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

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Procedural Approaches II, Picking

Week 10, Wed Mar 21

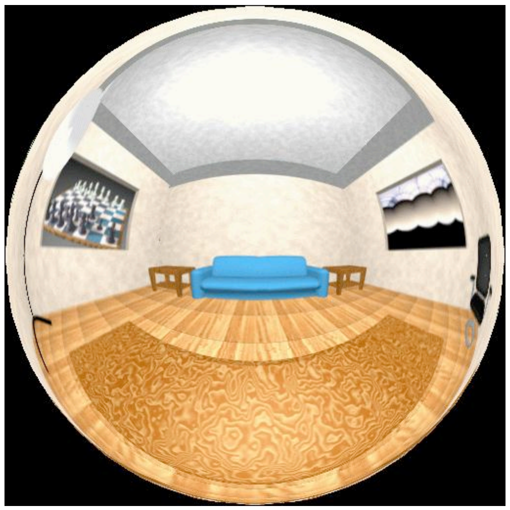
http://www.ugrad.cs.ubc.ca/~cs314/Vjan2007

News

- showing up for your project grading slot is **not** optional
  - 5 people have missed their slot, without notifying the TA in advance of the need to change
  - 2% penalty for noshows for P3 and P4

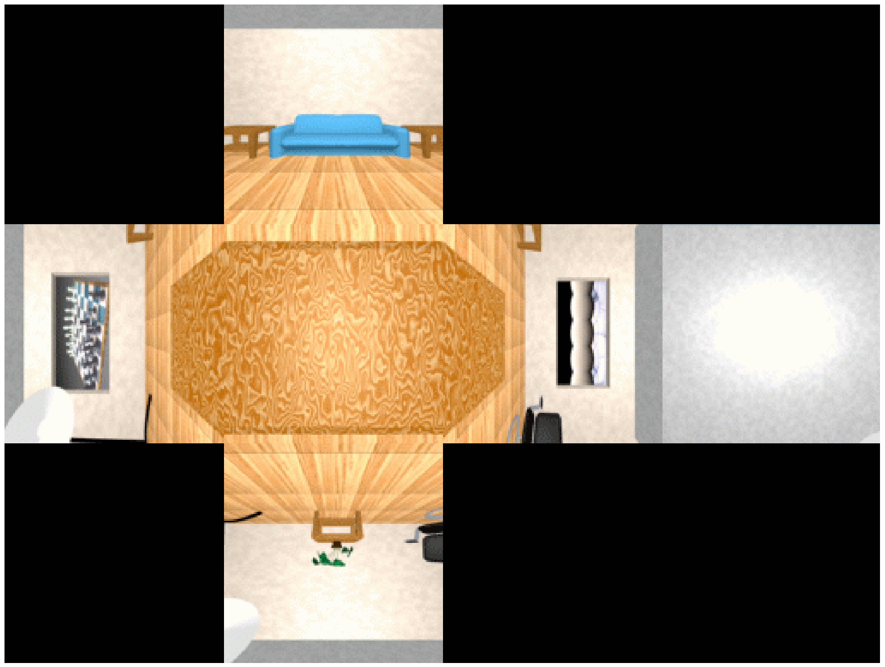
Review: Environment Mapping

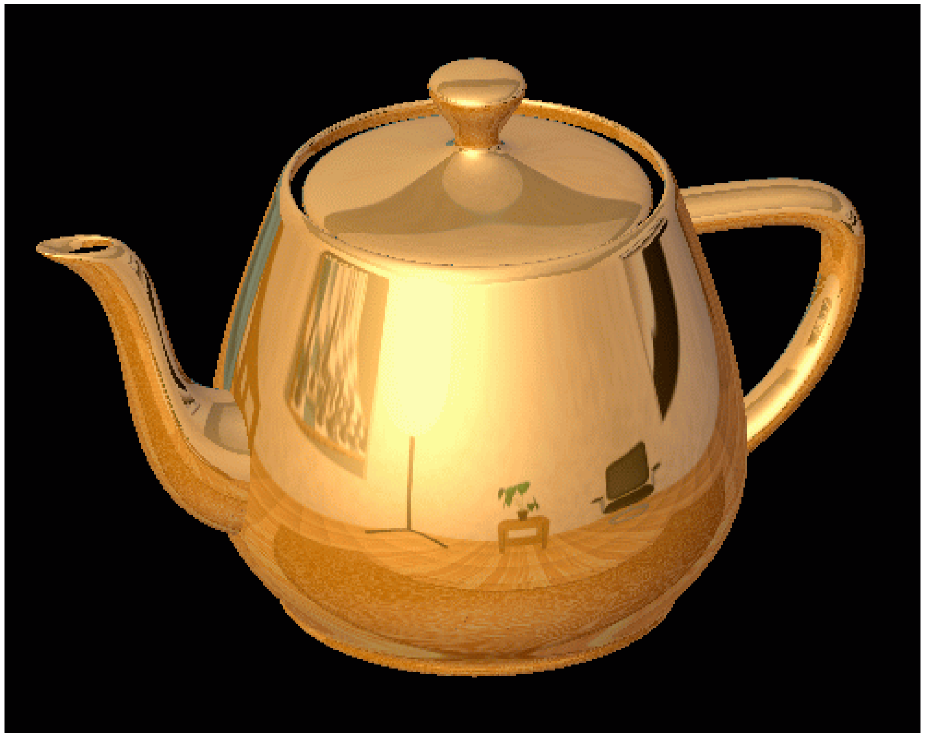
- cheap way to achieve reflective effect
    - generate image of surrounding
    - map to object as texture
- sphere mapping: texture is distorted fisheye view
    - point camera at mirrored sphere
    - use spherical texture coordinates



Review: Cube Environment Mapping

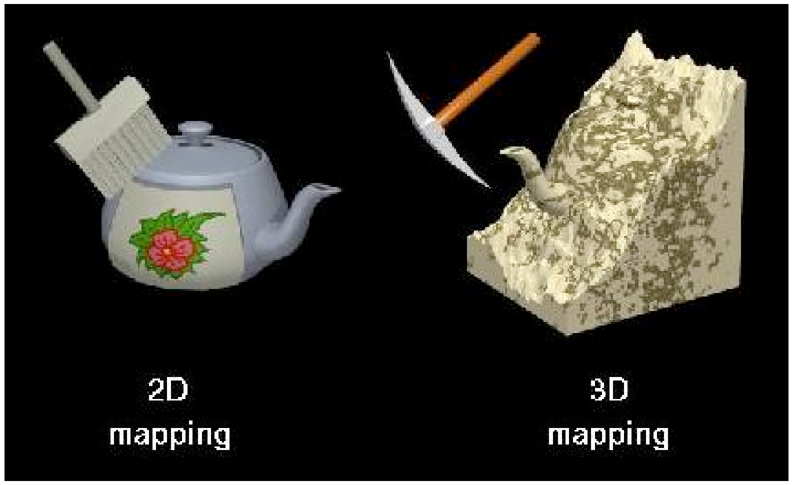
- 6 planar textures, sides of cube
  - point camera outwards to 6 faces
    - use largest magnitude of vector to pick face
    - other two coordinates for (s,t) texel location





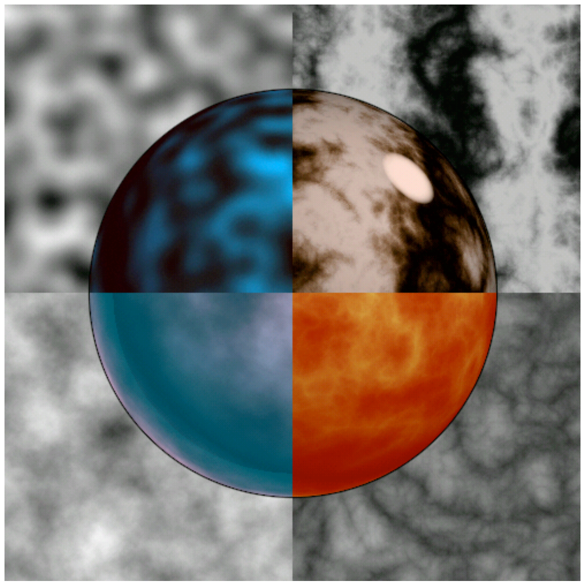
Review: Volumetric Texture

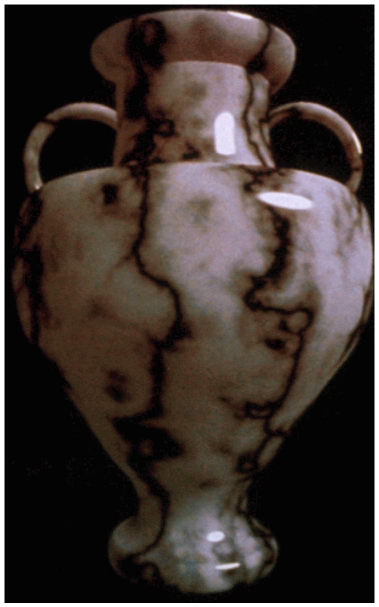
- define texture pattern over 3D domain - 3D space containing the object
  - texture function can be digitized or procedural
  - for each point on object compute texture from point location in space
- 3D function $\rho(x,y,z)$



Review: Perlin Noise: Procedural Textures

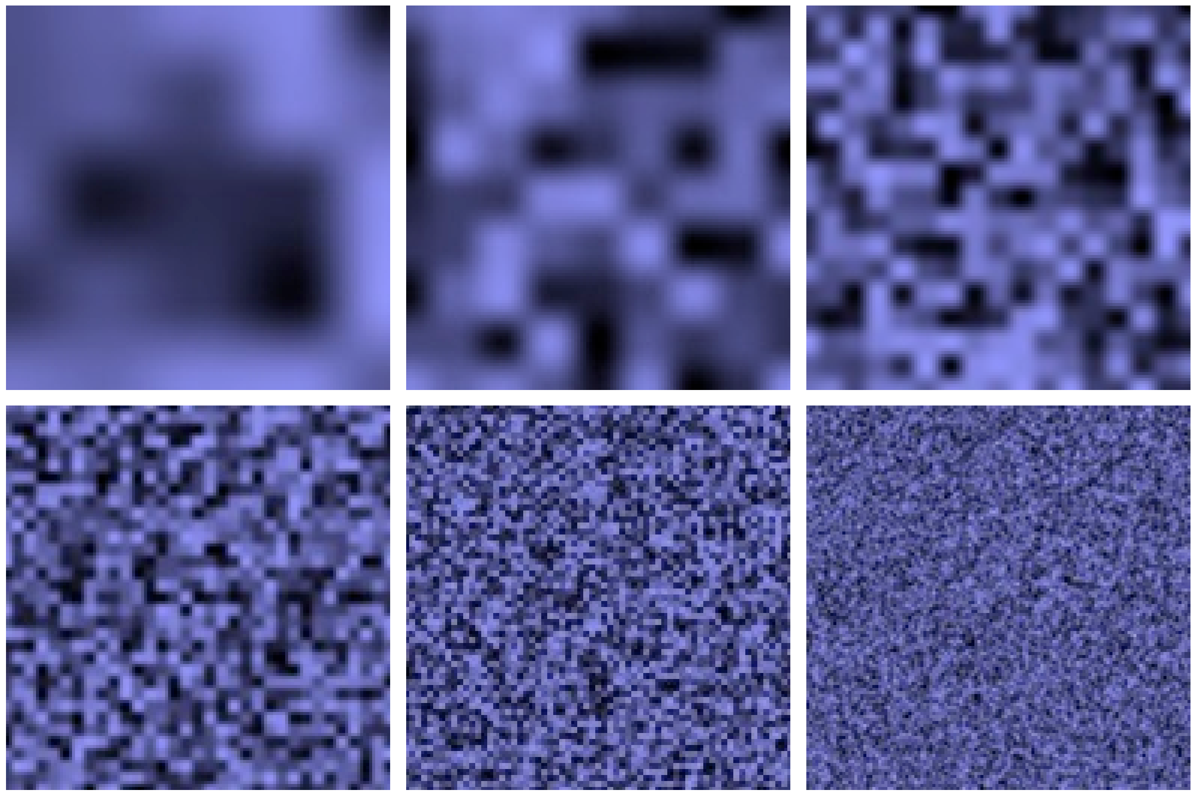
```
function marble(point)
 x = point.x + turbulence(point);
 return marble_color(sin(x))
```

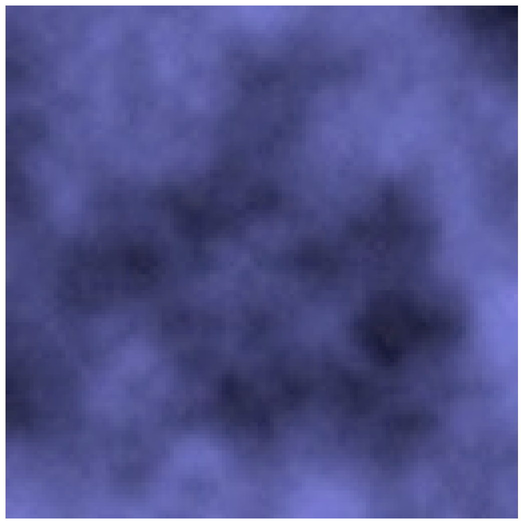




Review: Perlin Noise

- 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

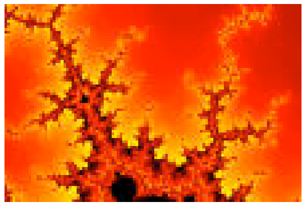
Review: Procedural Modeling

- 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

Procedural Approaches II

Fractal Landscapes

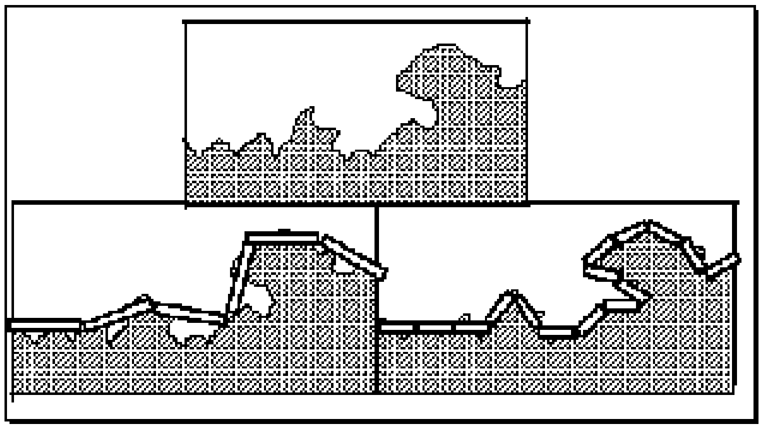
- fractals: not just for “showing math”
  - triangle subdivision
  - vertex displacement
  - recursive until termination condition



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

Self-Similarity

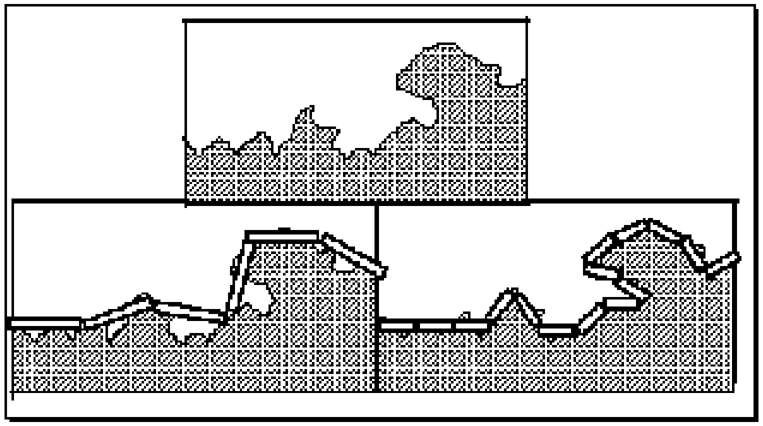
- infinite nesting of structure on all scales



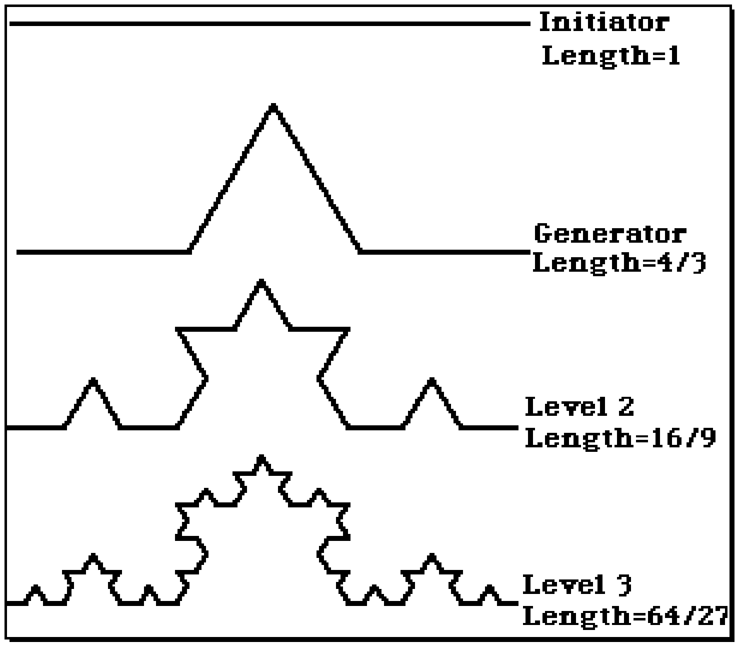
Fractal Dimension

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

coastline of Britain



Koch snowflake

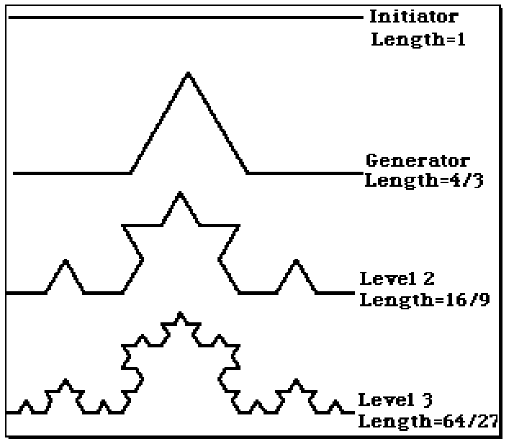


D = log(N)/log(r) D = log(4)/log(3) = 1.26

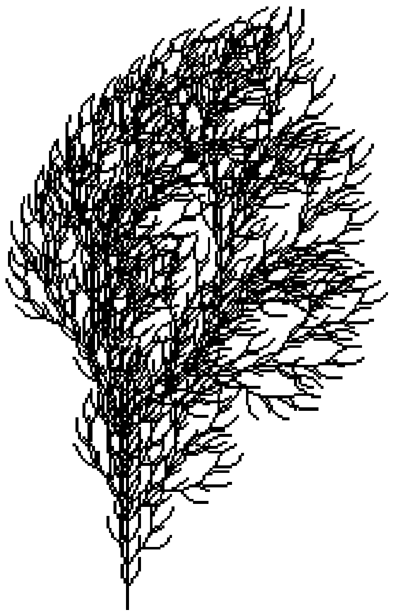
http://www.vanderbilt.edu/AnS/psychology/cogsci/chaos/workshop/Fractals.html

Language-Based Generation

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



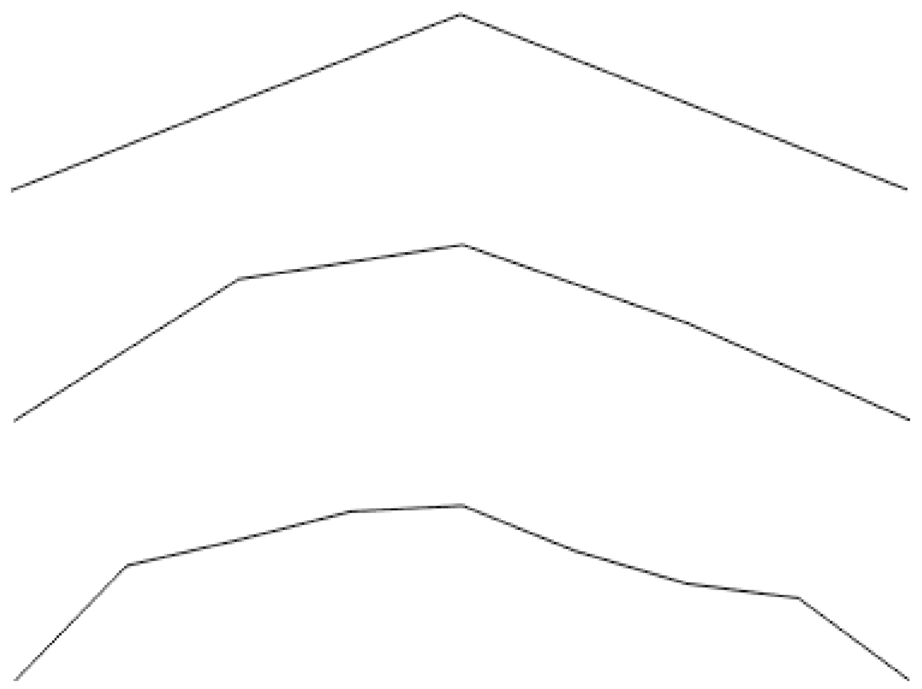
  - Mariano’s Bush:
    F=FF-[-F+F+F]+[+F-F-F] }
    - angle 16



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

1D: Midpoint Displacement

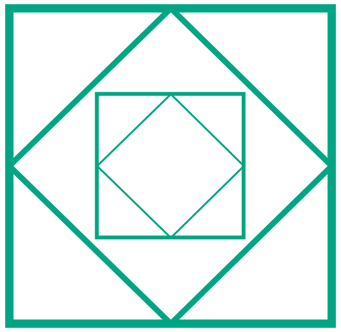
- divide in half
- randomly displace
- scale variance by half

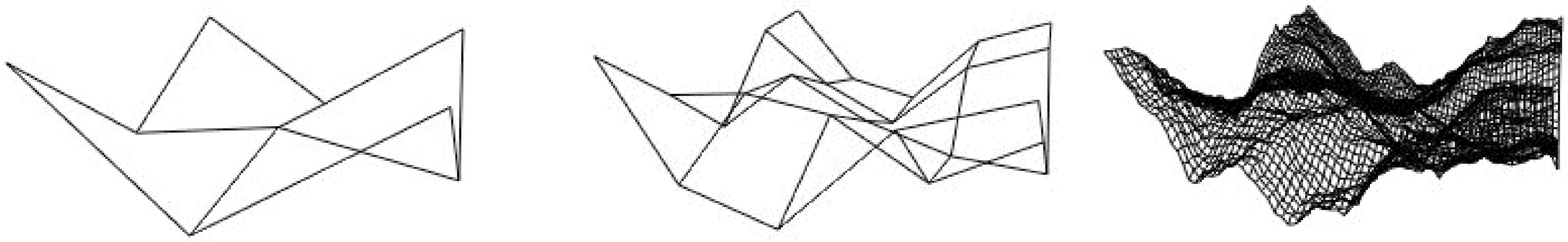


http://www.gameprogrammer.com/fractal.html

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



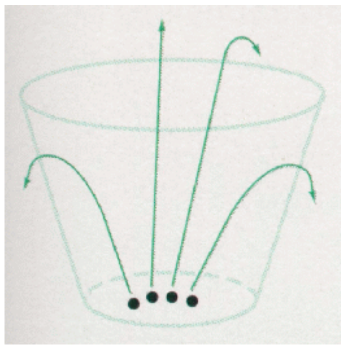


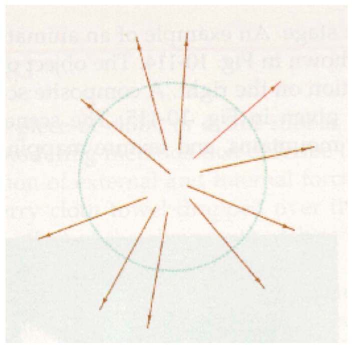
Particle Systems

- 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, explosion
- 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
  - flocking/swarming behavior
  - procedural motion
  - 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

Picking

Reading

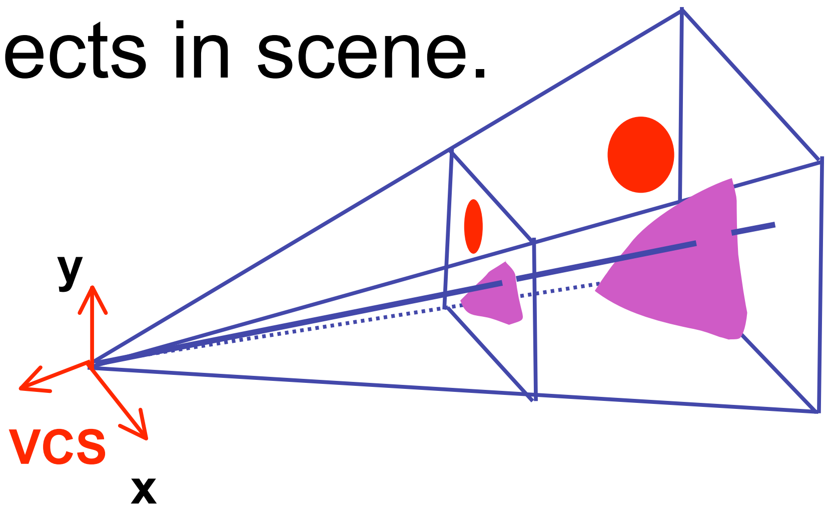
- Red Book
  - Selection and Feedback Chapter
    - all
  - Now That You Know Chapter
    - only Object Selection Using the Back Buffer

Interactive Object Selection

- move cursor over object, click
  - how to decide what is below?
- ambiguity
  - many 3D world objects map to same 2D point
- four common approaches
  - manual ray intersection
  - bounding extents
  - backbuffer color coding
  - selection region with hit list

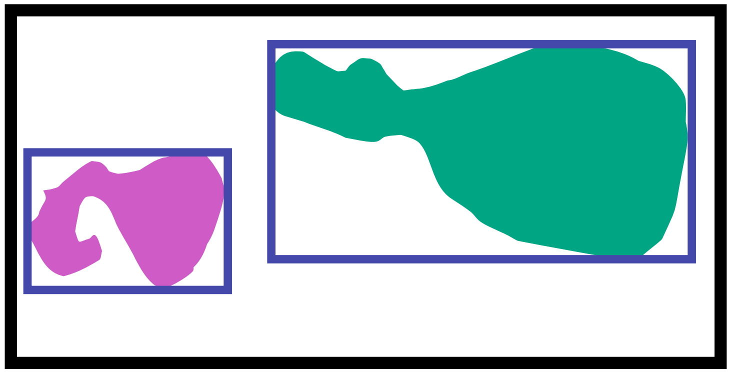
Manual Ray Intersection

- do all computation at application level
  - map selection point to a ray
  - intersect ray with all objects in scene.
- advantages
  - no library dependence
- disadvantages
  - difficult to program
  - slow: work to do depends on total number and complexity of objects in scene



Bounding Extents

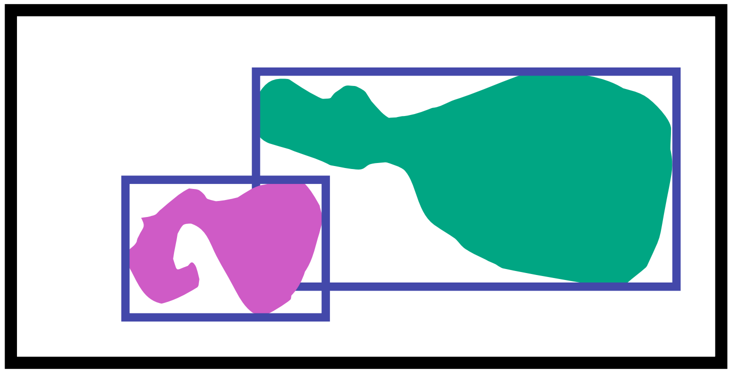
- keep track of axis-aligned bounding rectangles



- advantages
  - conceptually simple
  - easy to keep track of boxes in world space

Bounding Extents

- disadvantages
    - low precision
    - must keep track of object-rectangle relationship
- extensions
    - do more sophisticated bound bookkeeping
        - first level: box check.
        - second level: object check

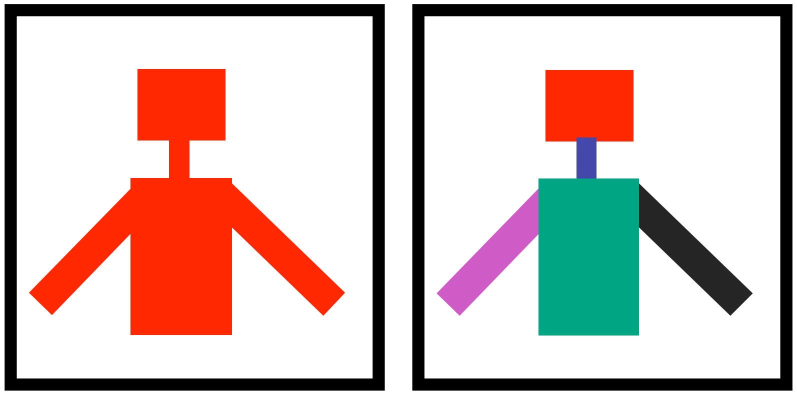


Backbuffer Color Coding

- use backbuffer for picking
  - create image as computational entity
  - never displayed to user
- redraw all objects in backbuffer
  - turn off shading calculations
  - set unique color for each pickable object
    - store in table
  - read back pixel at cursor location
    - check against table

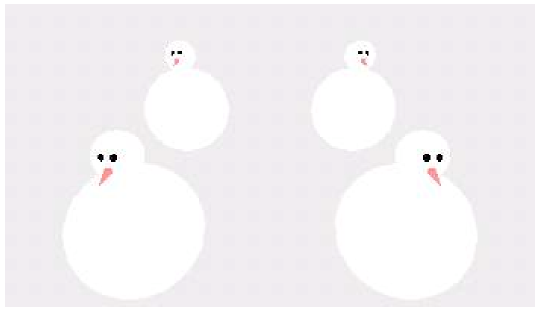
Backbuffer Color Coding

- advantages
  - conceptually simple
  - variable precision
- disadvantages
  - introduce 2x redraw delay
  - backbuffer readback very slow

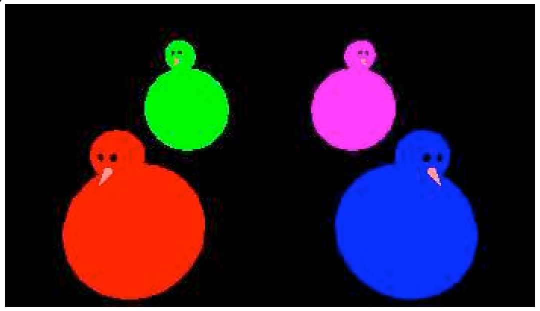


Backbuffer Example

```
glColor3f(1.0f, 1.0f, 1.0f);
for(int i = 0; i < 2; i++)
    for(int j = 0; j < 2; j++) {
        glPushMatrix();
        glTranslatef(i*3.0,0,-j * 3.0);
        glColor3f(1.0f, 1.0f, 1.0f);
        glCallList(snowman_display_list);
        glPopMatrix();
  }
```



```
for(int i = 0; i < 2; i++)
  for(int j = 0; j < 2; j++) {
    glPushMatrix();
    switch (i*2+j) {
      case 0: glColor3ub(255,0,0);break;
      case 1: glColor3ub(0,255,0);break;
      case 2: glColor3ub(0,0,255);break;
      case 3: glColor3ub(250,0,250);break;
    }
    glTranslatef(i*3.0,0,-j * 3.0)
    glCallList(snowman_display_list);
    glPopMatrix();
}
```



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

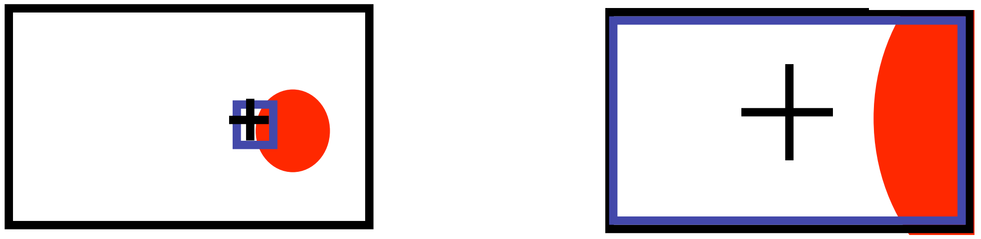
Select/Hit

- 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

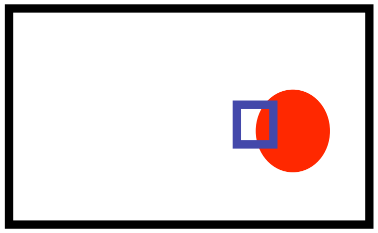
- small rectangle around cursor
  - change coord sys so fills viewport



- 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

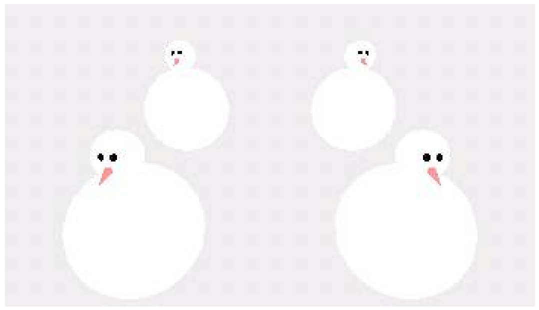
- glRenderMode(mode)
  - GL_RENDER: normal color buffer
    - default
  - GL_SELECT: selection mode for picking
  - (GL_FEEDBACK: report objects drawn)

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();
}
```



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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