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

Tamara Munzner

Textures III, Procedural Approaches

Week 10, Mon Mar 19

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

Reading for Last Time and Today

- FCG Chap 11 Texture Mapping
  - except 11.8
- RB Chap Texture Mapping
- FCG Sect 16.6 Procedural Techniques
- FCG Sect 16.7 Groups of Objects

Final Clarification: HSI/HSV and RGB

- HSV/HSI conversion from RGB
  - hue same in both
  - value is max, intensity is average

$$H = \cos^{-1}\left[\frac{\frac{1}{2}\left[(R-G)+(R-B)\right]}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right] \quad \boxed{\begin{array}{l}\text{if (B > G),}\\ H = 360 - H\end{array}}$$

- HSI: $S = 1 - \dfrac{\min(R,G,B)}{I}$ $\quad I = \dfrac{R+G+B}{3}$
- HSV: $S = 1 - \dfrac{\min(R,G,B)}{V}$ $\quad V = \max(R,G,B)$

News

- H3 Q2:
  - full credit for using either HSV or HIS
  - full credit even if do not do final 360-H step
- H3 Q4 typo
  - P1 typo, intended to be r=.5, g=.7, b=.1
  - also full credit for r=.5, b=.7, g=.1

News

- Project 3 grading slot signups
  - Mon 11-12
  - Tue 10-12:30, 4-6
  - Wed 11-12, 2:30-4

- go to lab after class to sign up if you weren't here on Friday
- everybody needs to sign up for grading slot!

News

- Project 1 Hall of Fame
  http://www.ugrad.cs.ubc.ca/~cs314/Vjan2007/p1hof

- Project 4 writeup
  - proposals due this Friday at 3pm
  - project due Fri Apr 13 at 6pm

- Homework 4 out later
- Midterm upcoming, Wed Mar 28

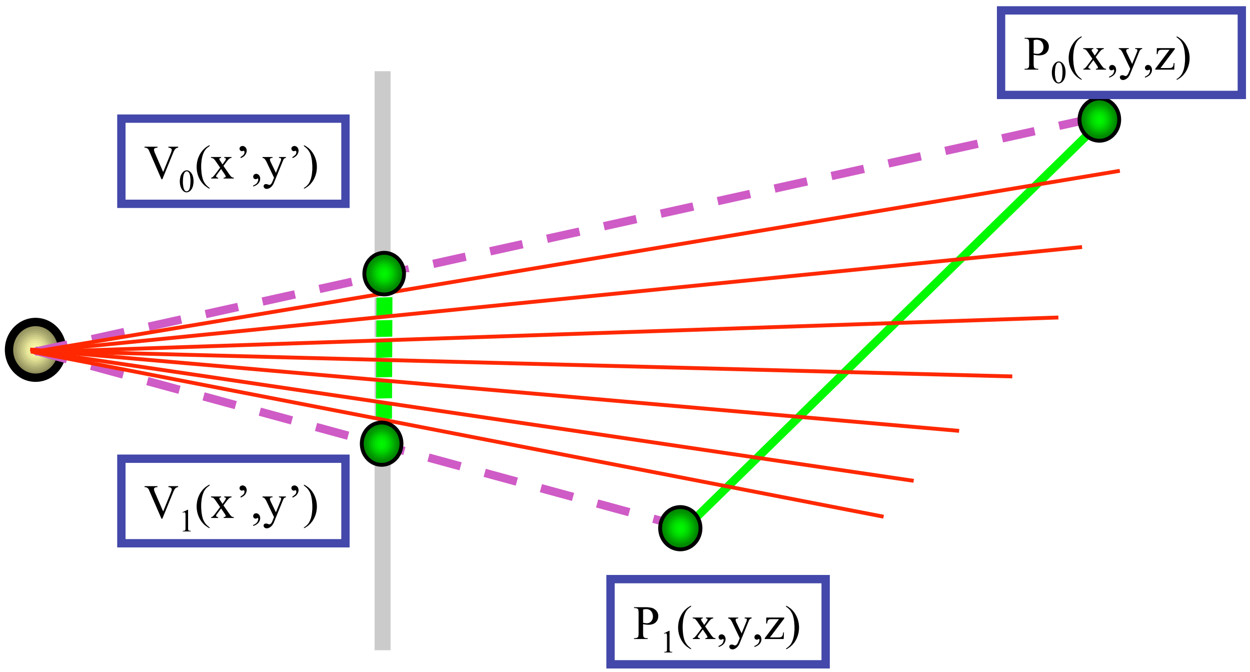
Review: Basic OpenGL Texturing

- setup
  - generate identifier: `glGenTextures`
  - load image data: `glTexImage2D`
  - set texture parameters (tile/clamp/...): `glTexParameteri`
  - set texture drawing mode (modulate/replace/...): `glTexEnvf`
- drawing
  - enable: `glEnable`
  - bind specific texture: `glBindTexture`
  - specify texture coordinates before each vertex: `glTexCoord2f`

Review: Perspective Correct Interpolation

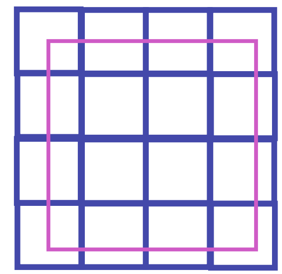
- screen space interpolation incorrect

$$s = \frac{\alpha \cdot s_0 / w_0 + \beta \cdot s_1 / w_1 + \gamma \cdot s_2 / w_2}{\alpha / w_0 + \beta / w_1 + \gamma / w_2}$$

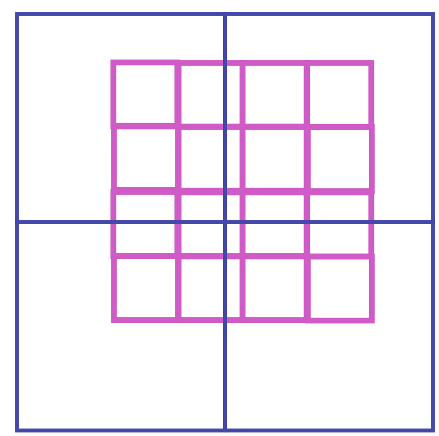


Review: Reconstruction

- how to deal with:
  - pixels that are much larger than texels?
    - apply filtering, “averaging”

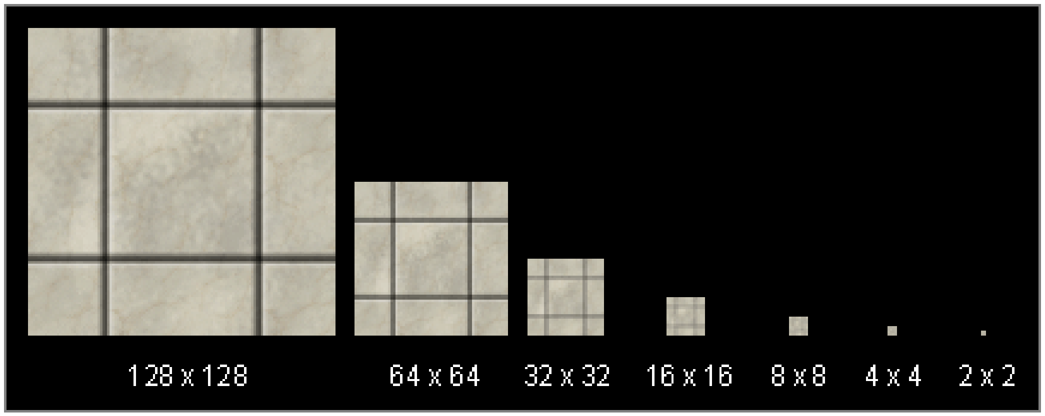


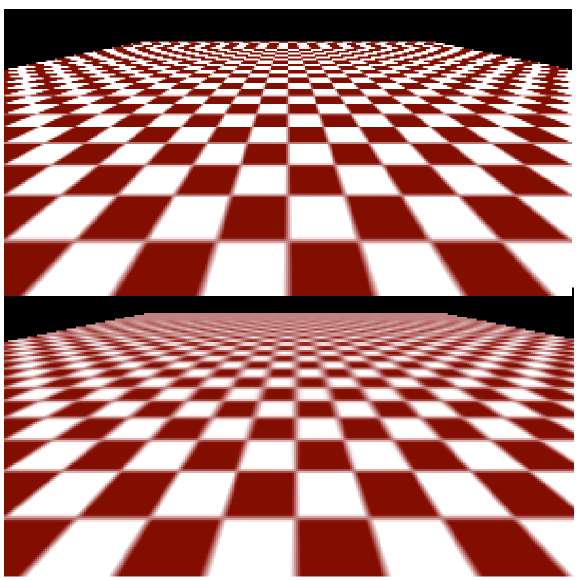
  - pixels that are much smaller than texels ?
    - interpolate

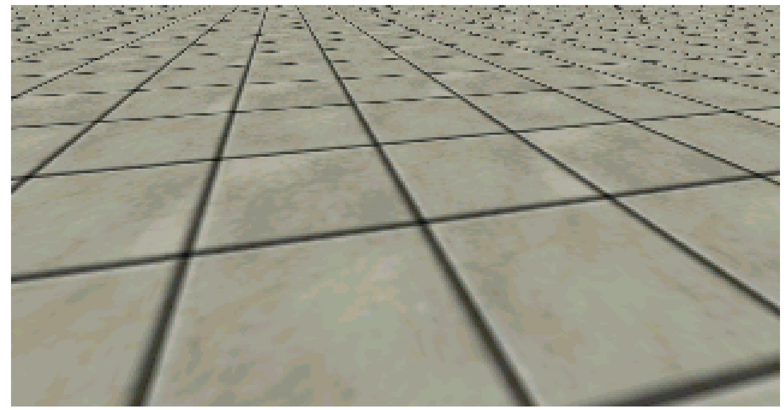


Review: MIPmapping

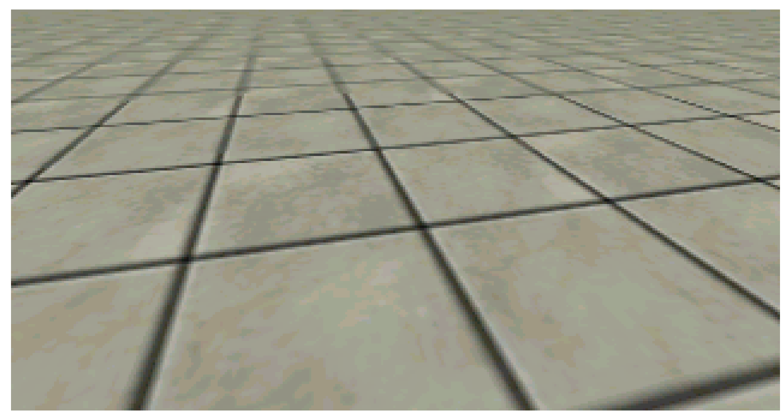
- image pyramid, precompute averaged versions







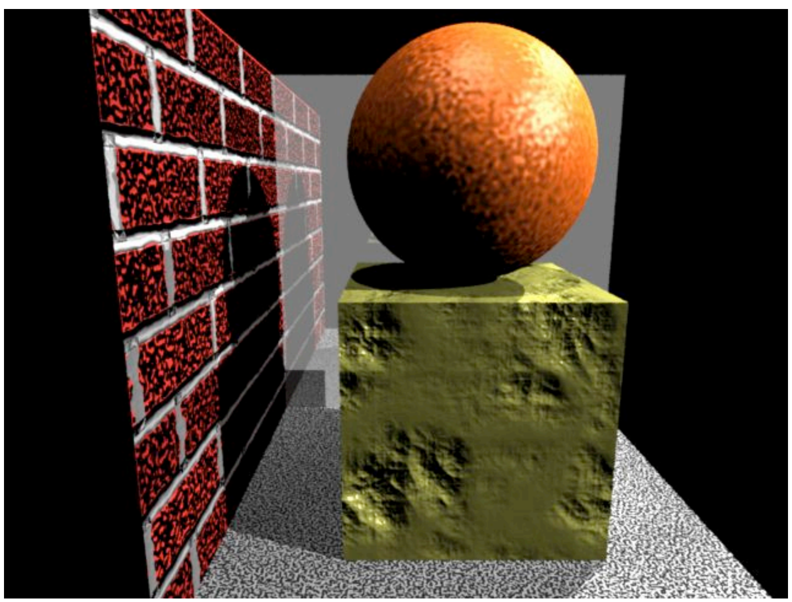
Without MIP-mapping

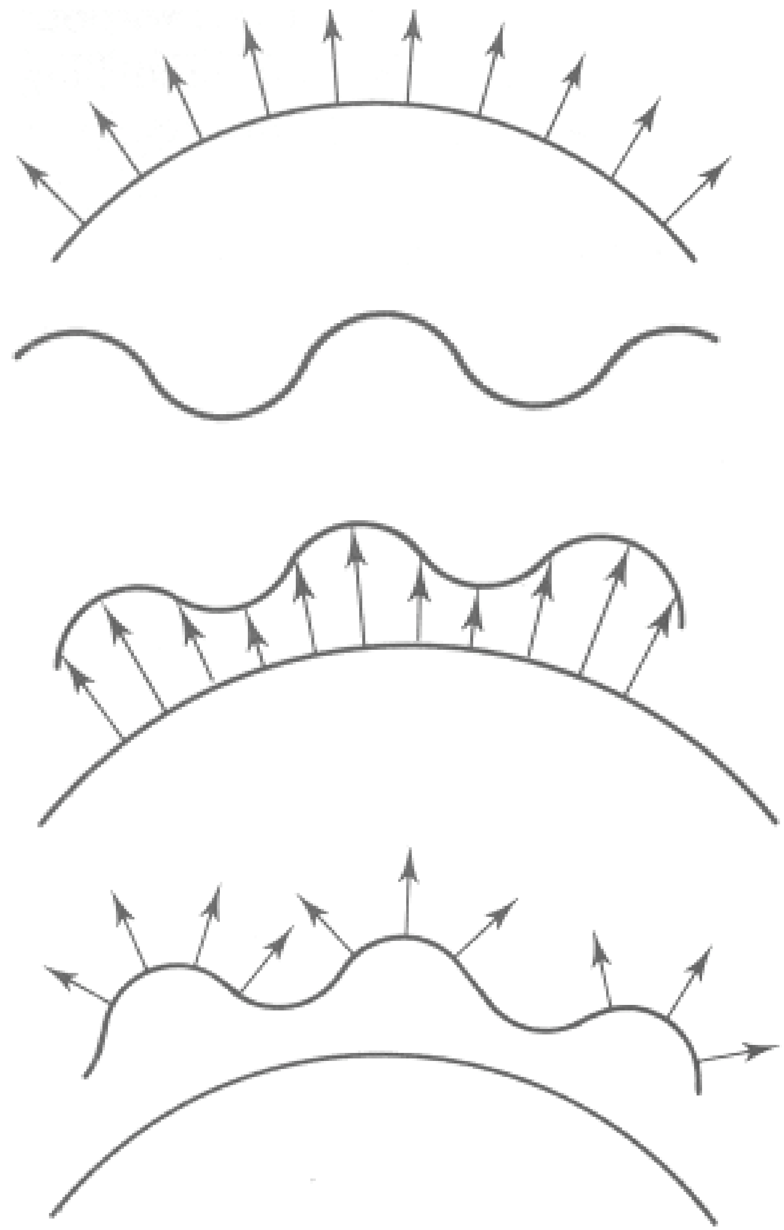


With MIP-mapping

Review: Bump Mapping: Normals As Texture

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

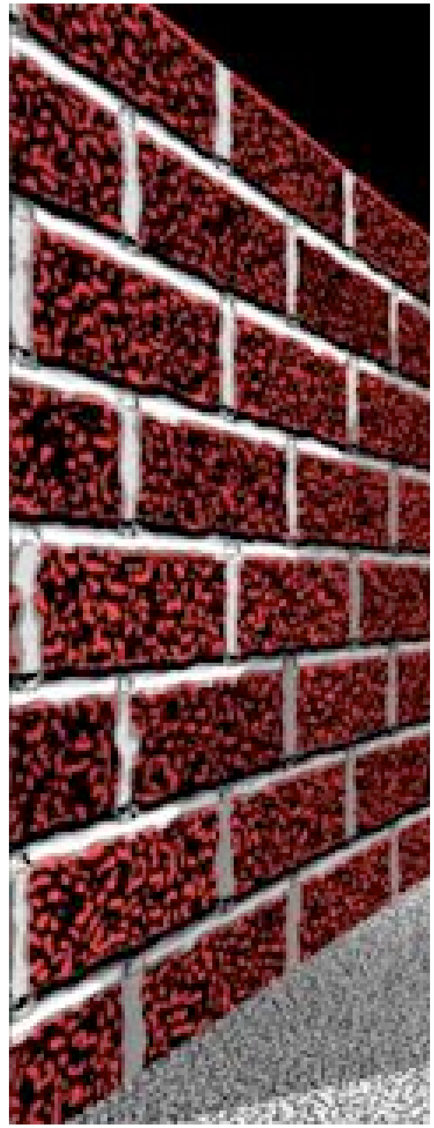




Texturing III

Displacement Mapping

- bump mapping gets silhouettes wrong
  - shadows wrong too
- change surface geometry instead
  - only recently available with realtime graphics
  - need to subdivide surface



Environment Mapping

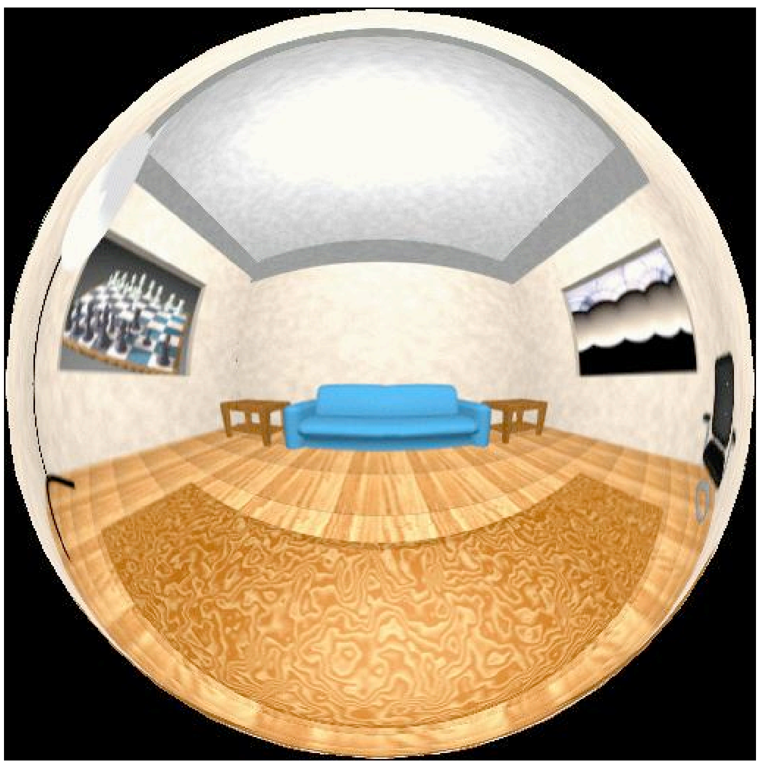
- cheap way to achieve reflective effect
  - generate image of surrounding
  - map to object as texture

Environment Mapping

- used to model object that reflects surrounding textures to the eye
  - movie example: cyborg in Terminator 2
- different approaches
  - sphere, cube most popular
    - OpenGL support
      - `GL_SPHERE_MAP, GL_CUBE_MAP`
  - others possible too

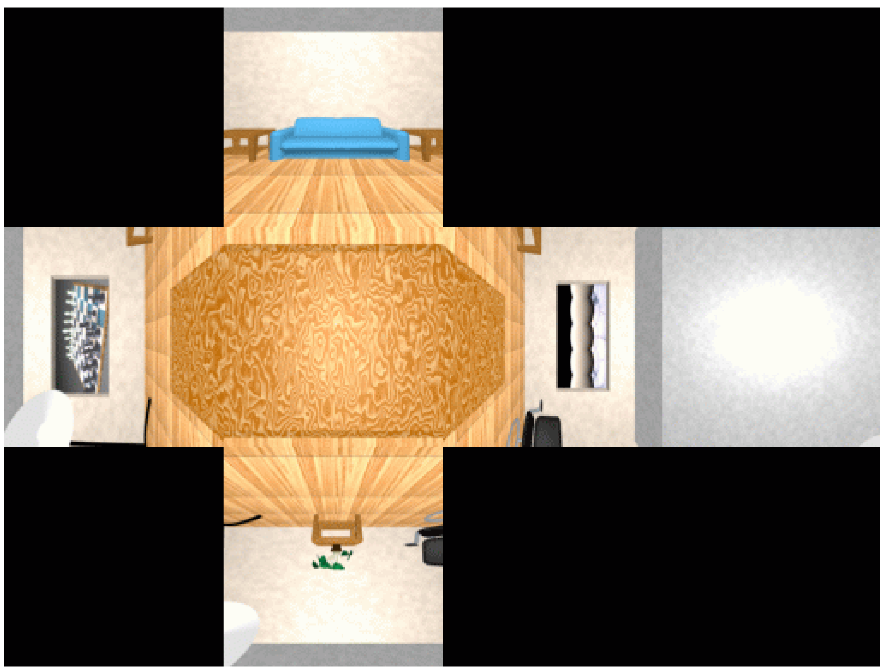
Sphere Mapping

- texture is distorted fish-eye view
  - point camera at mirrored sphere
  - spherical texture mapping creates texture coordinates that correctly index into this texture map

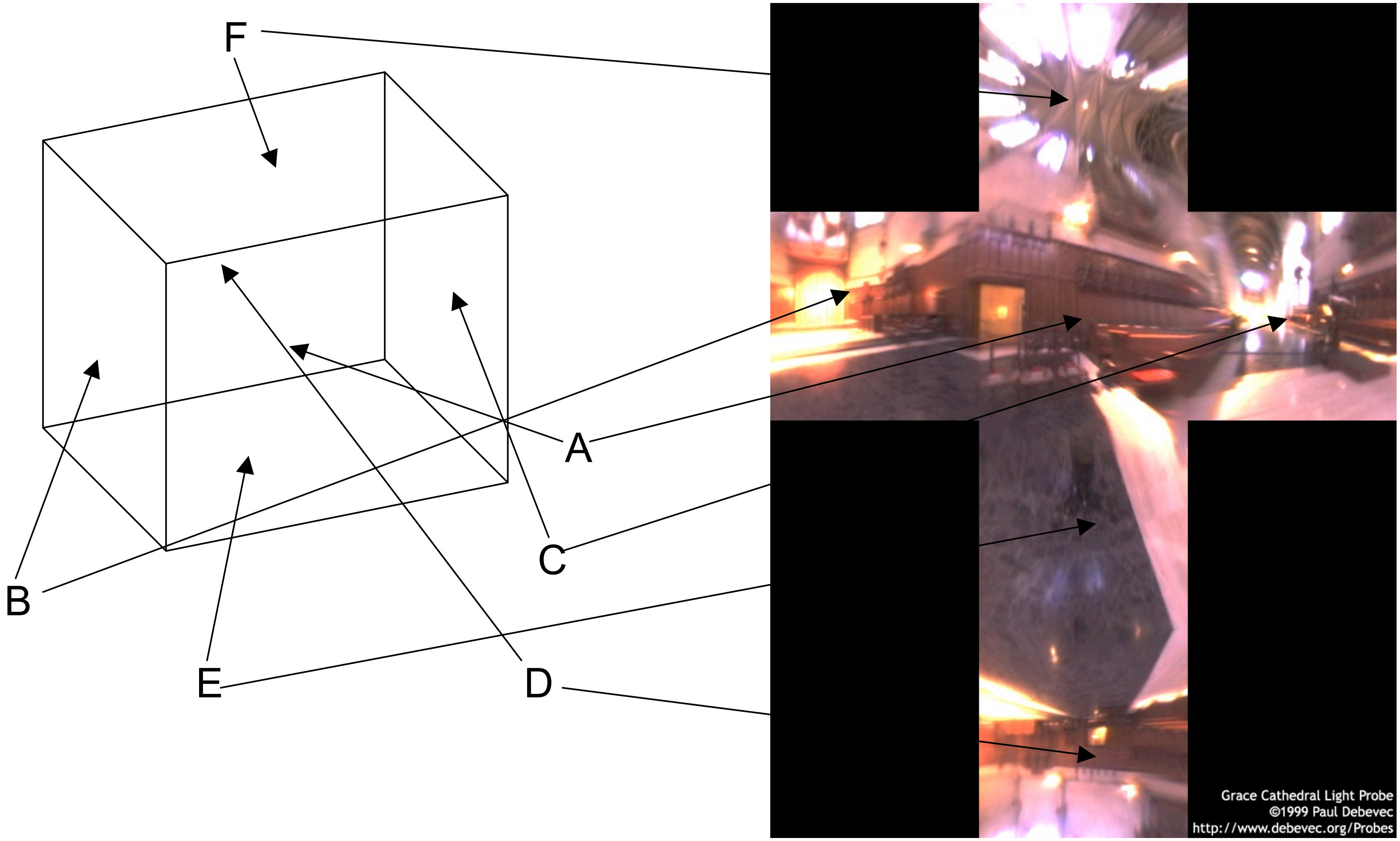


Cube Mapping

- 6 planar textures, sides of cube
  - point camera in 6 different directions, facing out from origin



Cube Mapping

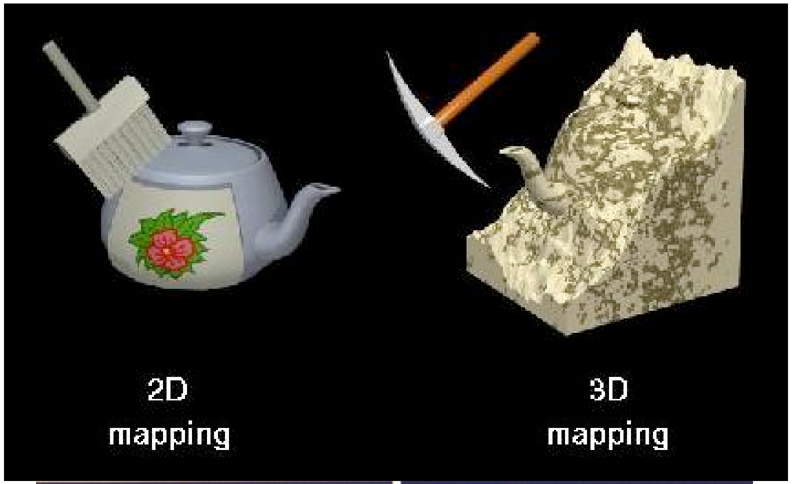


Cube Mapping

- direction of reflection vector *r* selects the face of the cube to be indexed
  - co-ordinate with largest magnitude
    - e.g., the vector (-0.2, 0.5, -0.84) selects the –Z face
  - remaining two coordinates (normalized by the 3rd coordinate) selects the pixel from the face.
    - e.g., (-0.2, 0.5) gets mapped to (0.38, 0.80).
- difficulty in interpolating across faces

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
- common for natural material/irregular textures (stone, wood,etc…)



Volumetric Bump Mapping

Marble

Bump

Volumetric Texture Principles

- 3D function $\rho(x,y,z)$
- texture space – 3D space that holds the texture (discrete or continuous)
- rendering: for each rendered point P(x,y,z) compute $\rho(x,y,z)$
- volumetric texture mapping function/space transformed with objects

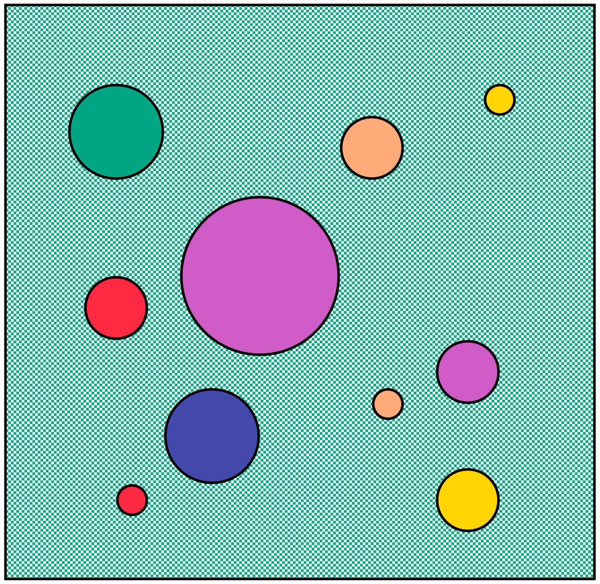
Procedural Approaches

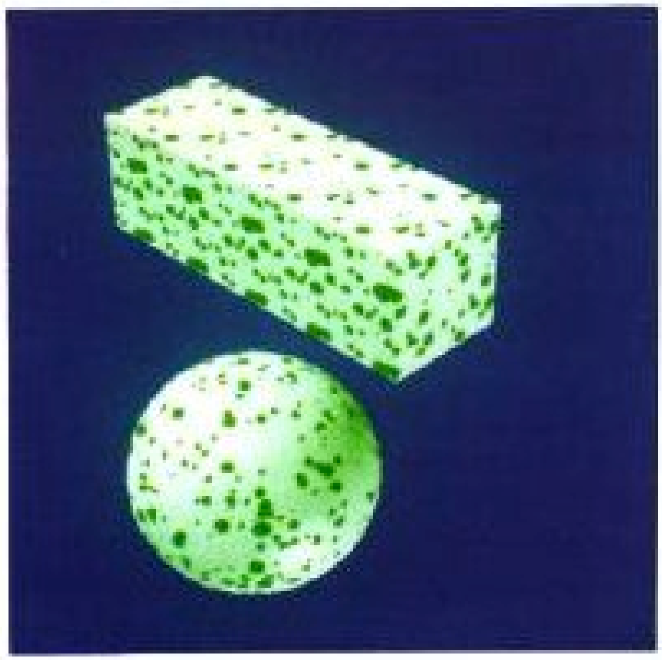
Procedural Textures

- generate “image” on the fly, instead of loading from disk
  - often saves space
  - allows arbitrary level of detail

Procedural Texture Effects: Bombing

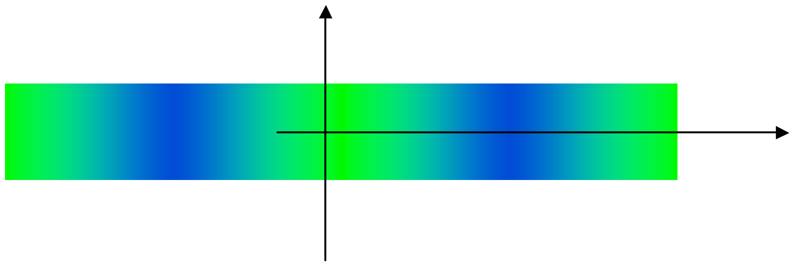
- randomly drop bombs of various shapes, sizes and orientation into texture space (store data in table)
  - for point P search table and determine if inside shape
    - if so, color by shape
    - otherwise, color by objects color





Procedural Texture Effects

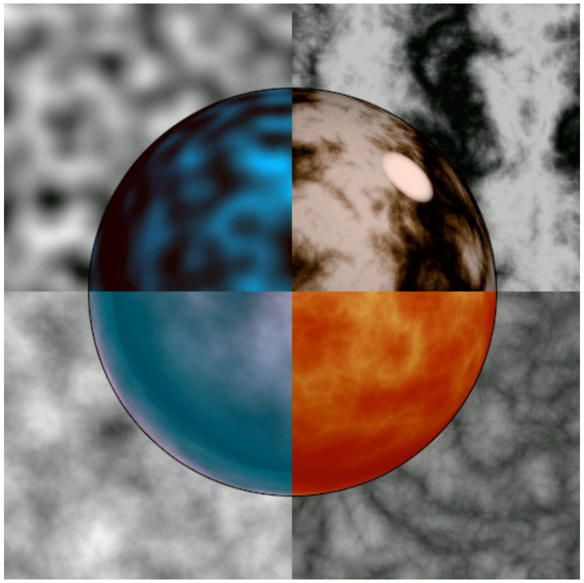
- simple marble

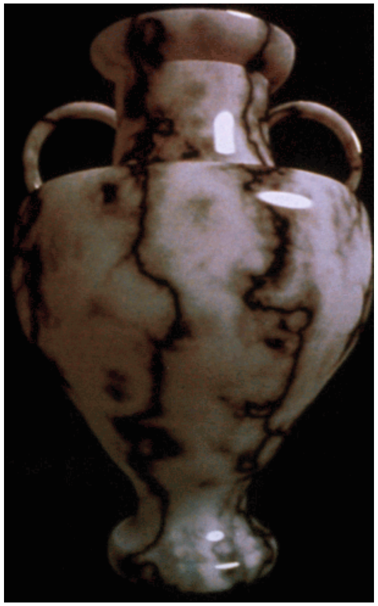


```
function boring_marble(point)
   x = point.x;
   return marble_color(sin(x));
   // marble_color maps scalars to colors
```

Perlin Noise: Procedural Textures

- several good explanations
  - FCG Section 10.1
  - http://www.noisemachine.com/talk1
  - http://freespace.virgin.net/hugo.elias/models/m_perlin.htm
  - http://www.robo-murito.net/code/perlin-noise-math-faq.html



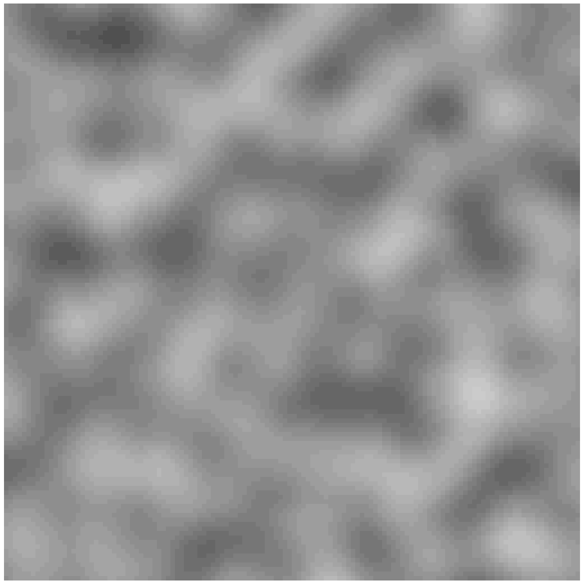


http://mrl.nyu.edu/~perlin/planet/

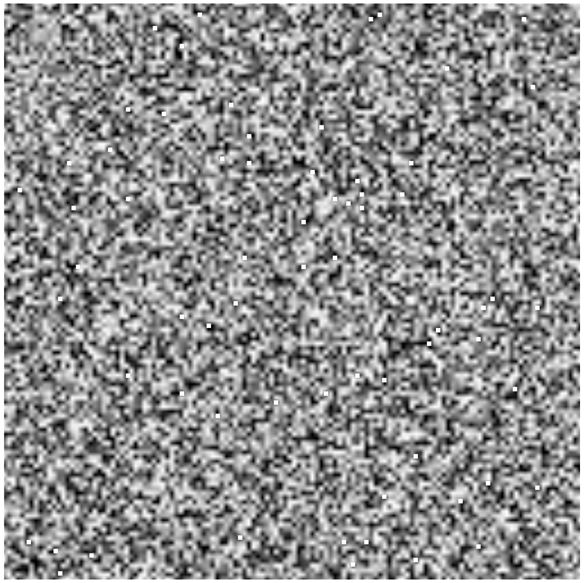
Perlin Noise: Coherency

- smooth not abrupt changes

coherent

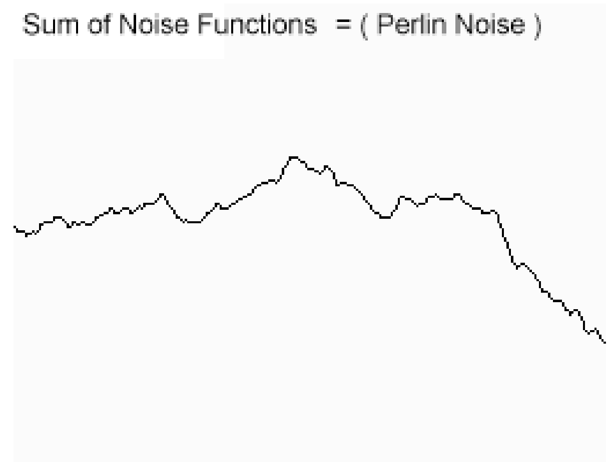


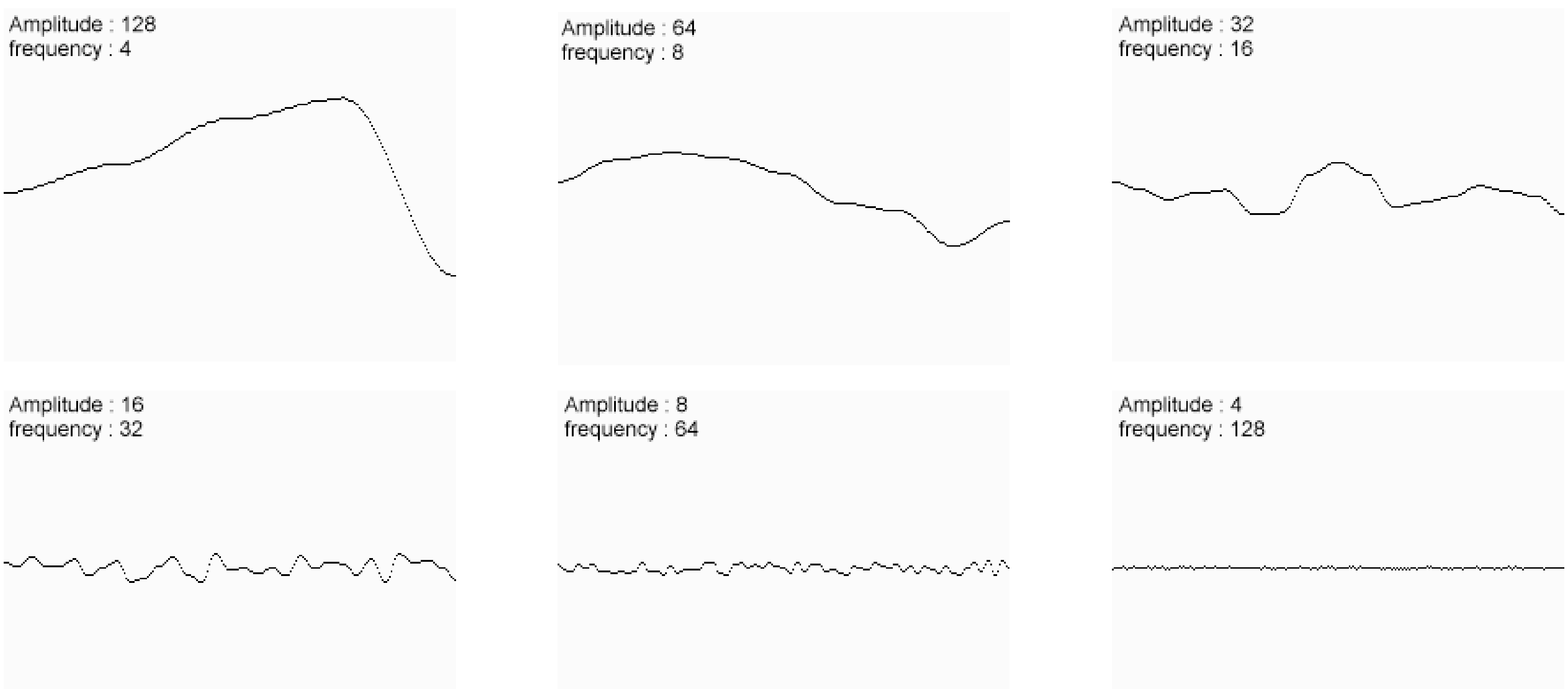
white noise



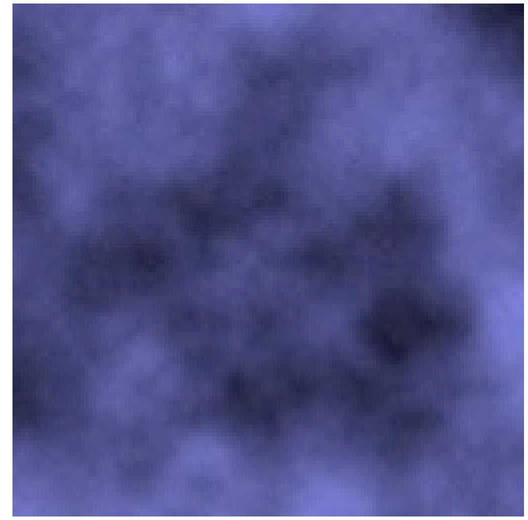
Perlin Noise: Turbulence

- multiple feature sizes
  - add scaled copies of noise

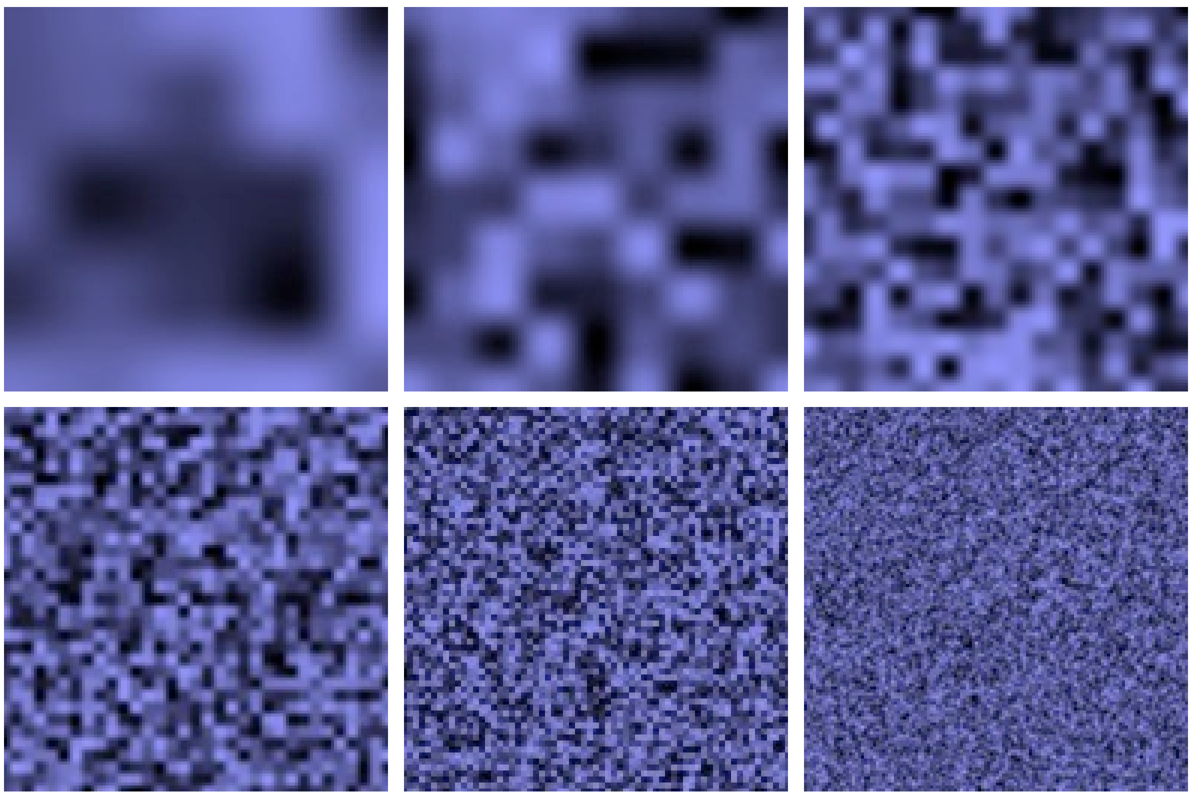




Perlin Noise: Turbulence

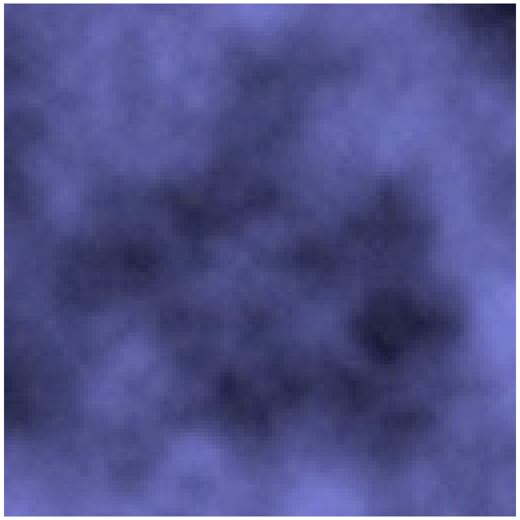


- multiple feature sizes
  - add scaled copies of noise



Perlin Noise: Turbulence

- multiple feature sizes
  - add scaled copies of noise



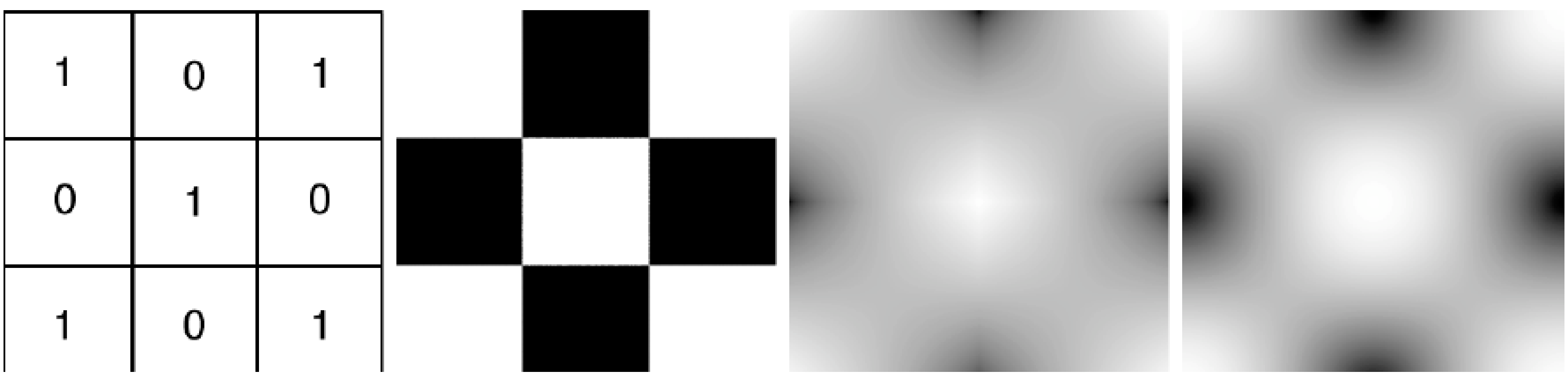
```
function turbulence(p)
        t = 0; scale = 1;
        while (scale > pixelsize) {
                t +=
abs(Noise(p/scale)*scale);
                scale/=2;
        } return t;
```

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

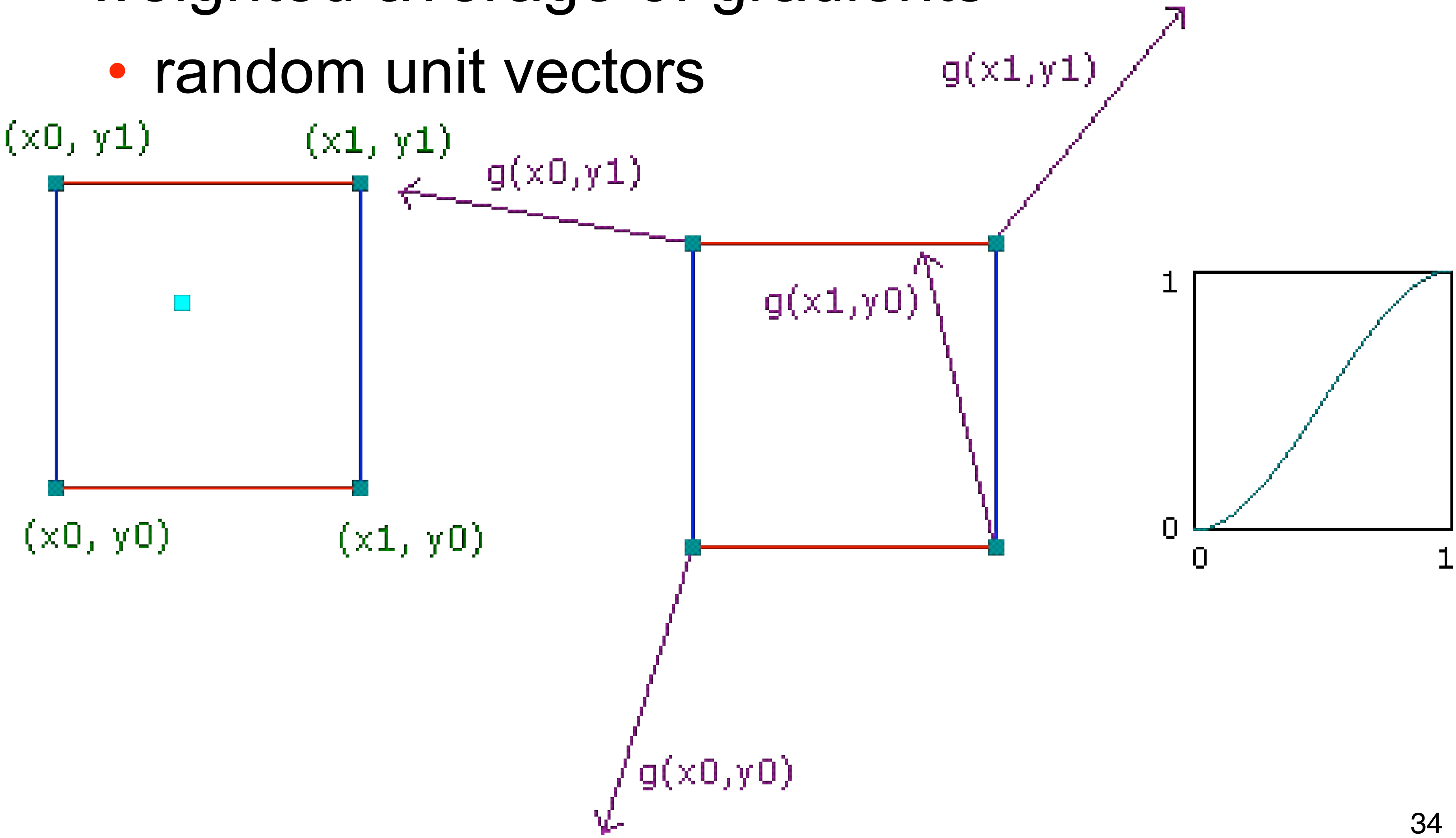
Interpolating Textures

- nearest neighbor
- bilinear
- hermite



Vector Offsets From Grid

- weighted average of gradients
  - random unit vectors



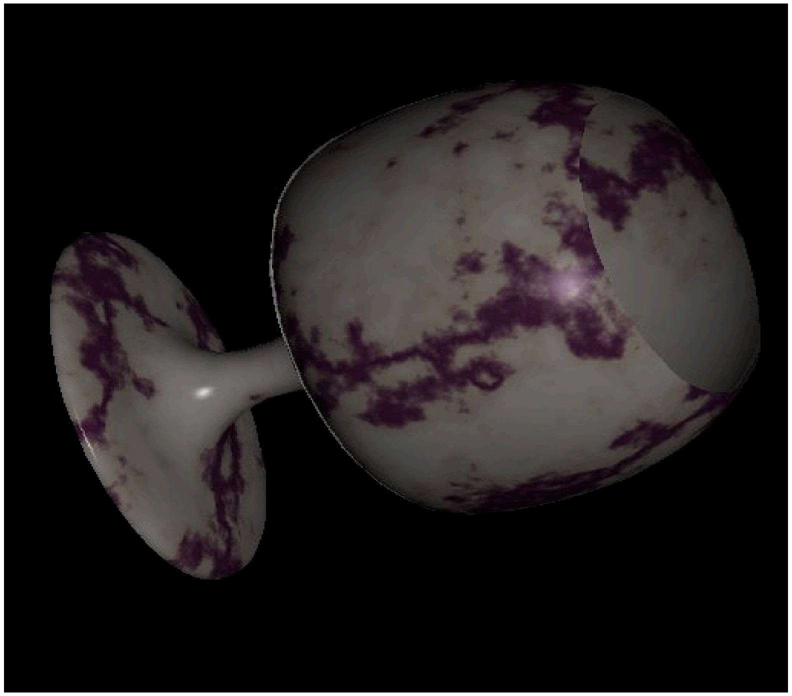
Optimization

- save memory and time
- conceptually:
  - 2D or 3D grid
  - populate with random number generator
- actually:
  - precompute two 1D arrays of size n (typical size 256)
    - random unit vectors
    - permutation of integers 0 to n-1
  - lookup
    - $g(i, j, k) = G[\,(\, i + P[\,(j + P[k]) \bmod n\,]\,) \bmod n\,]$

Perlin Marble

- use turbulence, which in turn uses noise:

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



Procedural Modeling

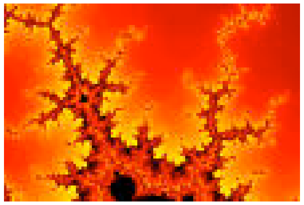
- textures, geometry
  - nonprocedural: explicitly stored in memory

- procedural approach
  - compute something on the fly
  - often less memory cost
  - visual richness

- fractals, particle systems, noise

Fractal Landscapes

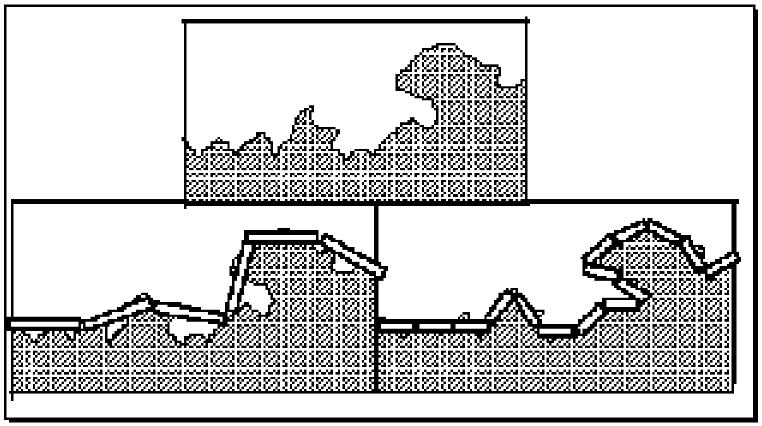
- fractals: not just for “showing math”
  - triangle subdivision
  - vertex displacement
  - recursive until termination condition



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

Self-Similarity

- infinite nesting of structure on all scales

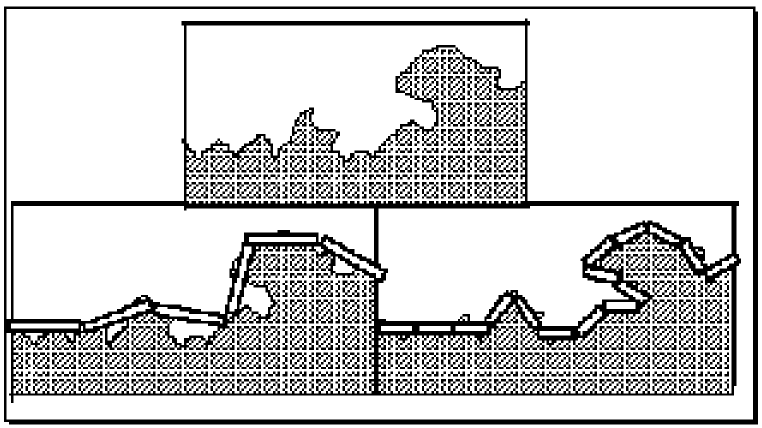


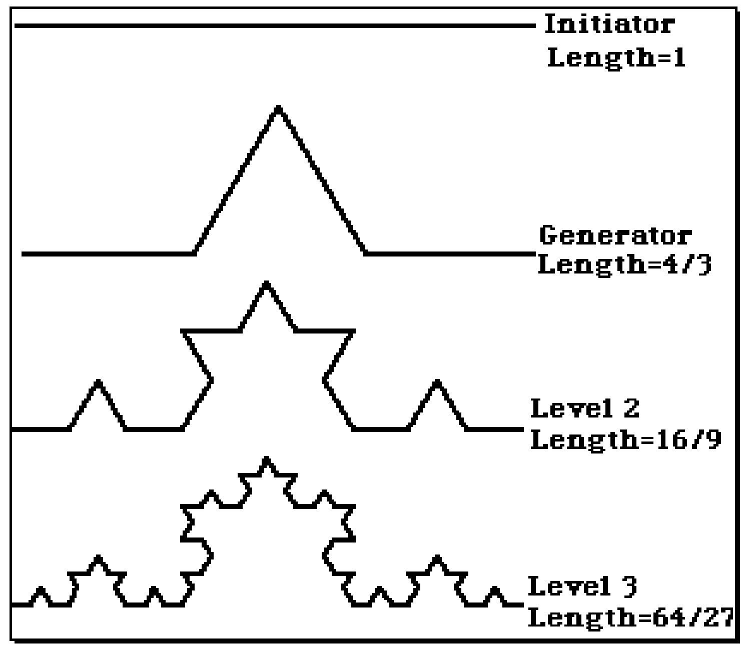
Fractal Dimension

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

Koch snowflake

coastline of Britain



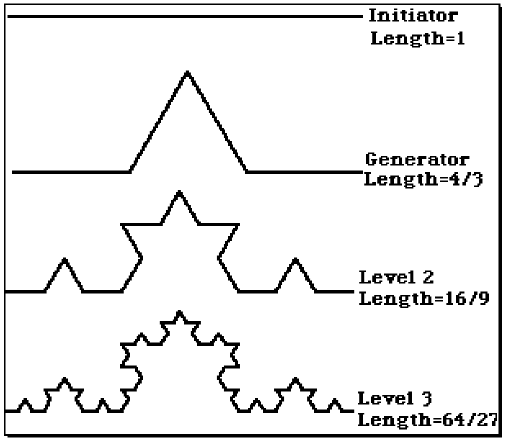


D = log(N)/log(r) D = log(4)/log(3) = 1.26

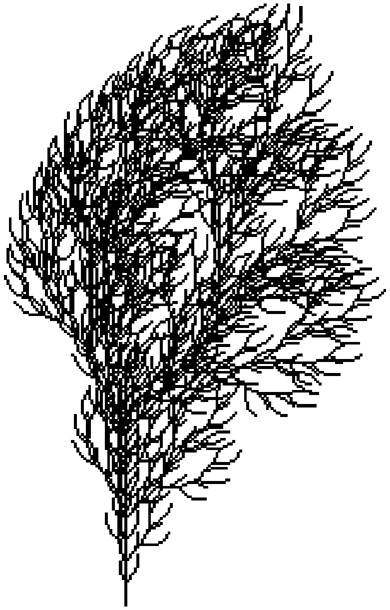
http://www.vanderbilt.edu/AnS/psychology/cogsci/chaos/workshop/Fractals.html

Language-Based Generation

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



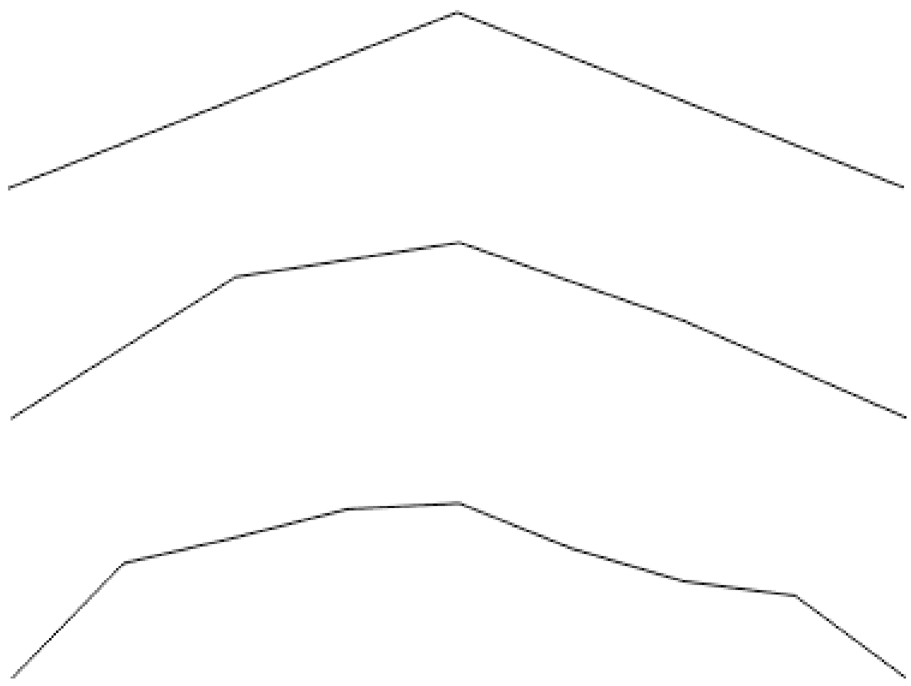
  - Mariano's Bush:
    F=FF-[-F+F+F]+[+F-F-F] }
    - angle 16



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

1D: Midpoint Displacement

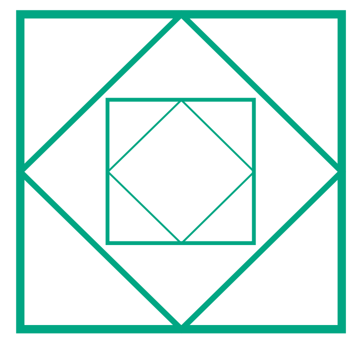
- divide in half
- randomly displace
- scale variance by half

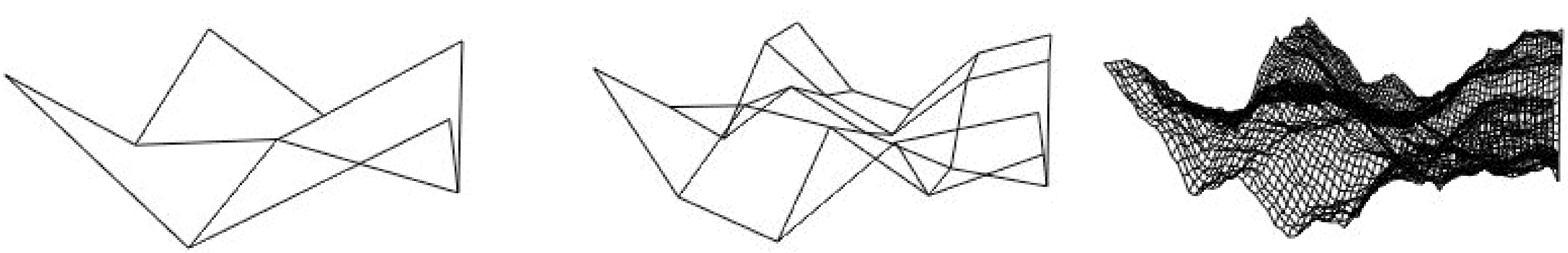


http://www.gameprogrammer.com/fractal.html

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



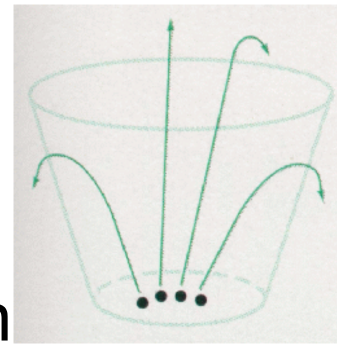


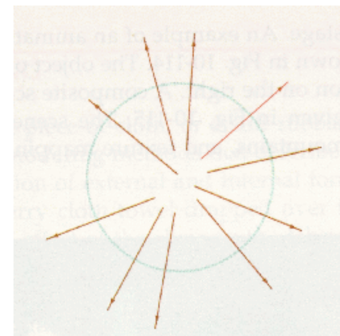
Particle Systems

- 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
  - 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