Announcements

Written Assignment 2 is due 3/8

Advanced Texturing

Bump Mapping
Displacement Mapping
Environment Mapping
Procedural Textures

Shirley Chapter 11

COMPUTER GRAPHICS

15-462

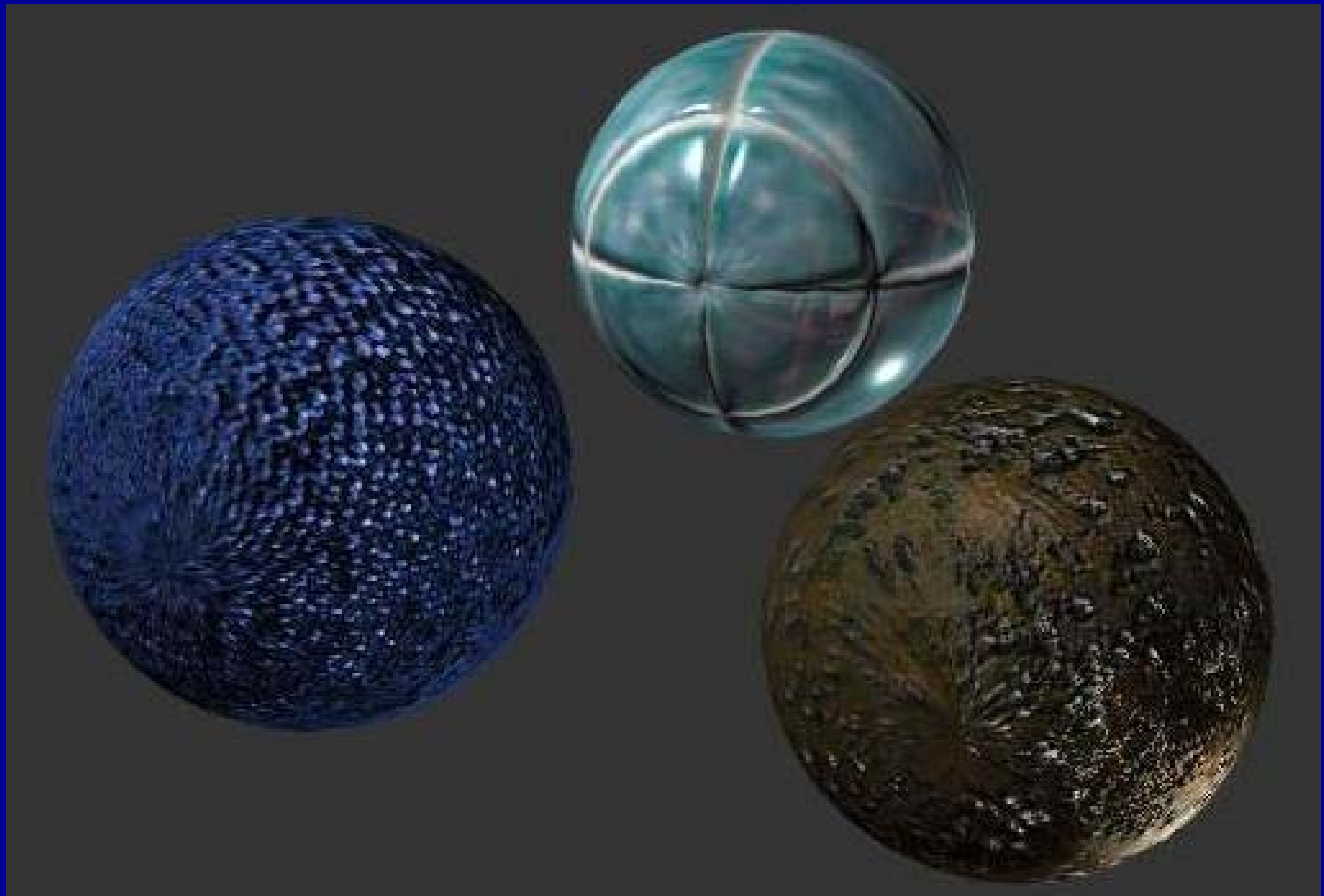
03/06/07

Uses for Texture Mapping (Heckbert 1986)

Use texture to affect a variety of parameters

- surface color (Catmull 1974) - color (radiance) of each point on surface
- surface reflectance - reflectance coefficients k_d, k_s, or n_{shiny}
- normal vector - bump mapping (Blinn 1978)
- geometry - displacement mapping
- transparency - transparency mapping (clouds) (Gardener 1985)
- light source radiance - environment mapping (Blinn 1978)

Fine Surface Detail

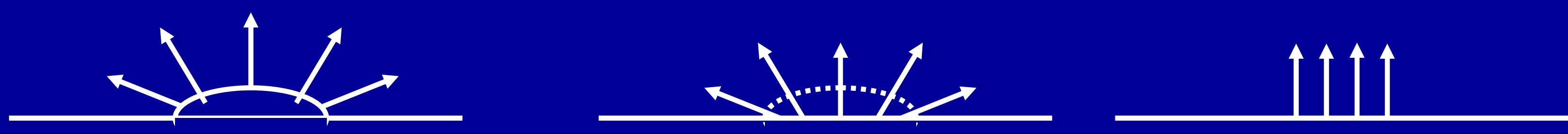


http://www.siggraph.org/education/materials/HyperGraph/mapping/bumpmap.htm

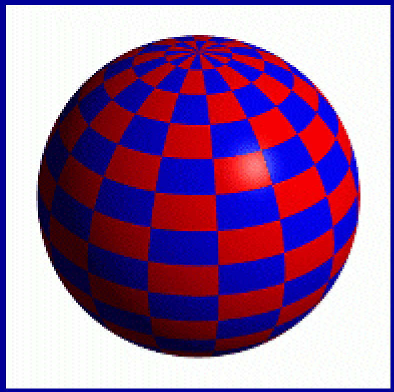
How can we model this level of detail?

Bump Mapping

- Basic texture mapping paints on to a smooth surface
- How do you make a surface look *rough*?
  - Option 1: model the surface with many small polygons
  - Option 2: perturb the normal vectors before the shading calculation



Real Bump **Fake Bump** **Flat Plane**



Sphere w/Diffuse Texture Map

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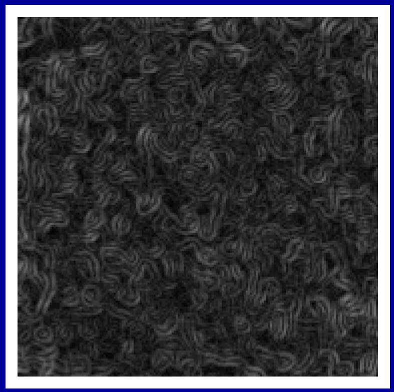

Bump Map

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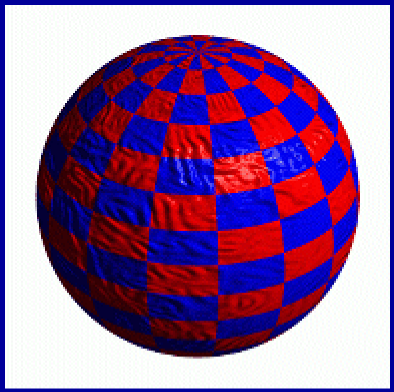
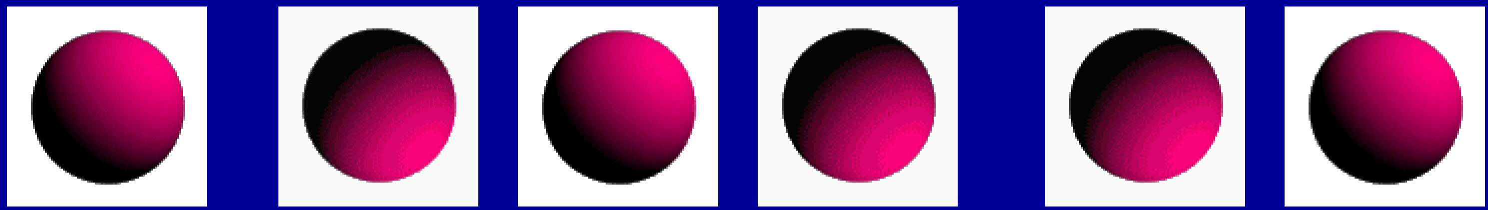


Sphere w/Diffuse Texture + Bump Map

Why Does this Work?

- Which spots bulge out, and which are indented?



- The human visual system is hard-coded to expect light to come from above (the sun)

Implementing Bump Mapping

- At each point, displace the normal by some amount to change lighting
- Displacements stored in bump-map (texture image)

blackboard

[Demo]

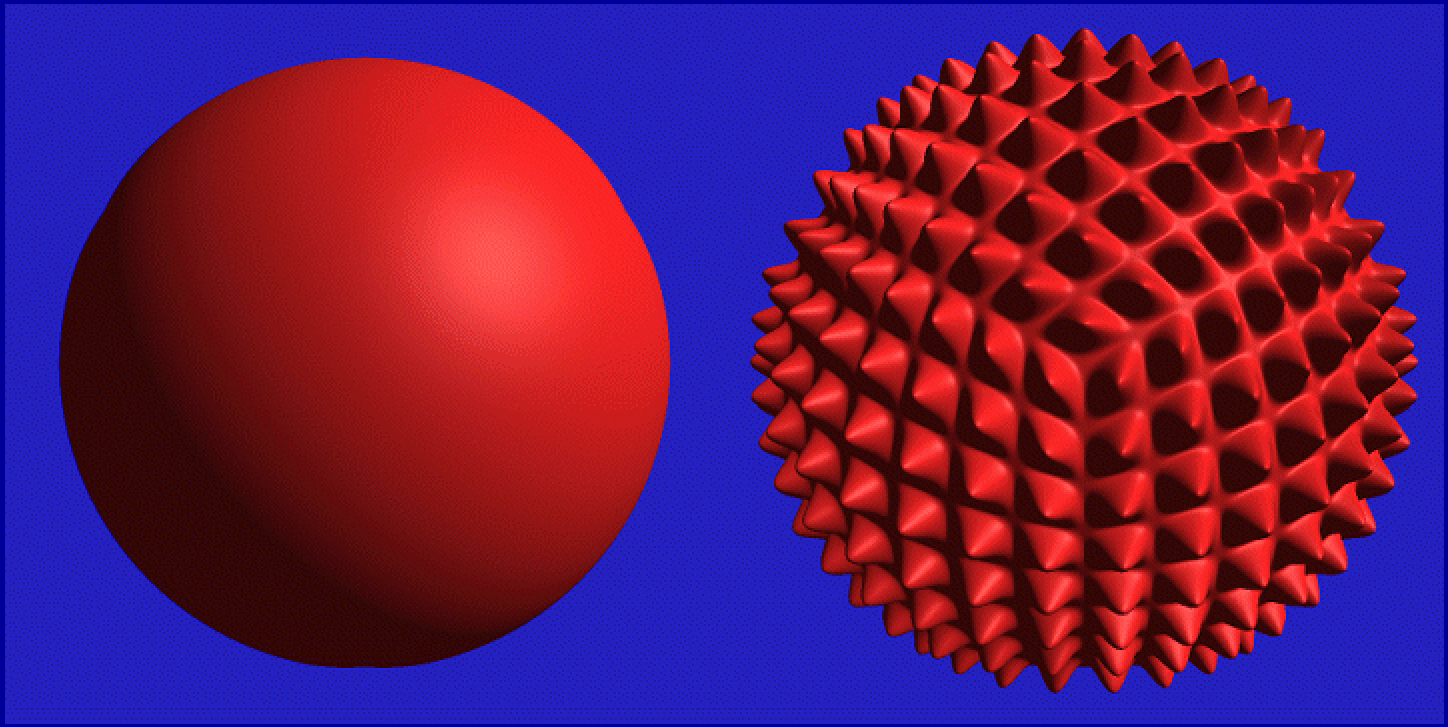
Bump Mapping is a Hack

- What anomalies do you see in the image below?

Greg Turk

Displacement Mapping

- Use texture map to displace each point on the surface
  - Texture value gives amount to move in direction normal to surface

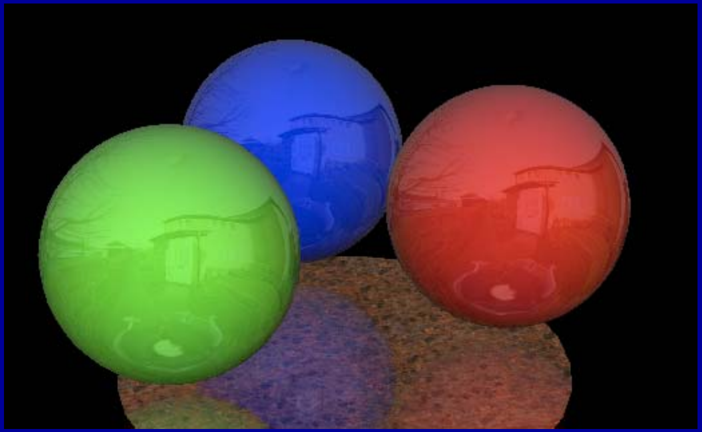


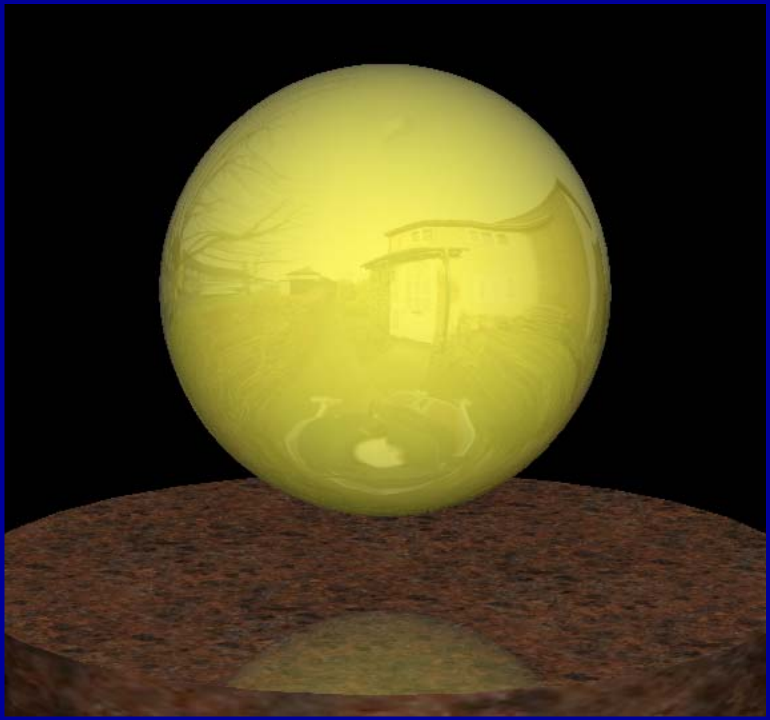
- How is this better/worse than bump mapping?

[Demo]

Environment Mapping

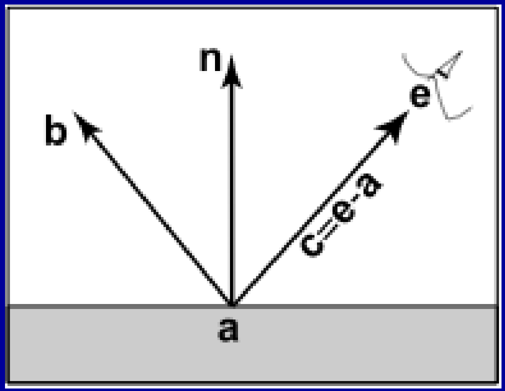
- Very shiny objects show reflections of their surroundings
  - To do this properly, we use ray tracing to calculate multiple bounces
  - That's a lot of computation: how can we fake it?
  - Use a pre-rendered environment
  - (Won't support inter-object reflections)





Environment Mapping (Spherical)

- Imagine that object is surrounded by an infinitely large sphere
  - Calculate reflection vector, project on to sphere
  - Need a seamless texture for the sphere



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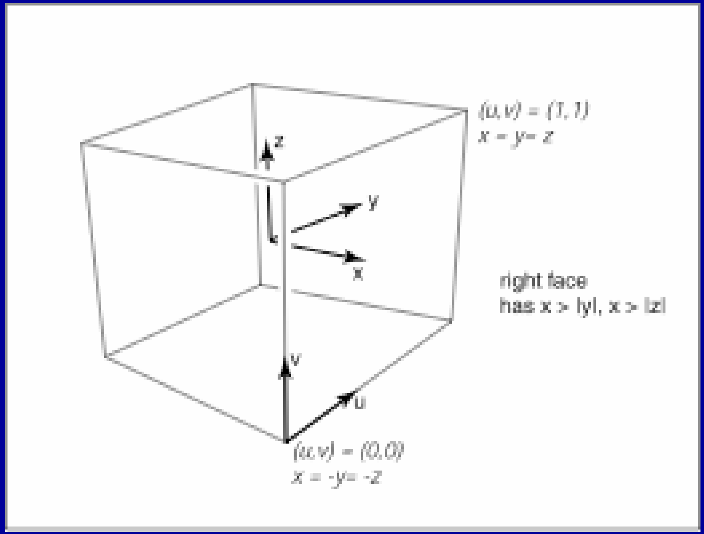
Jerome Dewhurst

Environment Mapping (Cube Map)

- Same idea as spherical map, but with 6 textures forming a cube



- OpenGL supports both methods of environment mapping:
  – glEnable(GL_TEXTURE_CUBE_MAP_EXT);
  – glEnable(GL_TEXTURE_GEN_S); glEnable(GL_TEXTURE_GEN_T);

- What are the advantages/disadvantages of each method?

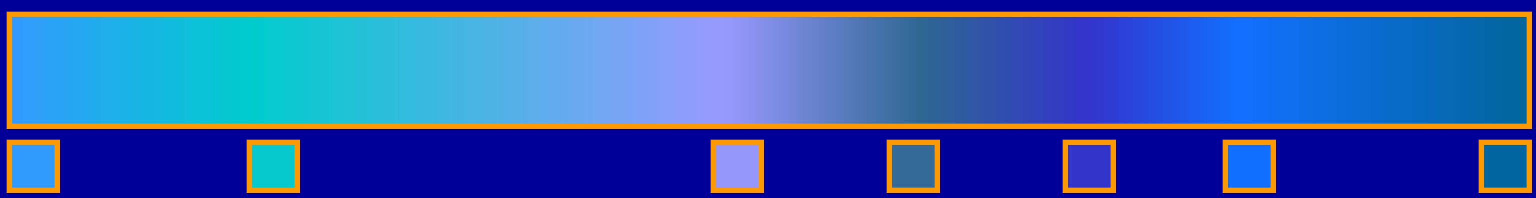
[Demo]

Color Mapping

- Mapping from R->R^3, specifically from (0,1)->$(0,1)^3$
- Allows us to convert scalar-valued functions to colors
- Option 1: Color table

0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0

  – Abrupt transitions, but dead simple to implement
- Option 2: Color spline



  – Linear/cubic/C-R/Hermite interpolation between colors
  – Can create both sharp transitions and smooth gradients

Procedural Textures

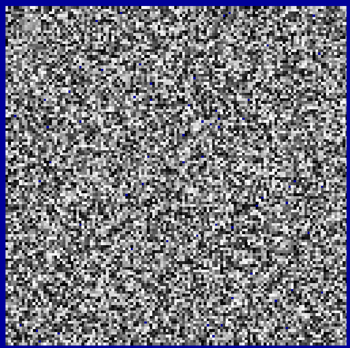
- What if we want to generate textures procedurally?
  - To save space
  - To get effects not possible with photographic textures (solid texture)
  - To animate textures
  - To get the correct texture scale

- Basic procedural textures are regular, boring
  - Built with periodic functions like sin(), cos()

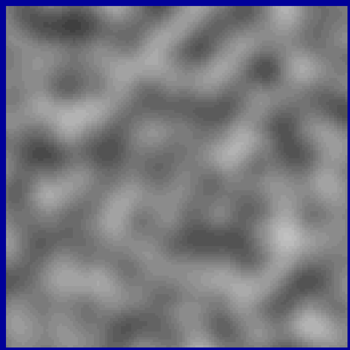
- Need to add "interestingness" to textures
  - Disturb the regularity of basic textures

Perlin Noise

- Random perturbation function with the following characteristics:
  - – Repeatable function of <x,y,z> input
  - – Known range [-1,1]
  - – Band-limited (coherent)
  - – No obvious periodicity
  - – Stationary
  - – Isotropic



White Noise



Perlin Noise

Perlin Noise Algorithm

- Perlin Noise is also known as gradient noise
  - Gradient value at each integer point in the 3-space lattice
  - Gradient determined by repeatable hash of floor(x),floor(y),floor(z)
  - Take dot product of each gradient with distance to lattice point
  - Weighted average using ease function: $6t^5-15t^4+10t^3$

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

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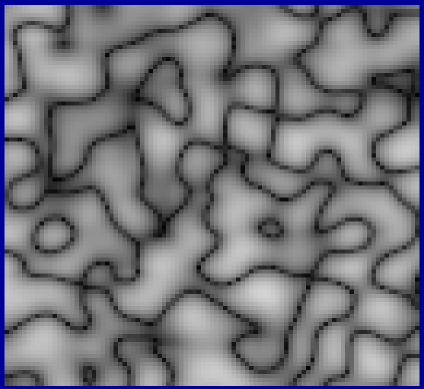
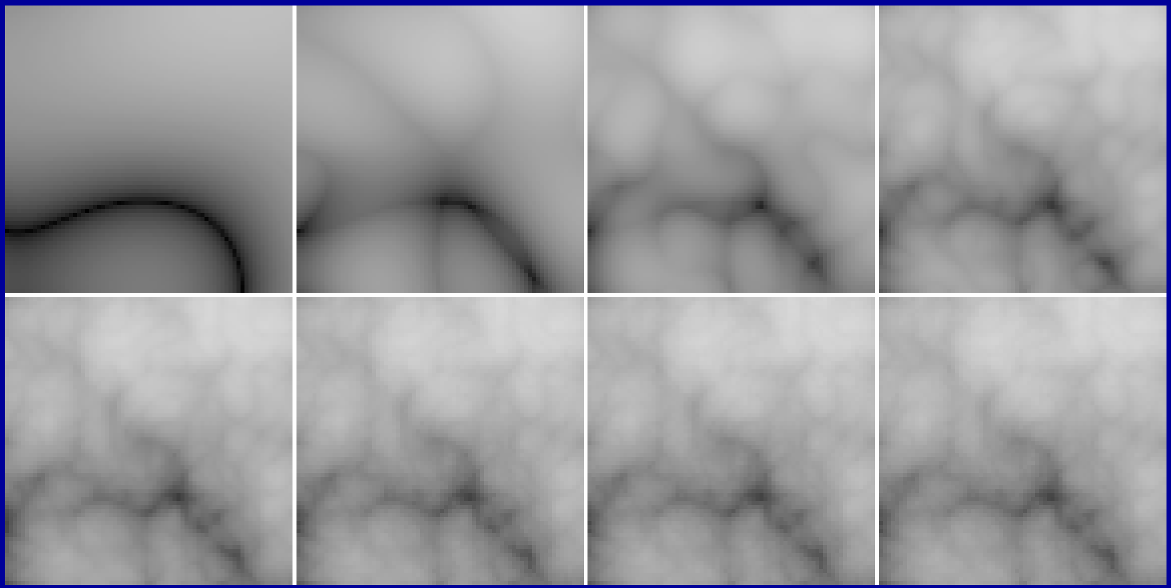
Turbulence

- Noise has a range of [-1,1], must convert to [0,1]
- Can scale noise using 0.5(noise+1)
- abs(noise) creates dark veins at zero crossings



Octaves of Noise

- Feature size of basic Perlin noise is relatively uniform
- Sum multiple calls to noise(), scaling input
- Typically, we scale the input by 2^i
- Number of iterations = number of octaves



1-8 Octaves of Turbulence

Using Noise

- Clouds: noise(point+offset)*intensity
- Fire: abs(noise3(point)+offset)
- Marble: sin(offset + turbulence(point))
- Wood: noise(point)*scale - int(noise(point)*scale)
- Animated texture: add time-varying offset vector to point

[Demo]

Reaction Diffusion (Witkin & Kass 91)

- Originally developed by Alan Turing as a way to model morphogenesis
- Two (or more) morphogens whose concentration varies over a 2D grid
- Concentration affected by:
  - Decay of morphogens
  - Movement of morphogen from areas of high concentration to low (diffusion)
  - Interactions between morphogens which create and destroy them (reaction)

blackboard

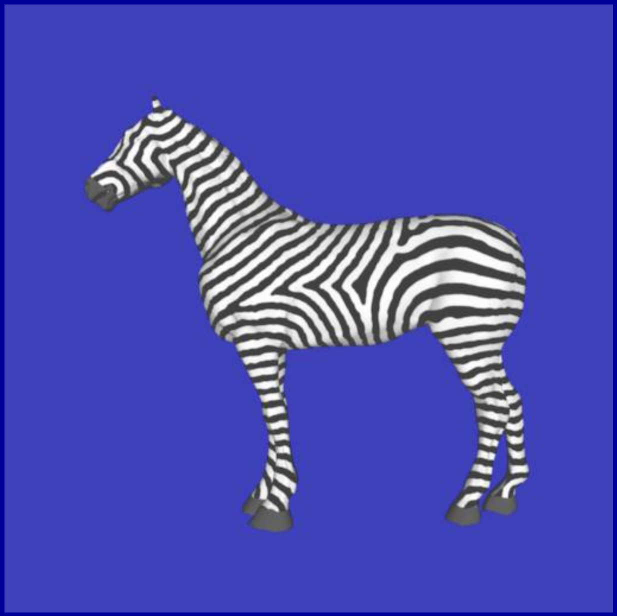
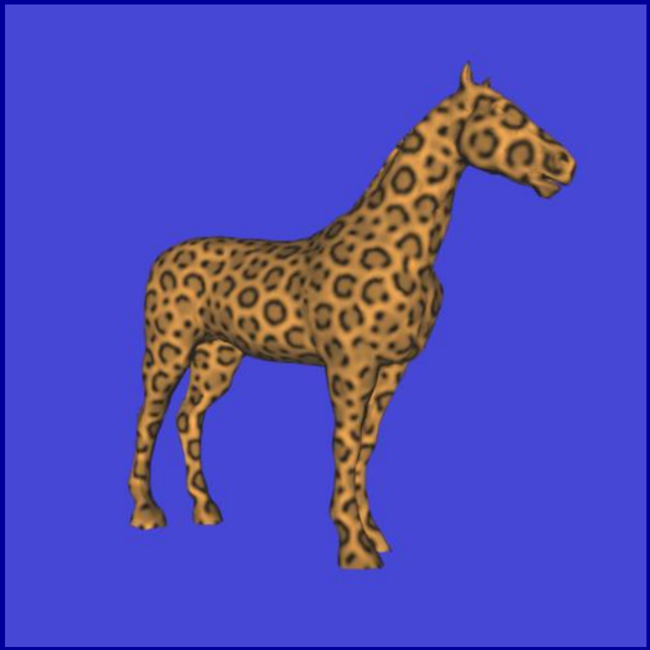
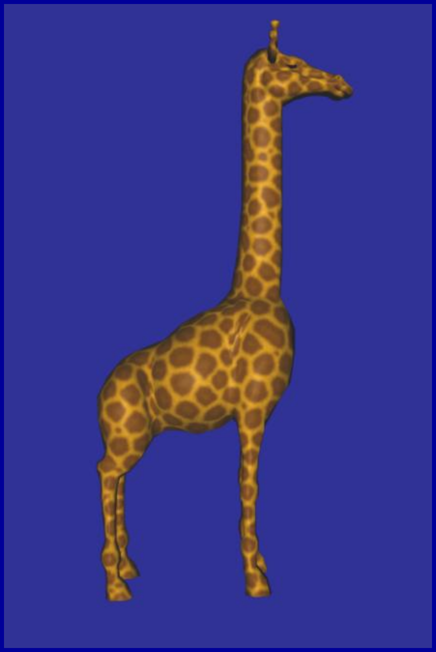
Reaction Diffusion: R Functions

- Difference in concentrations: giraffe markings
- Max of differences (3+ morphogens): maze-like
- Difference of abs (3+ morphogens): woven twigs

[Video]

Reaction Diffusion

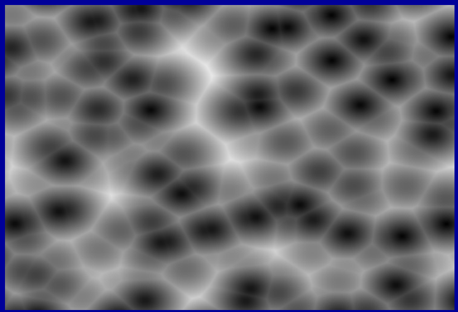
- Varying anisotropy by curvature or location allows for more complicated effects
  - Zebra's stripes wrap correctly
  - Girrafe's pattern is larger on smooth areas

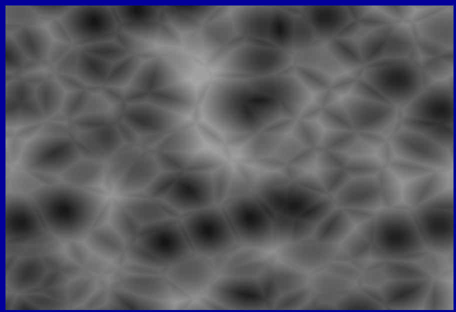
Turk

Cellular Textures (Worley)

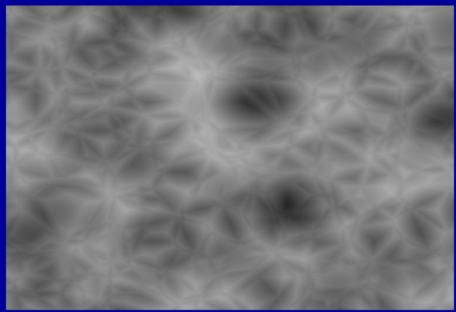
- Based on the idea that there are “feature points” in 3-space, and we care about the distance to the n^{th} closest feature
- $F_i(x,y)$ is the distance to the i^{th} closest randomly distributed feature



F_1



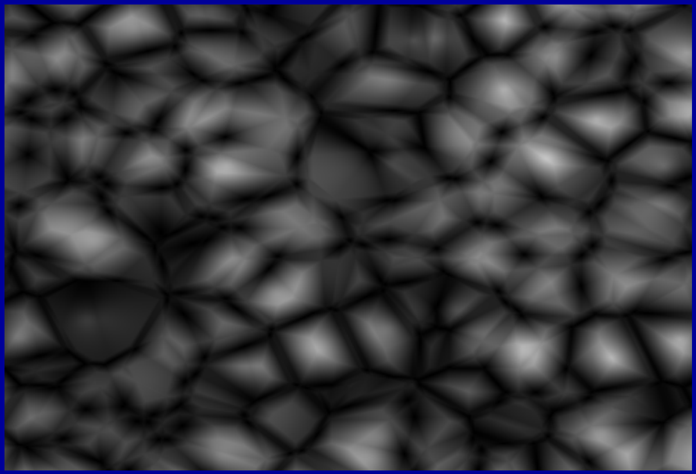
F_2



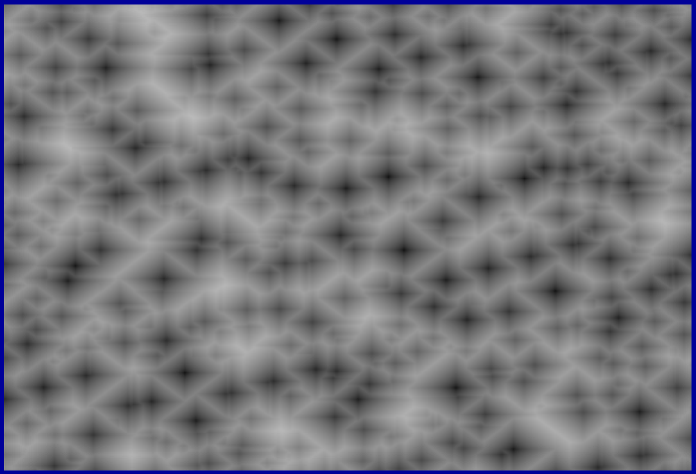
F_3

Cellular Texture Variations

- Cellular texture algorithm very “hackable”
- Change distribution of feature points
- Fractal sum of multiple octaves (water/tin foil)
- Linear/nonlinear combinations of F_is
- Unique ID number per feature point (flagstones)
- Different distance metrics (Manhattan, super-quadratic)



$F_2 - F_1$



Manhattan Distance

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