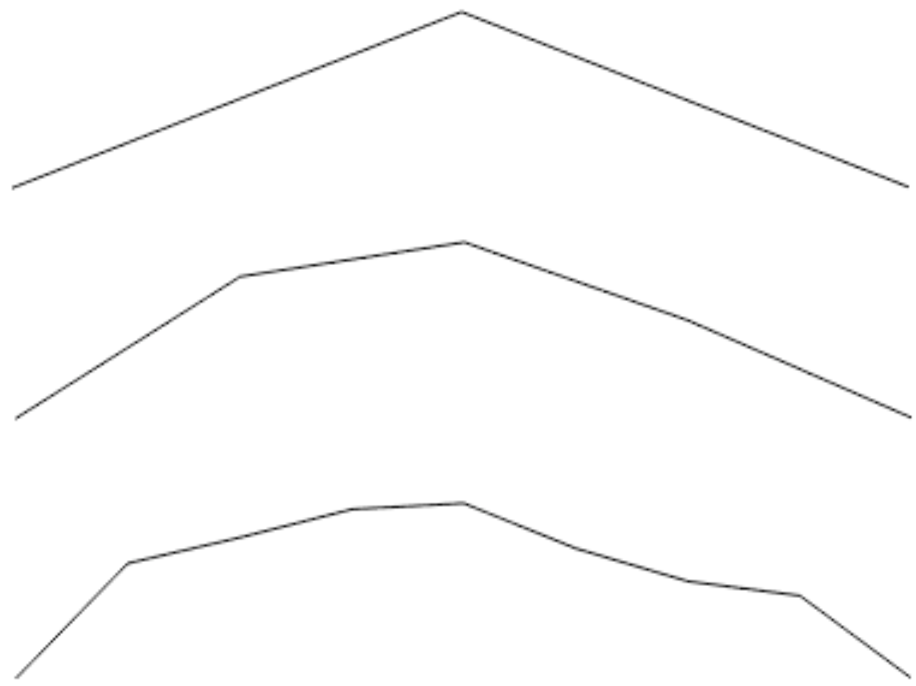
  - Mariano's Bush:
    F=FF-[-F+F+F]+[+F-F-F] }
    - angle 16



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

1D: Midpoint Displacement

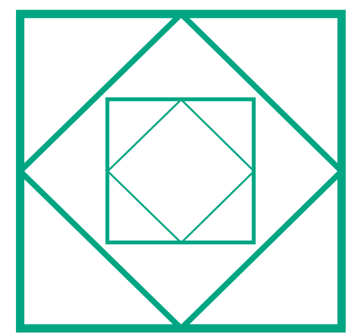
- divide in half
- randomly displace
- scale variance by half

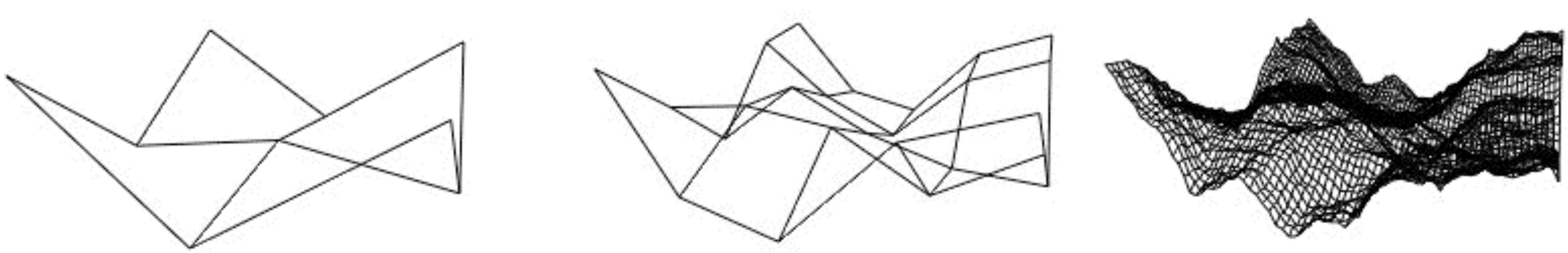


http://www.gameprogrammer.com/fractal.html

2D: Diamond-Square

- fractal terrain with diamond-square approach
  - generate a new value at midpoint
  - average corner values + random displacement
  - scale variance by half each time



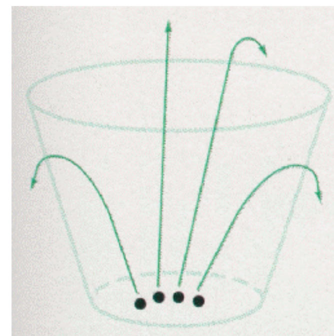


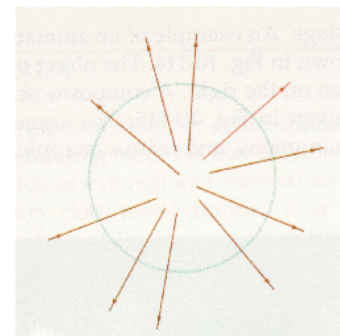
Particle Systems

- loosely defined
  - modeling, or rendering, or animation
- key criteria
  - collection of particles
  - random element controls attributes
    - position, velocity (speed and direction), color, lifetime, age, shape, size, transparency
    - predefined stochastic limits: bounds, variance, type of distribution

Particle System Examples

- objects changing fluidly over time
  - fire, steam, smoke, water
- objects fluid in form
  - grass, hair, dust
- physical processes
  - waterfalls, fireworks, explosions
- group dynamics: behavioral
  - birds/bats flock, fish school,
    human crowd, dinosaur/elephant stampede





Particle Systems Demos

- general particle systems
  - http://www.wondertouch.com
- boids: bird-like objects
  - http://www.red3d.com/cwr/boids/

Particle Life Cycle

- generation
  - randomly within “fuzzy” location
  - initial attribute values: random or fixed
- dynamics
  - attributes of each particle may vary over time
    - color darker as particle cools off after explosion
  - can also depend on other attributes
    - position: previous particle position + velocity + time
- death
  - age and lifetime for each particle (in frames)
  - or if out of bounds, too dark to see, etc

Particle System Rendering

- expensive to render thousands of particles
- simplify: avoid hidden surface calculations
  - each particle has small graphical primitive (blob)
  - pixel color: sum of all particles mapping to it
- some effects easy
  - temporal anti-aliasing (motion blur)
    - normally expensive: supersampling over time
    - position, velocity known for each particle
    - just render as streak

Procedural Approaches Summary

- Perlin noise
- fractals
- L-systems
- particle systems

- not at all a complete list!
  - big subject: entire classes on this alone

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

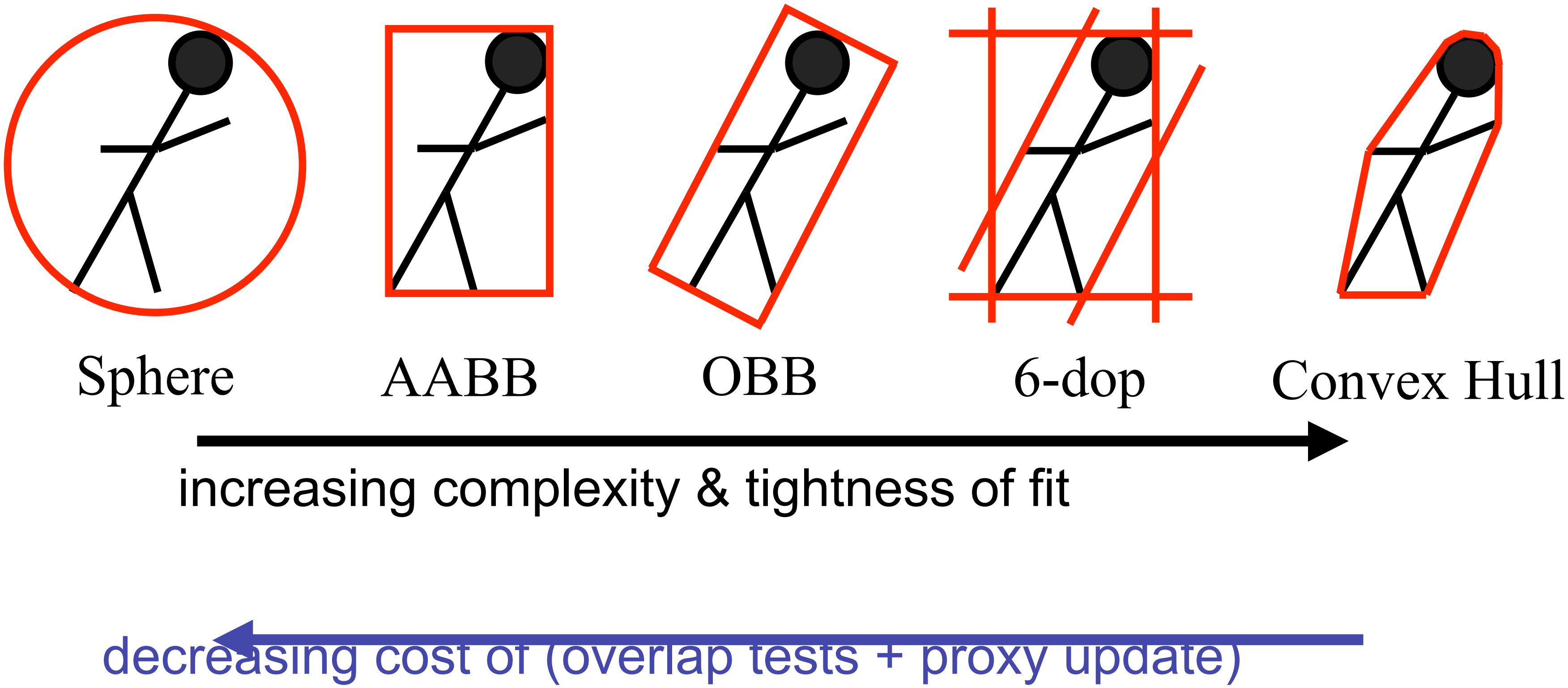
Accelerating Collision Detection

- 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

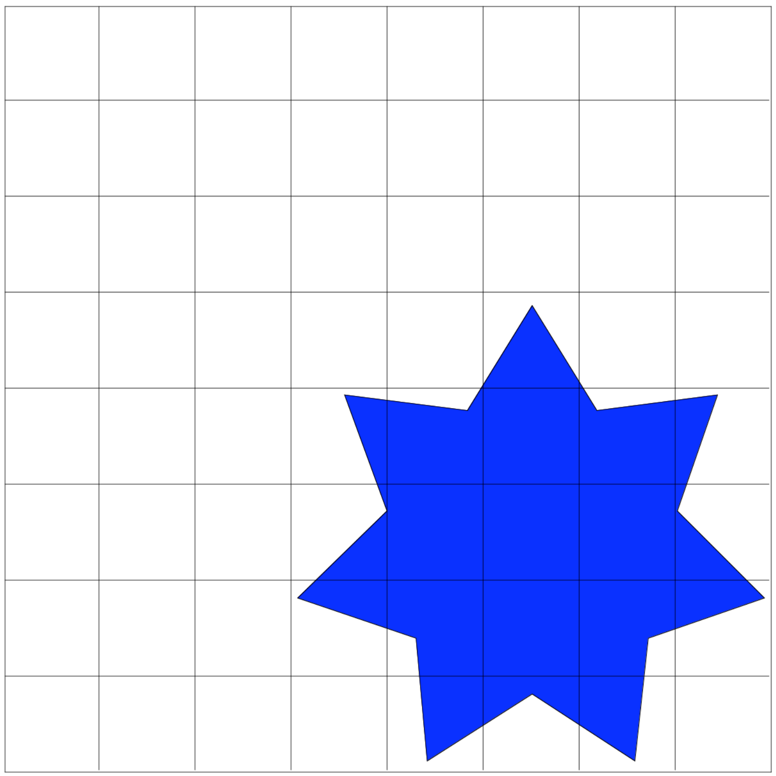
- want proxy for any moving object requiring collision detection
- before pair of objects tested in any detail, quickly test if proxies intersect
- when lots of moving objects, even this quick bounding sphere test can take too long: N^2 times if there are N objects
- reducing this N^2 problem is called *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

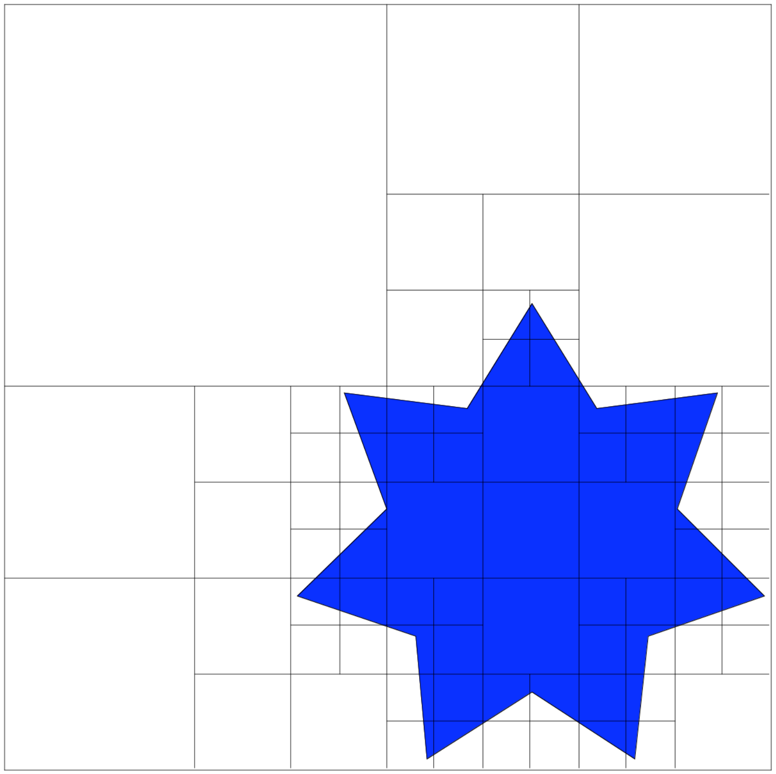
Uniform Grids

- axis-aligned
- divide space uniformly



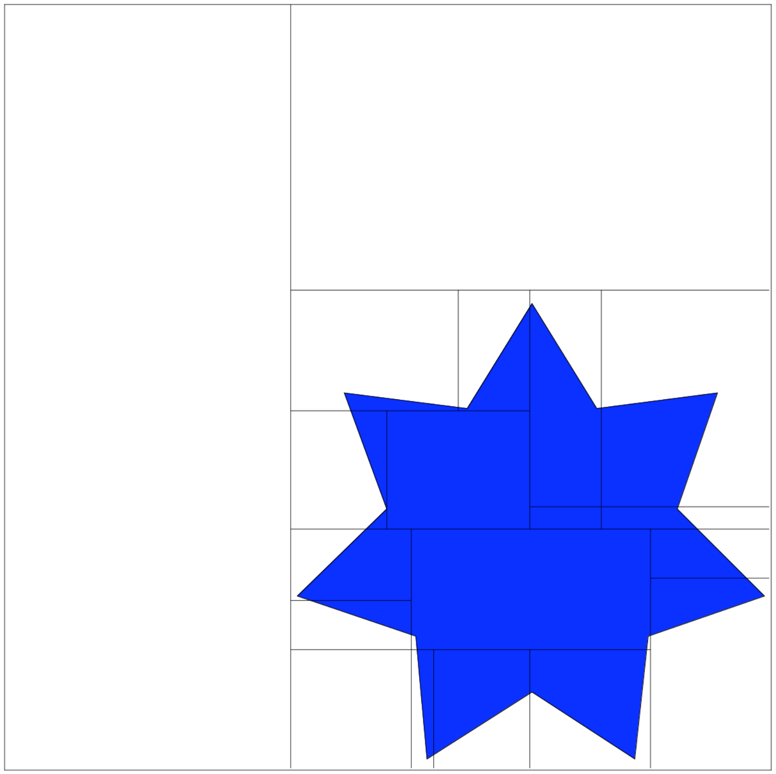
Quadtrees/Octrees

- axis-aligned
- subdivide until no points in cell



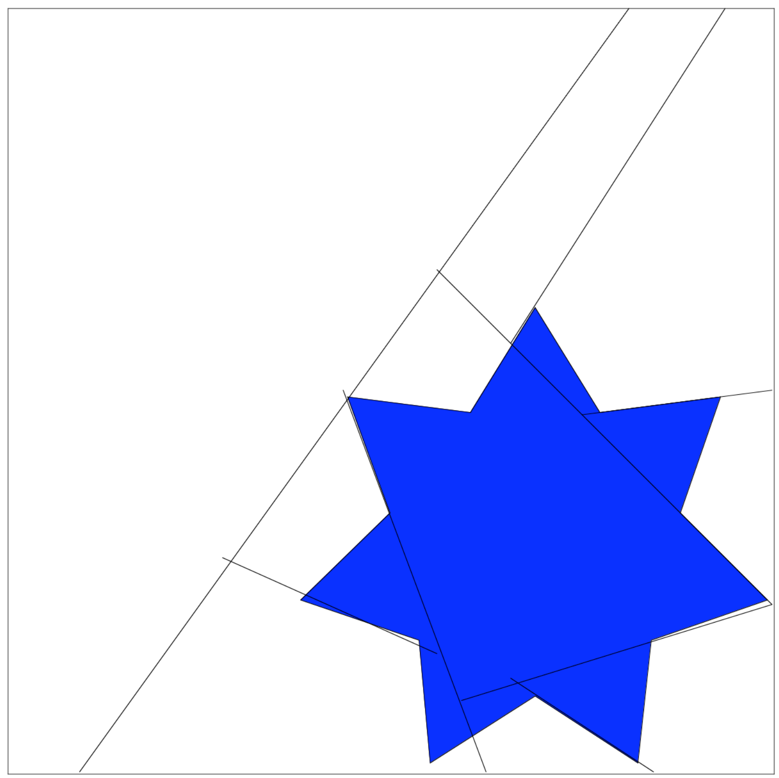
KD Trees

- axis-aligned
- subdivide in alternating dimensions

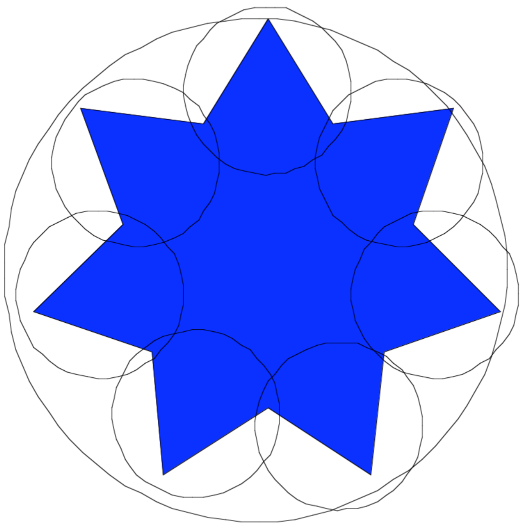


BSP Trees

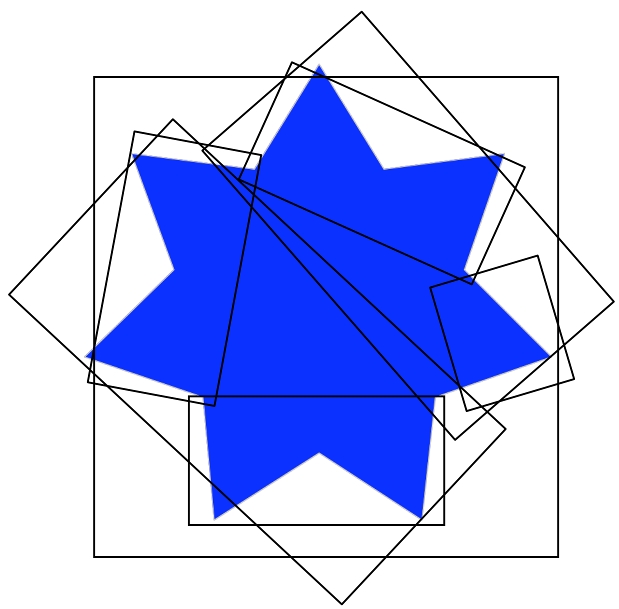
- planes at arbitrary orientation



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