Shading

Flat shading
Gouraud shading
Phong shading

Flat Shading and Perception

- *Lateral inhibition*: exaggerates perceived intensity
- *Mach bands*: perceived "stripes" along edges

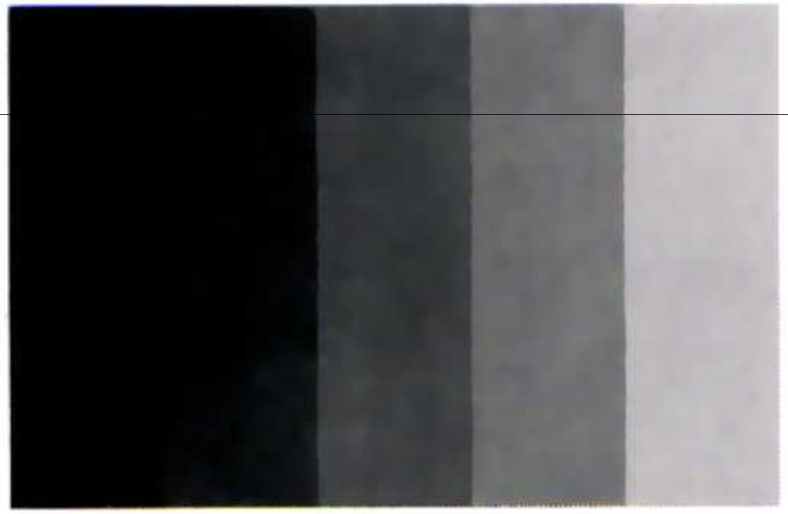


Figure 6.28 Step chart.

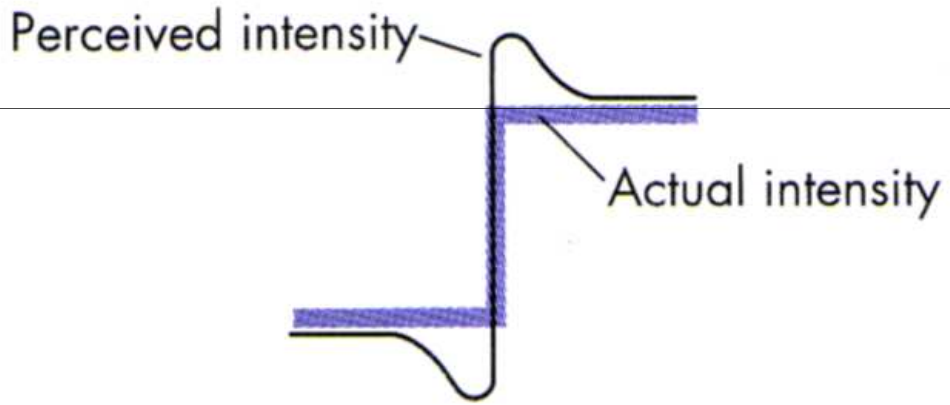
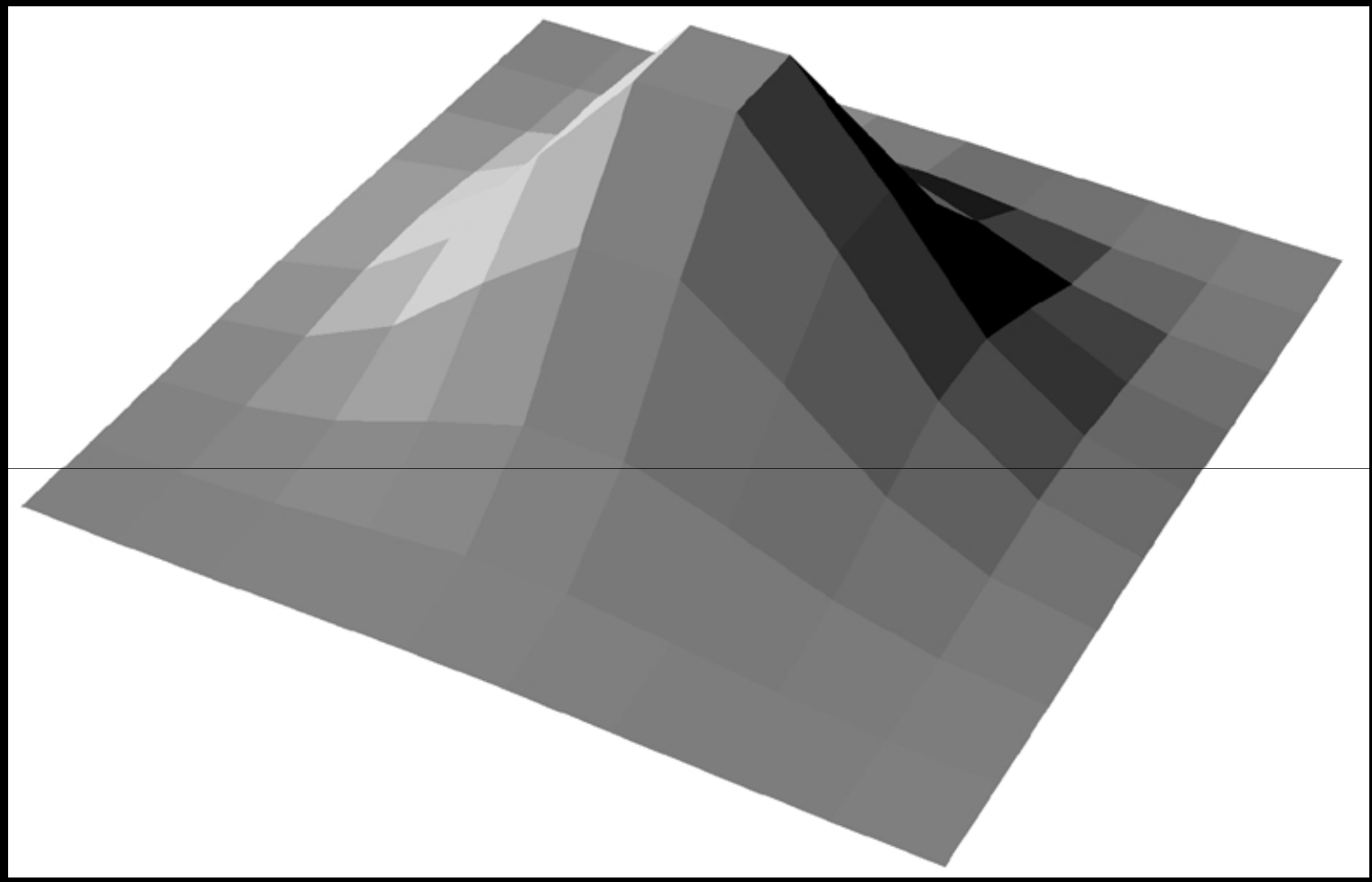
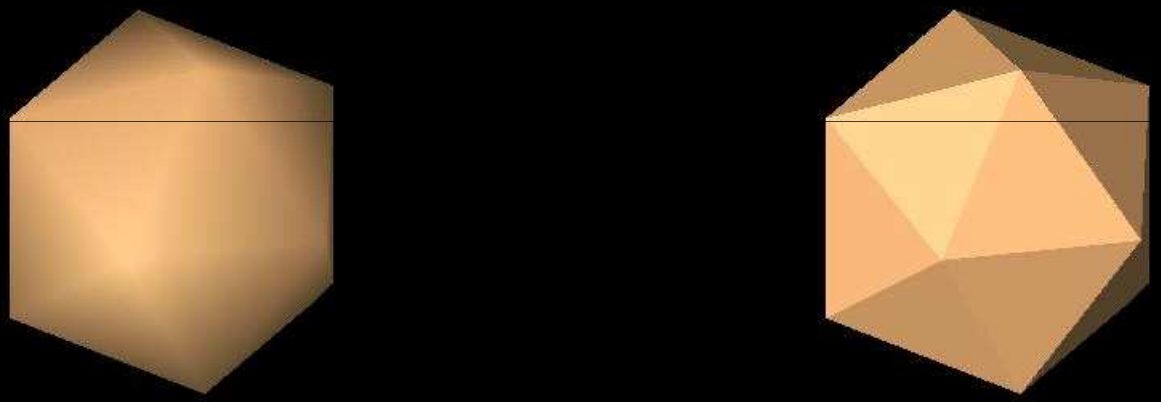


Figure 6.29 Perceived and actual intensities at an edge.

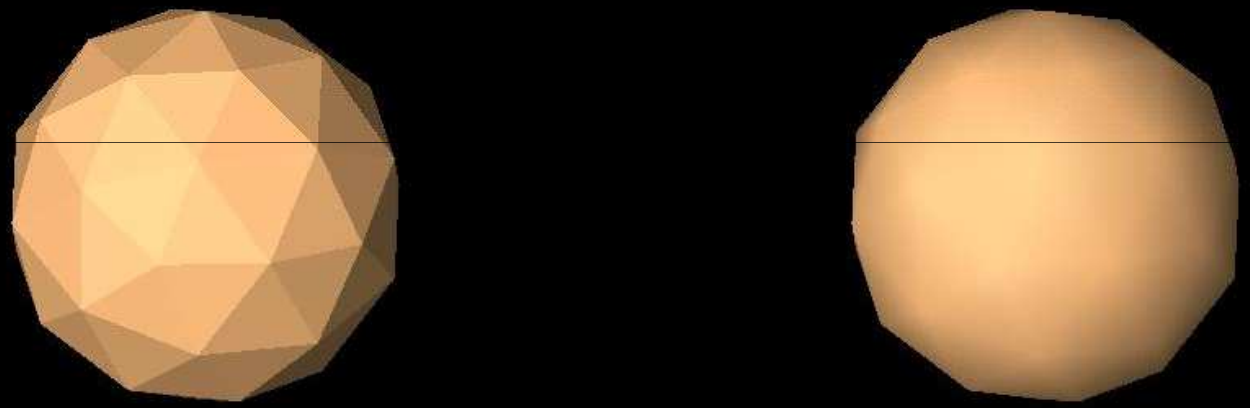


Icosahedron with Sphere Normals

- Gouraud shading vs flat shading effect



One Subdivision



Two Subdivisions

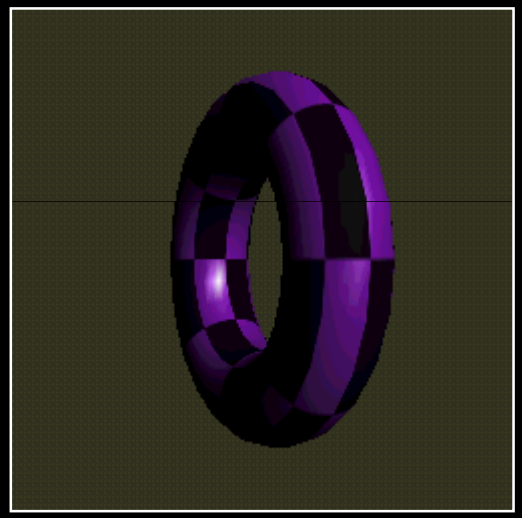
- Each time, multiply number of faces by 4

Three Subdivisions

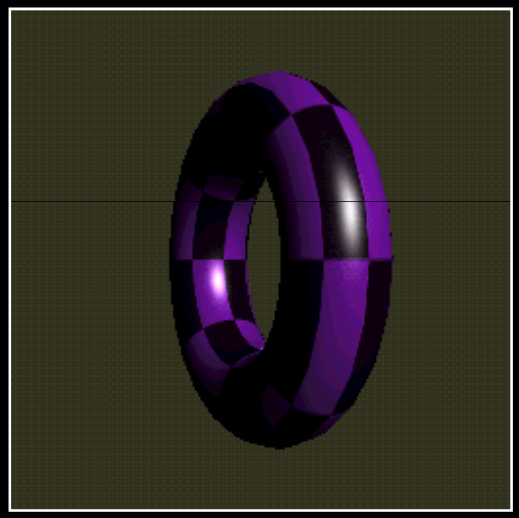
- Reasonable approximation to sphere

Phong Shading Results

Michael Gold, Nvidia



Phong Lighting
Gouraud Shading

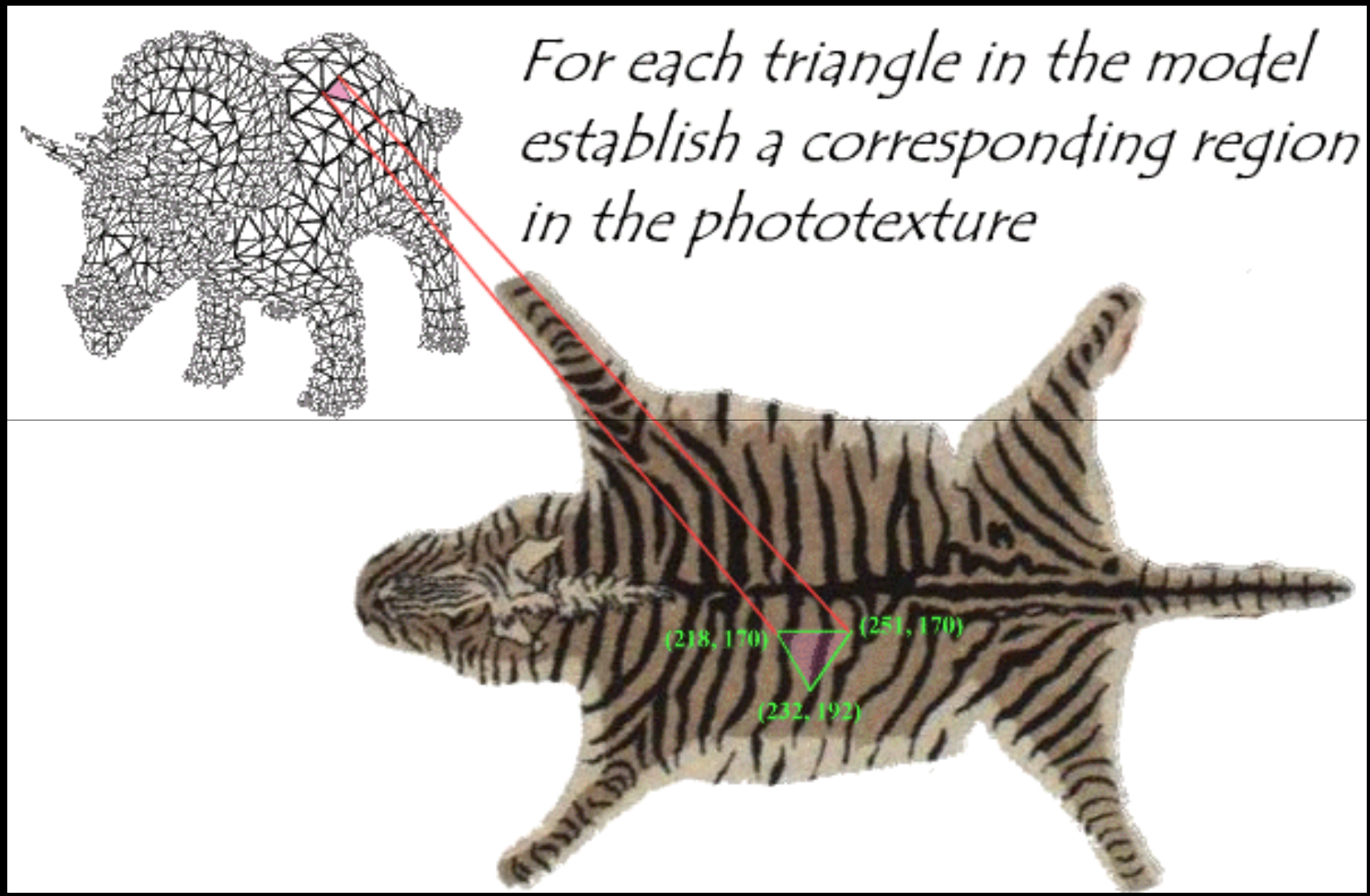


Phong Lighting,
Phong Shading

Texture and other Mappings

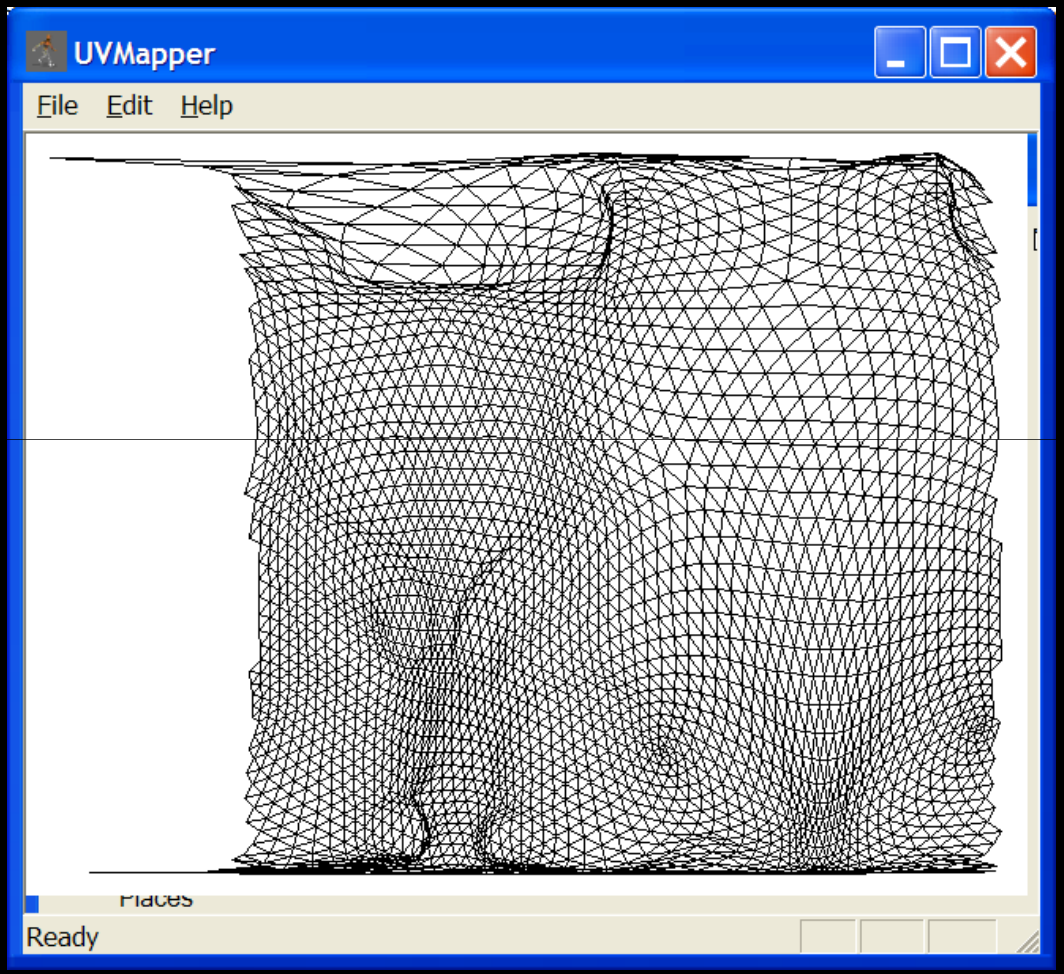
Texture Mapping
Bump Mapping
Displacement Mapping
Environment Mapping

We *could* specify all texture coordinates by hand…



Tools help us unroll an object to “paint” it

- www.uvmapper.com

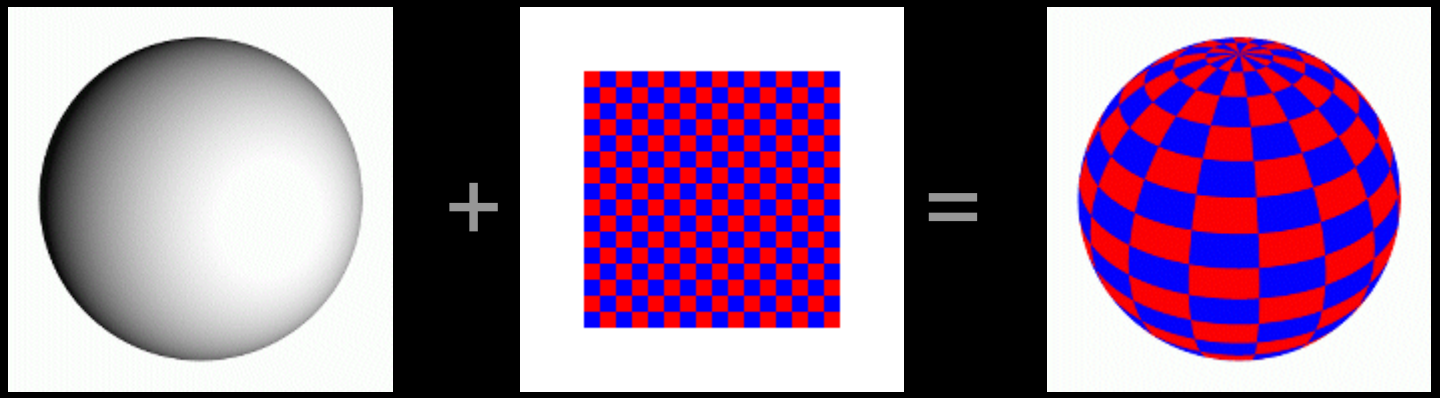


Uses for Texture Mapping

Use texture to affect a variety of parameters

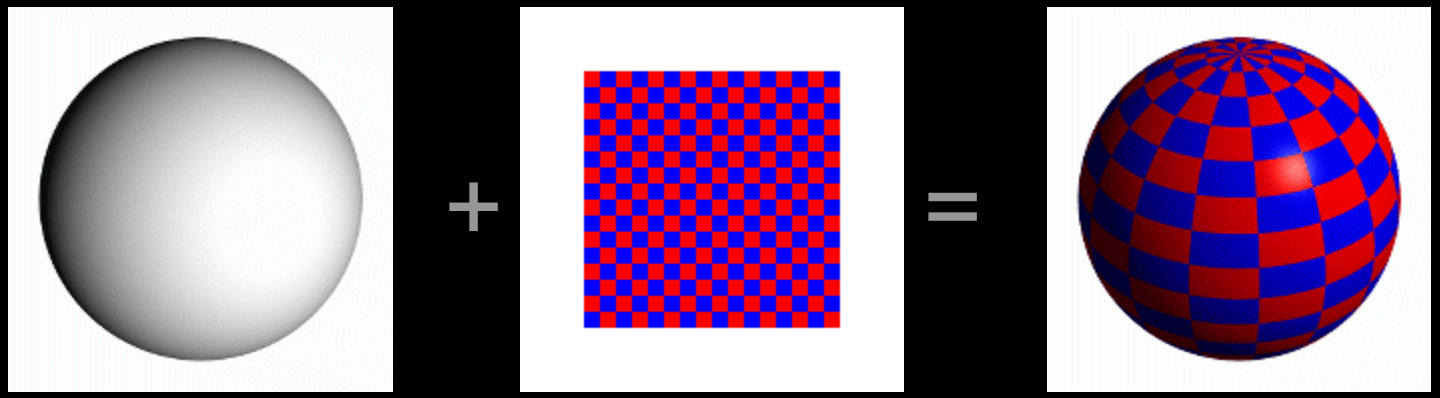
- surface color - radiance of each point on surface (Catmull 1974)
- surface reflectance - reflectance coefficients k_d, k_s, or n_{shiny}
- normal vector - bump mapping (Blinn 1978)
- geometry - displacement mapping
- transparency - transparency mapping (clouds) (Gardener 1985)
- light source radiance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

Radiance vs. Reflectance Mapping



Sphere w/ Uniform Diffuse coefficient Radiance Map Sphere w/ Radiance Map

Texture specifies (isotropic) radiance for each point on surface

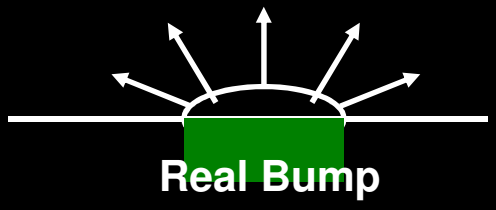


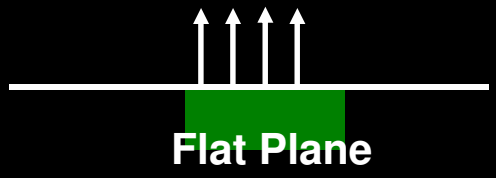
Sphere w/ Uniform Diffuse coefficient Reflectance (k_d) Map Sphere w/ Reflectance Map

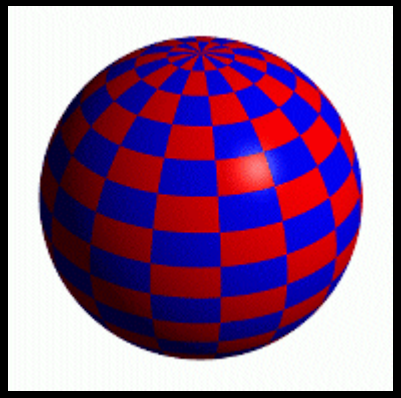
Texture specifies diffuse color (k_d coefficients) for each point on surface
- three coefficients, one each for R, G, and B radiance channels

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





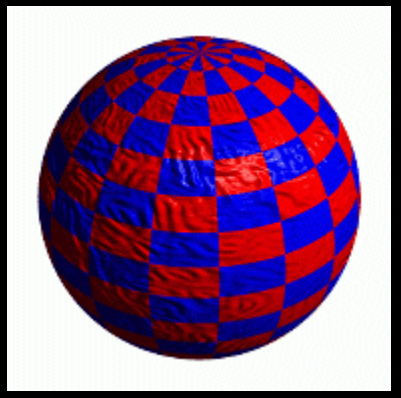


Sphere w/Diffuse Texture Map

+

Bump Map

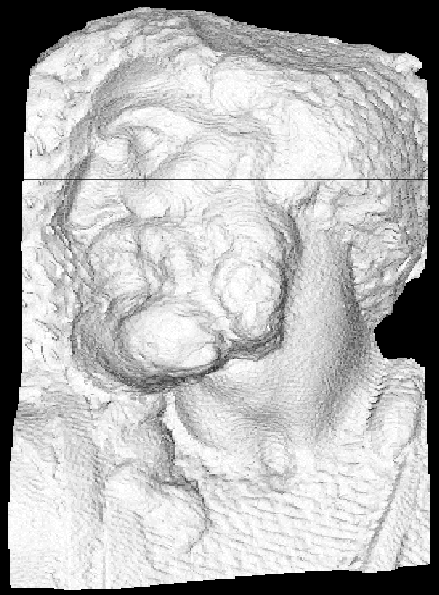
=



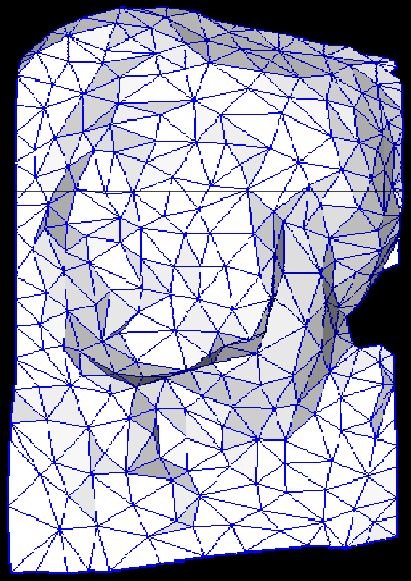
Sphere w/Diffuse Texture + Bump Map

Bump Mapping

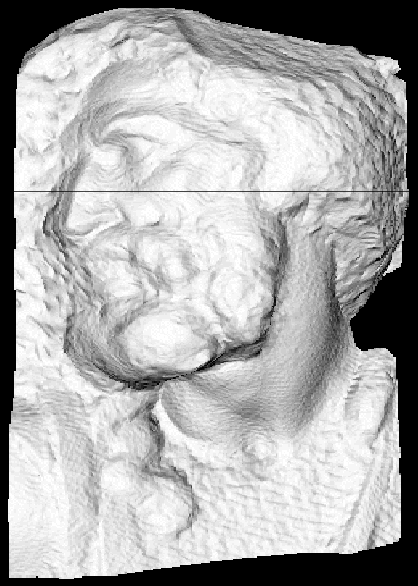
- We can perturb the normal vector without having to make any actual change to the shape.
- This illusion can be seen through—how?



Original model (5M)

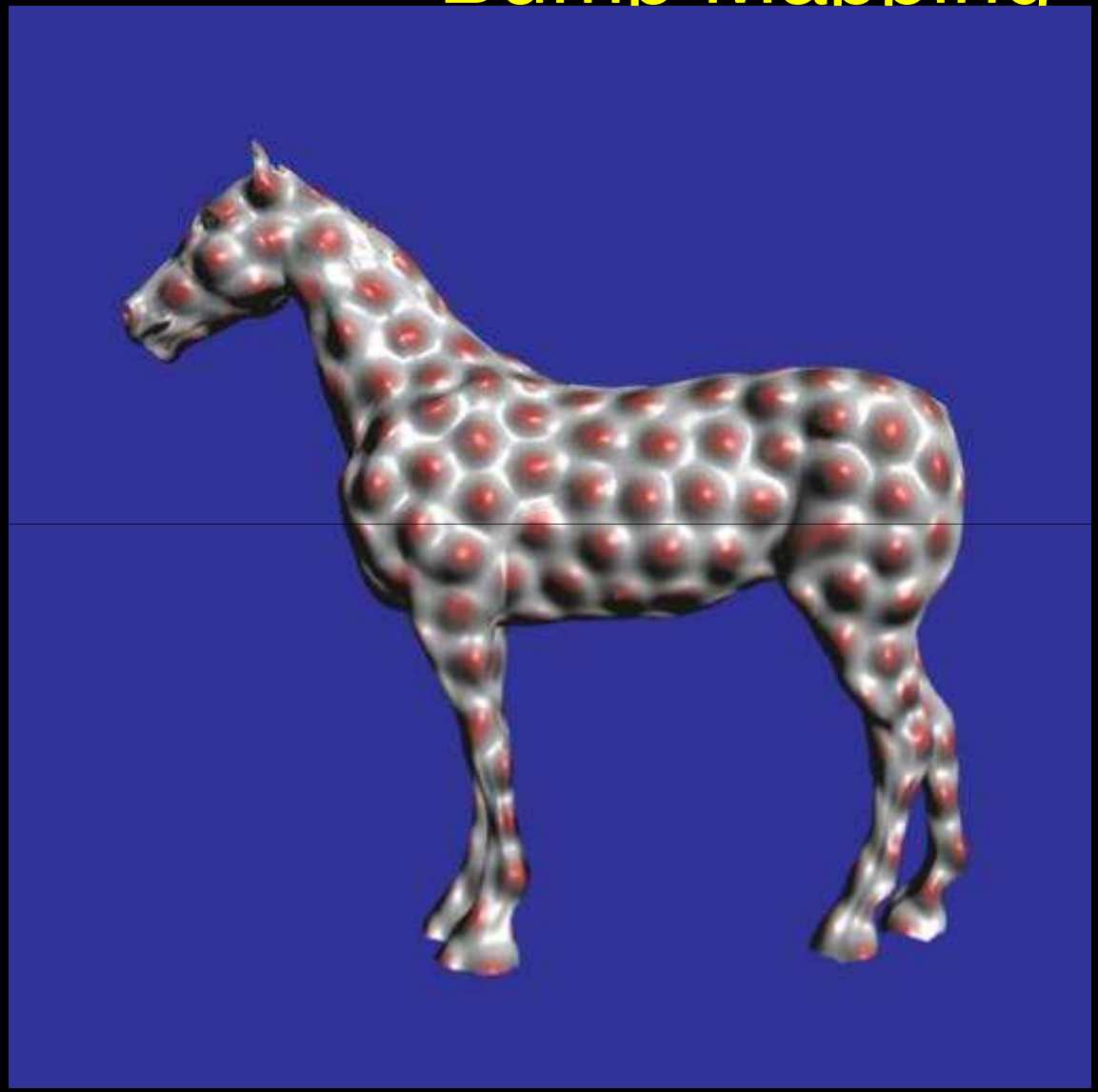


Simplified (500)



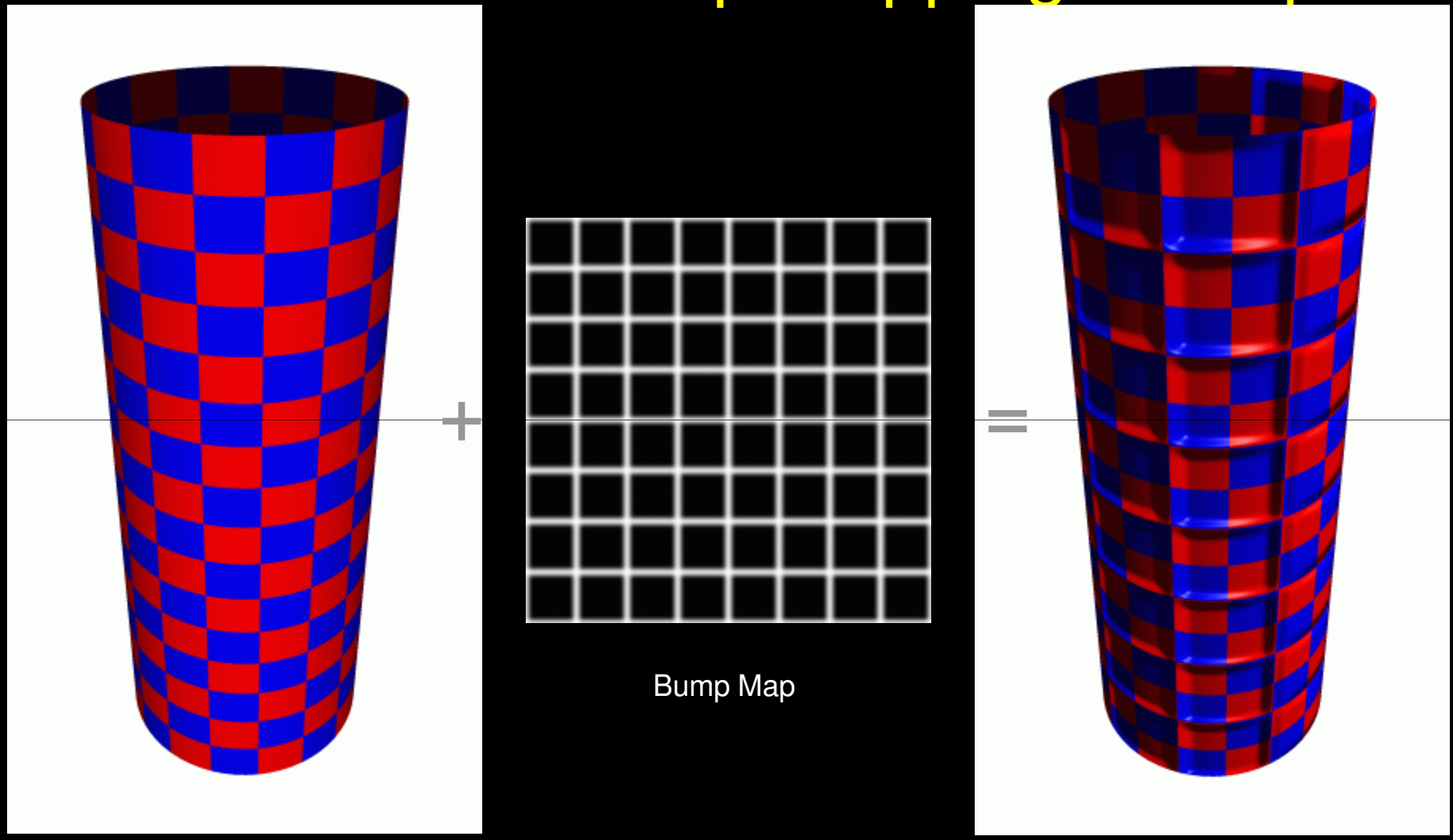
Simple model with bump map

Bump Mapping



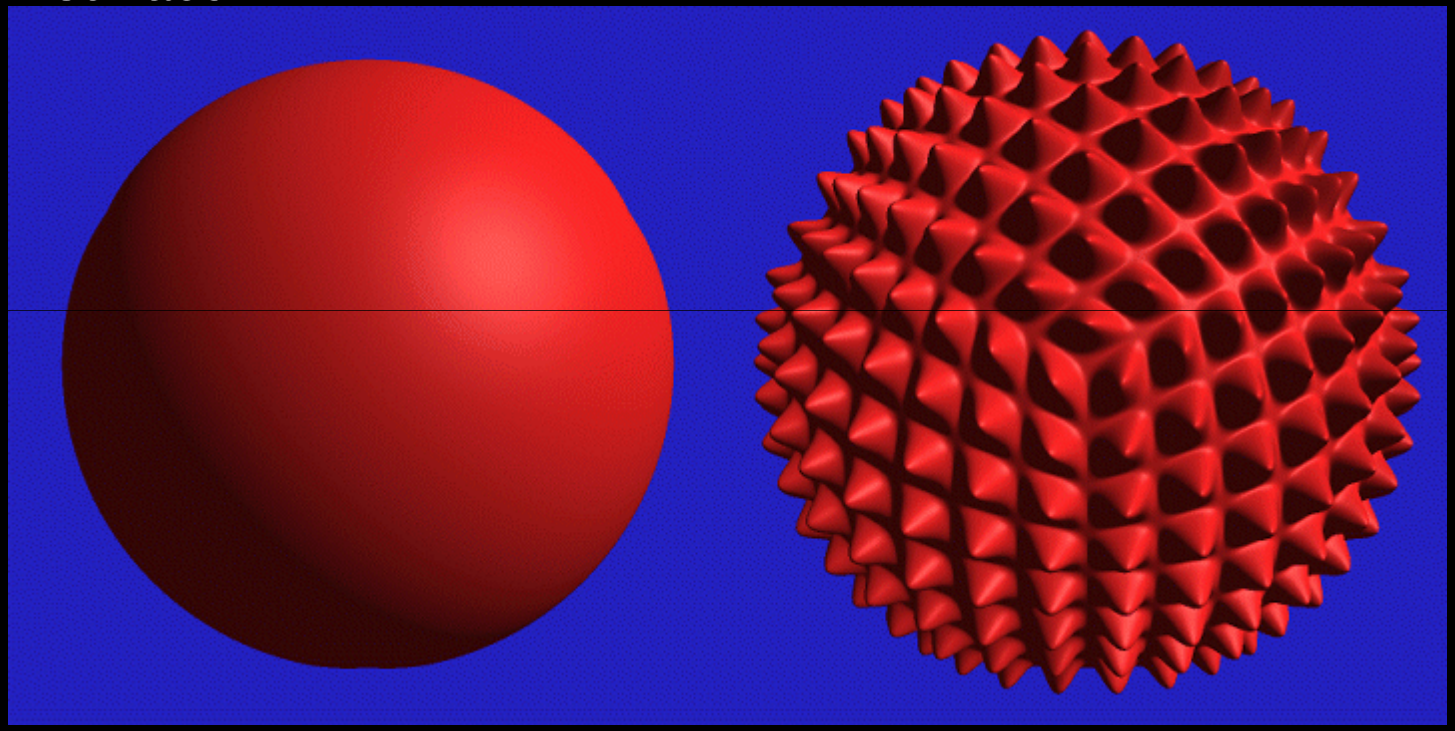
Greg Turk

Another Bump Mapping Example



Displacement Mapping

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



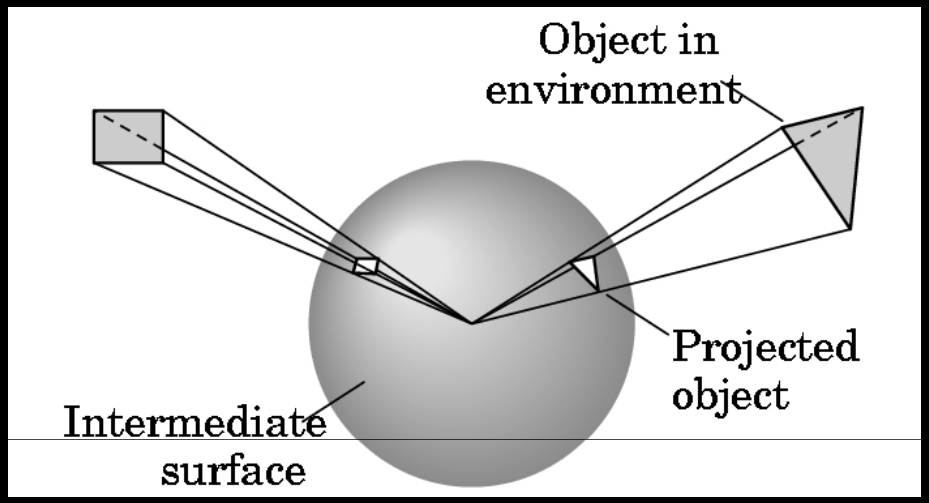
- How is this different from bump mapping?

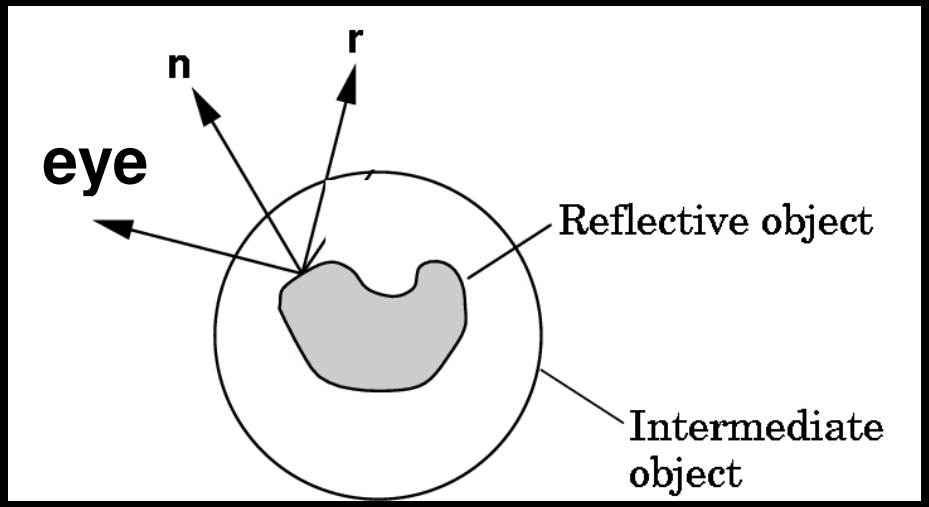
Environment Mapping

Specular reflections that mirror the environment

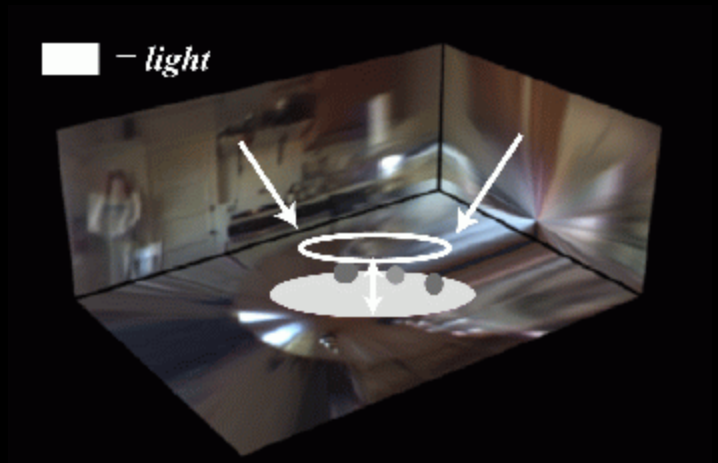
Environment Mapping

Specular reflections that mirror the environment

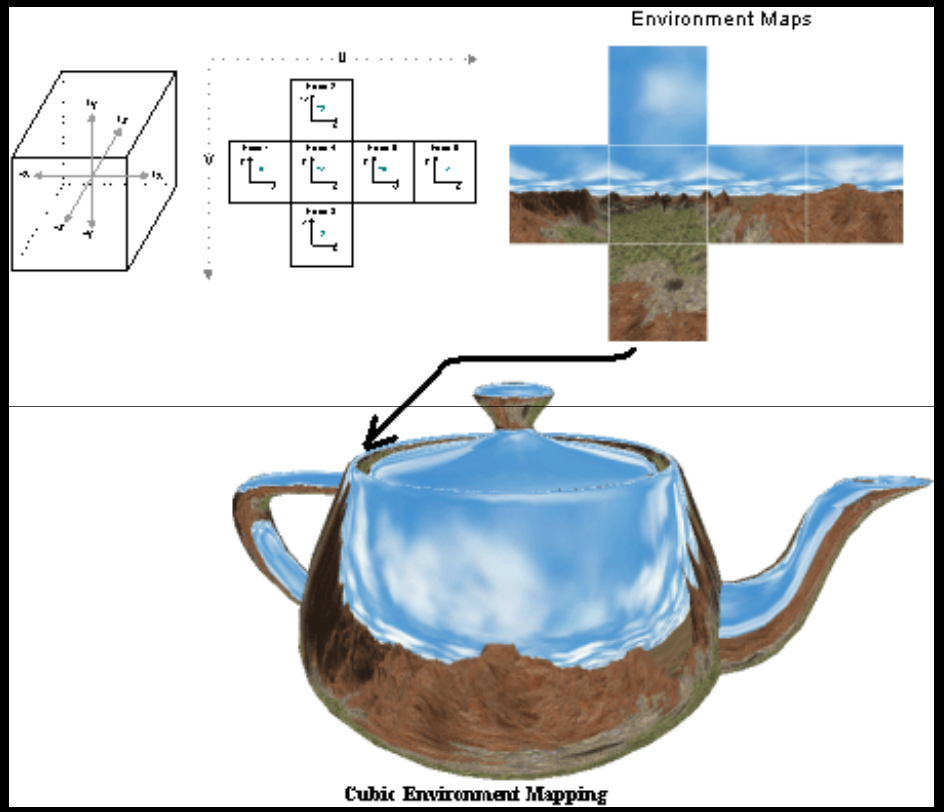




Cube is a natural intermediate object for a room



Environment Mapping: Cube Maps

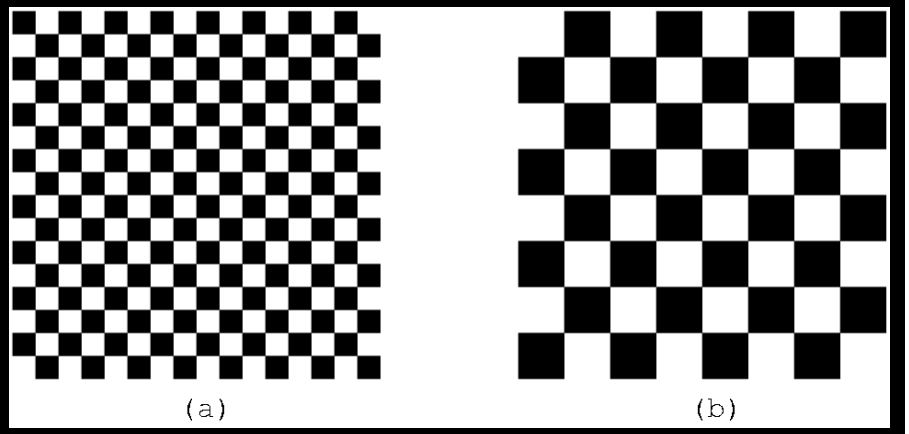


Basics of Texture Mapping in OpenGL

```
Glubyte my_texels[512][512][3];
Gluint texID;

glGenTextures(1, &texID);
glBindTexture(GL_TEXTURE_2D, texID);
glTexImage2D(GL_TEXTURE_2D, 0, GL_RGB, 512, 512, 0,
             GL_RGB,GL_UNSIGNED_BYTE, my_texels);
/* level, components, w, h, border, format, type, tarray */

/* assign texture coordinates */
glEnable(GL_TEXTURE_2D);
glBegin(GL_QUAD);
       glTexCoord2f(0.0, 0.0);
       glVertex3f(x1,y1,z1);
       glTexCoord2f(1.0, 0.0);
       glVertex3f(x2,y2,z2);
       glTexCoord2f(1.0,1.0);
       glVertex3f(x3,y3,z3);
       glTexCoord2f(0.0,1.0);
       glVertex3f(x4,y4,z4);
glEnd();
glDisable(GL_TEXTURE_2D);
```



Grungy details we've ignored

- Specify s or t out of range? Use **GL_TEXTURE_WRAP** in **glTexParameter** because many textures are carefully designed to repeat

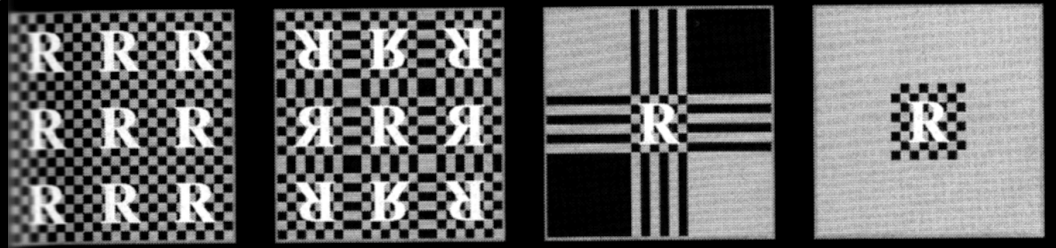
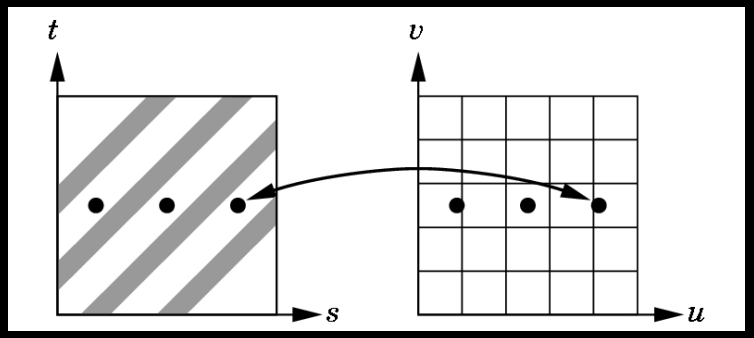


Figure 5.6. Image texture repeat, mirror, clamp, and border functions in action.

- Aliasing? Mapping doesn't send you to the center of a texel. Can average nearest 2x2 texels using **GL_LINEAR**

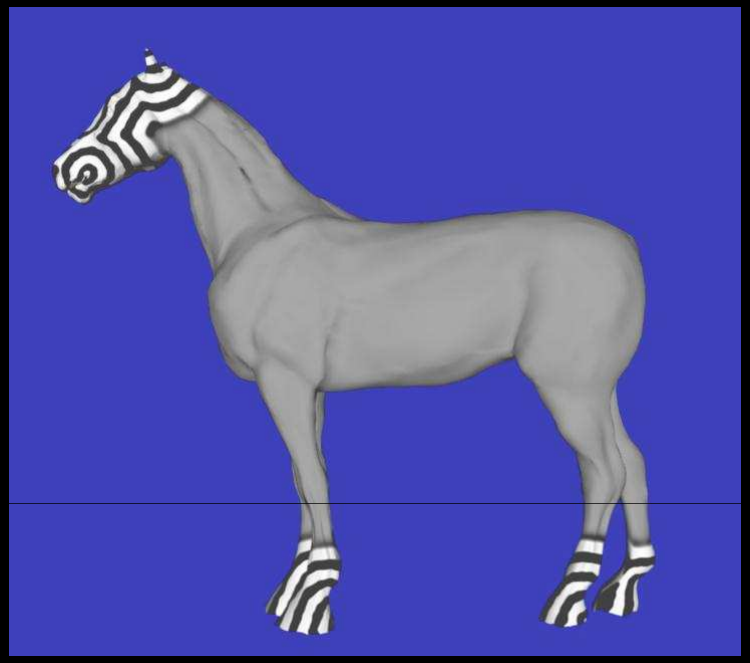


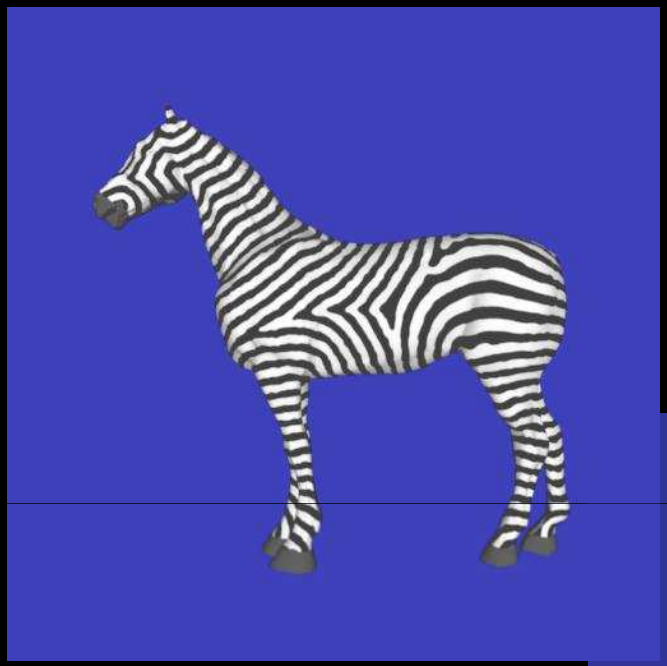
- Mipmapping: use textures of varying resolutions. 64x64 becomes 32x32,16x16,8x8,4x4,2x2 and 1x1 arrays with **gluBuild2Dmipmaps**

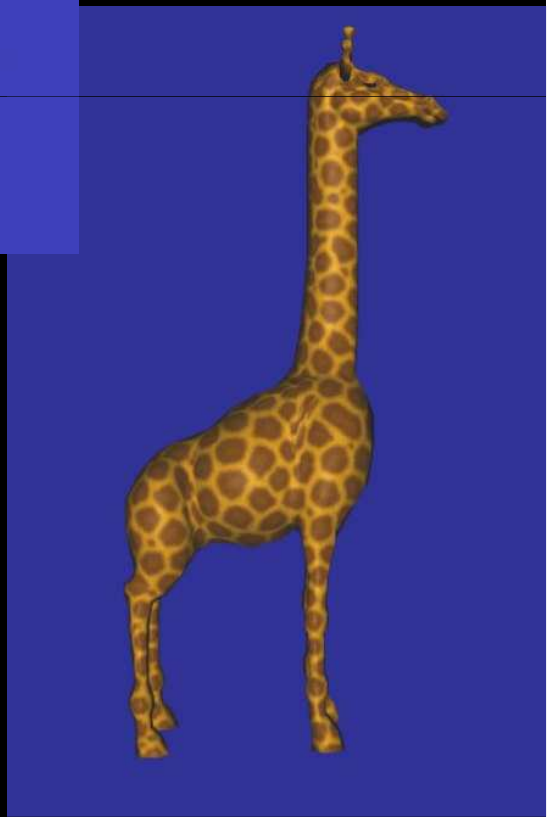
Texture Generation

Photographs
Drawings
Procedural methods (2D or 3D)
(2D: stripe, wave, and noise patterns
3D: sculpting in marble and granite)

Procedural Methods



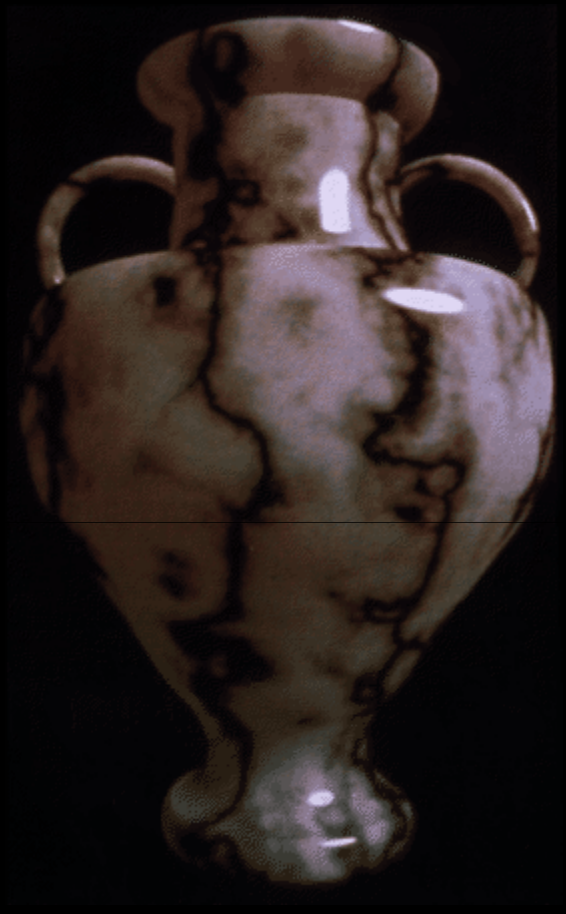




Reaction-Diffusion
Greg Turk, Siggraph ‘91

Solid Textures

- Have a 3-D array of texture values (e.g., a block of marble)
- In practice the map is often defined procedurally
  - No need to store an entire 3D array of colors
  - Just define a function to generate a color for each 3D point
- The most interesting solid textures are random ones
- Evaluate the texture coordinates in object coordinates - otherwise moving the object changes its texture!
- Ken Perlin's talk "Making Noise"



From: *An Image Synthesizer* by Ken Perlin, SIGGRAPH '85