12. Texture Mapping

Reading

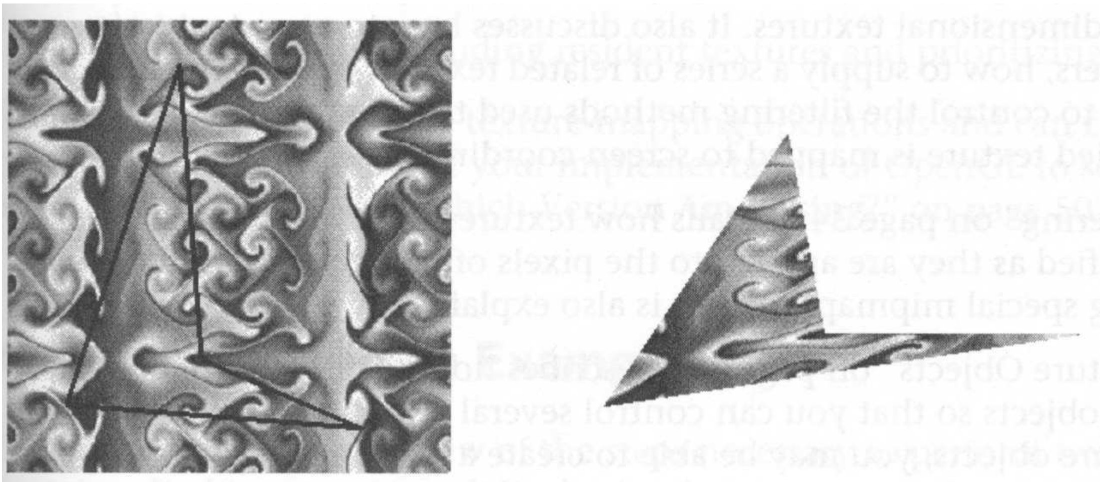
Recommended:

- Hearn and Baker, 14.8–14.9
- Woo, Neider, & Davis, Chapter 9

Optional:

- James F. Blinn and Martin E. Newell. Texture and reflection in computer generated images. *Communications of the ACM* 19(10): 542–547, October 1976.
- Paul S. Heckbert. Survey of texture mapping. *IEEE Computer Graphics and Applications* 6(11): 56–67, November 1986.

Texture mapping



Texture mapping (Woo et al., fig 9-1)

Texture mapping allows you to take a simple polygon and give it the appearance of something much more complex.

- Due to Ed Catmull, PhD thesis, 1974
- Refined by Blinn & Newell, 1976

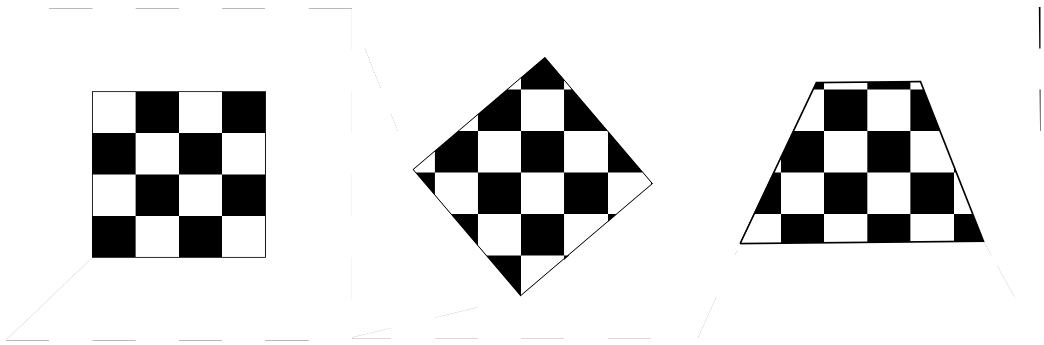
Texture mapping ensures that "all the right things" happen as a textured polygon is transformed and rendered.

Applications

The applications of texture mapping are endless:

- Image warping
- Transparency mapping
- Painting on surfaces
- Solid textures for marble, wood, etc.
- "Slide projection"
- Volume rendering

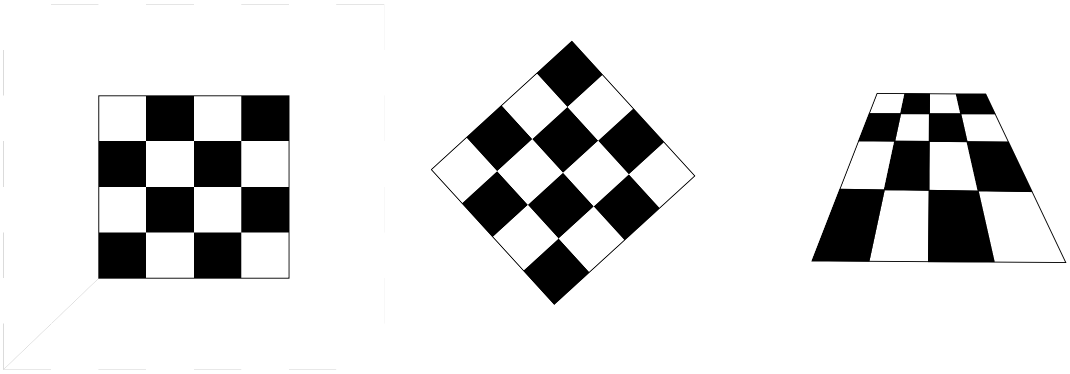
Non-parametric texture mapping



With "non-parametric texture mapping":

- Texture size and orientation are fixed
- They are unrelated to size and orientation of polygon
- Gives cookie-cutter effect

Parametric texture mapping



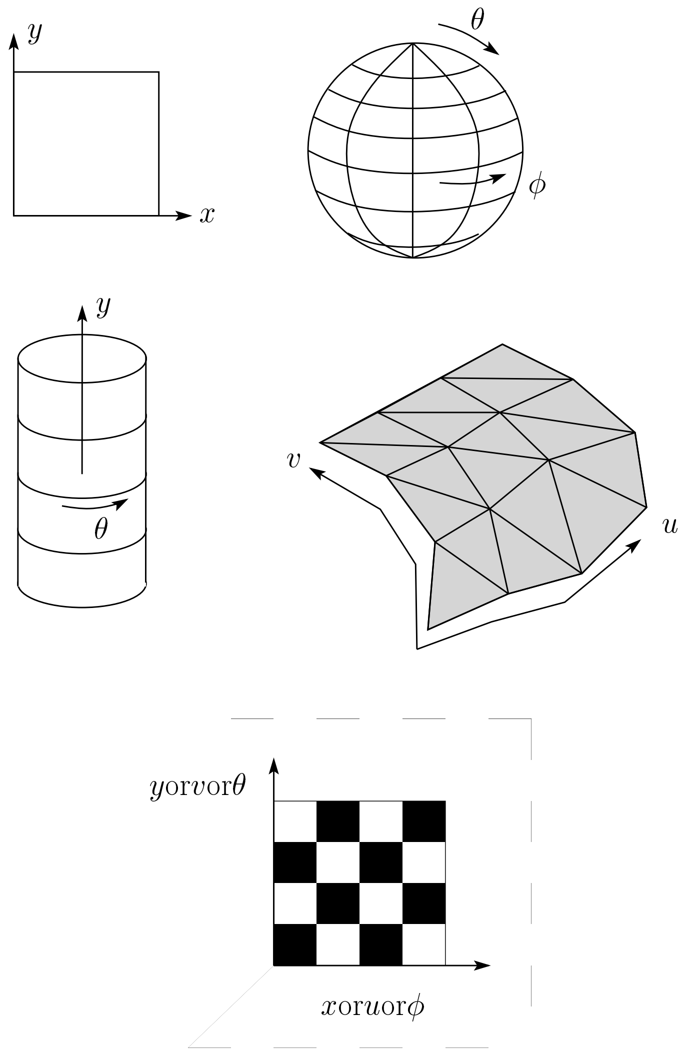
With "parametric texture mapping," texture size and orientation are tied to the polygon.

Idea:

- Separate "texture space" and "screen space"
- Texture the polygon as before, but in texture space
- Deform (render) the textured polygon into screen space

<u>Implementing texture mapping</u>

Textures can be wrapped around many different surfaces:



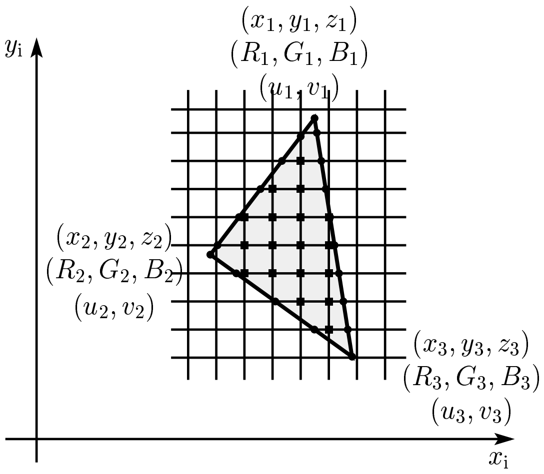
Computing (u, v) texture coordinates in a ray tracer is fairly straightforward.

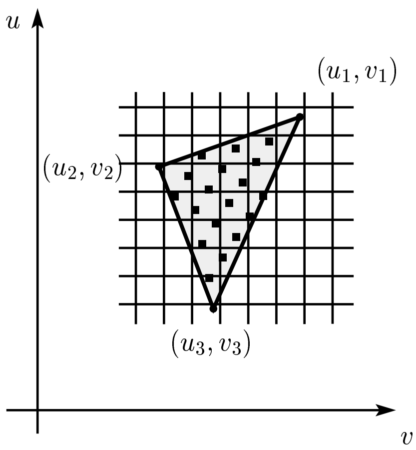
Implementing texture mapping, cont'd

Texture-mapping can also be handled in z-bufer algorithms.

Method:

- Scan conversion is done in screen space, as usual
- Each pixel is colored according to the texture
- Texture coordinates are found by Gouraud-style interpolation

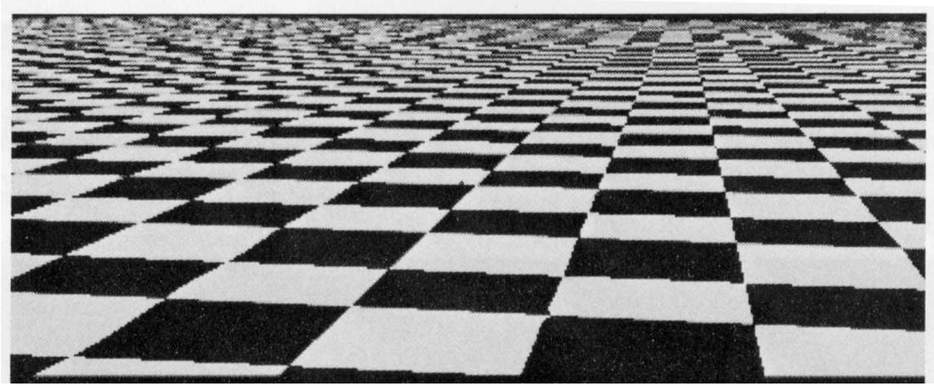




Note: Mapping is more complicated if you want to do perspective right!

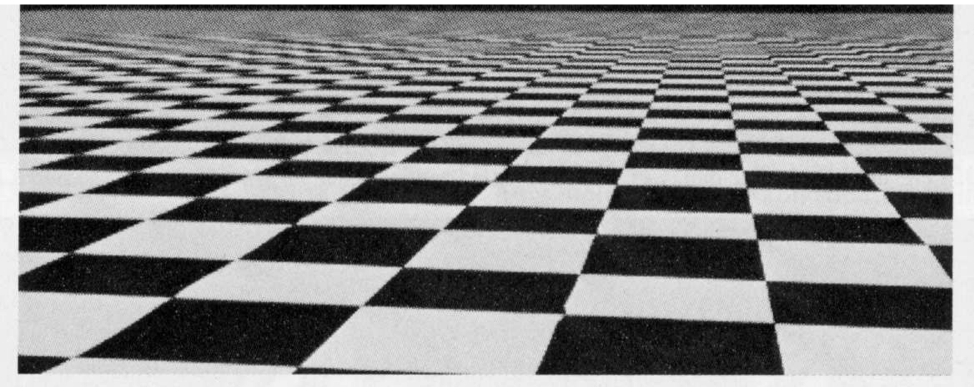
Antialiasing

If you point-sample the texture map, you get aliasing:



From Crow, SIGGRAPH '84

Proper antialiasing requires area averaging in the texture:



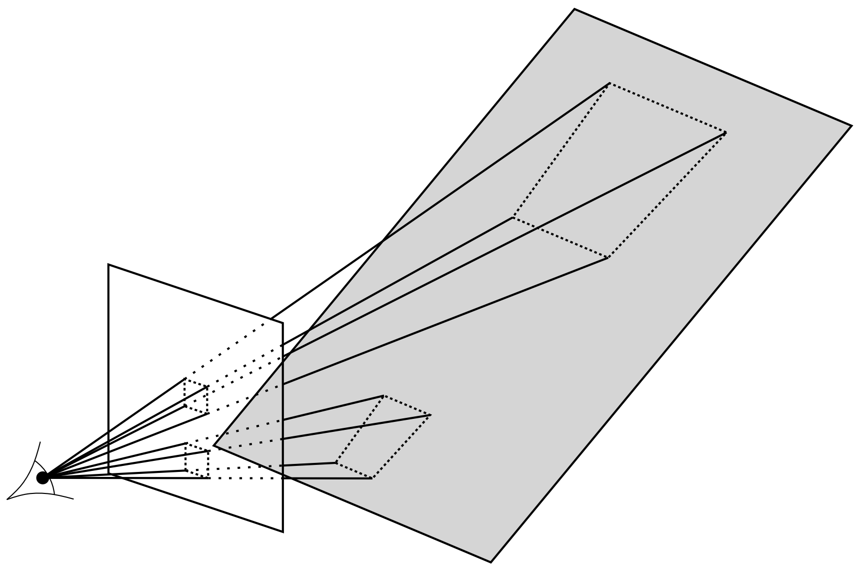
From Crow, SIGGRAPH '84

Computing the average color

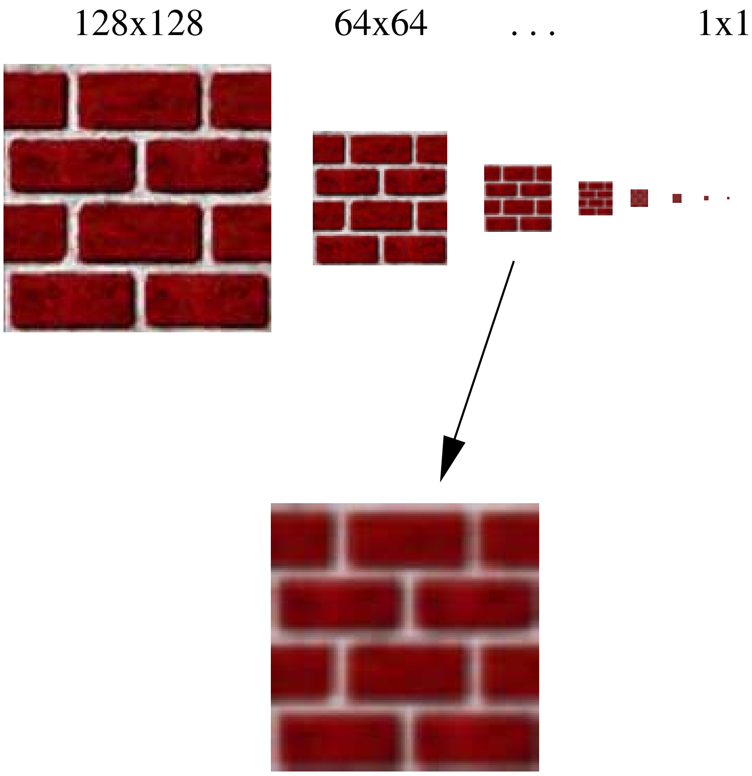
The computationally difficult part is summing over the covered pixels.

Several methods have been used:

1. Brute force:
    - Just sum
    - (Original method)



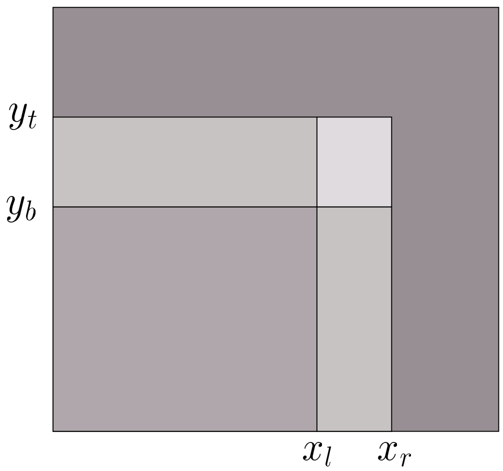
Computing the average color, cont'd



2. "Mip maps":
   - Lance Williams, 1983
   - Stands for "multum in parvo" — many things in a small place
   - Keep textures prefiltered at multiple resolutions.
   - Figure out closest two levels
   - Linear interpolate between the two

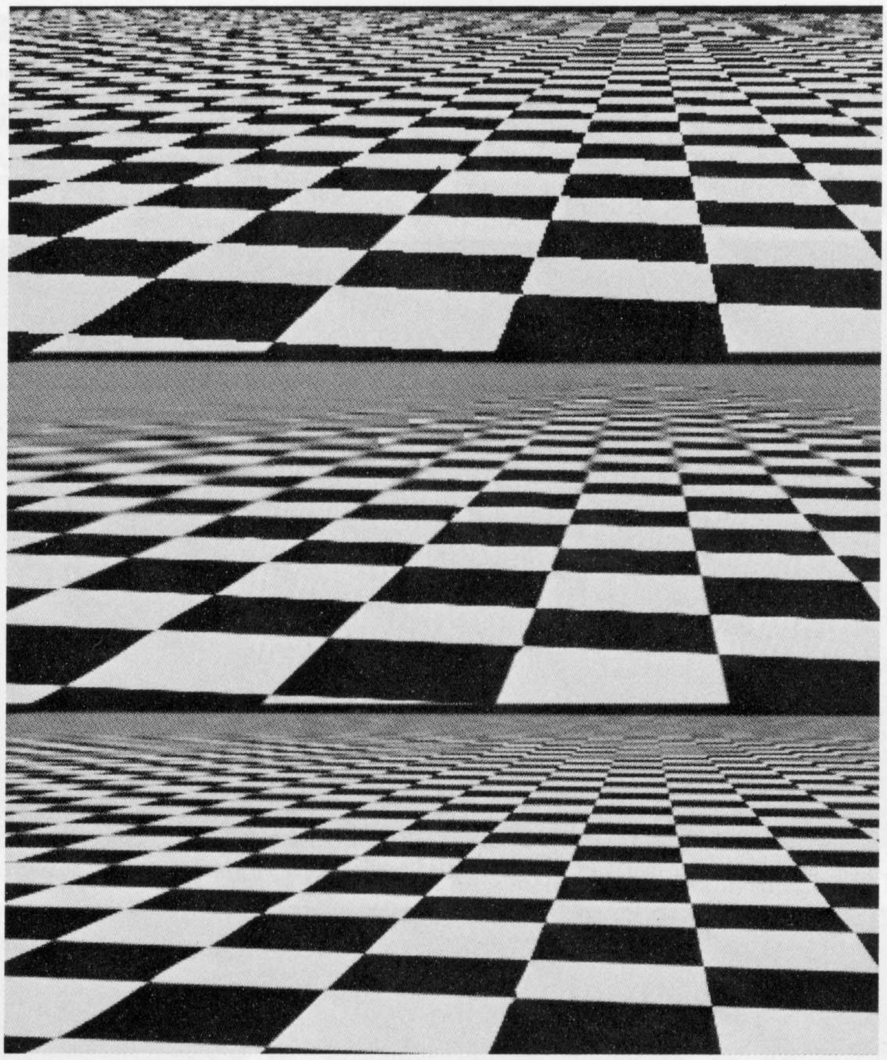
Computing the average color, cont'd

3. "Summed area tables":
   - Frank Crow, 1984
   - Keep sum of everything below and to the left
   - Use four table lookups:



   - Requires more memory
   - Gives less blurry textures

Comparison of techniques



Point sampled

MIP–mapped

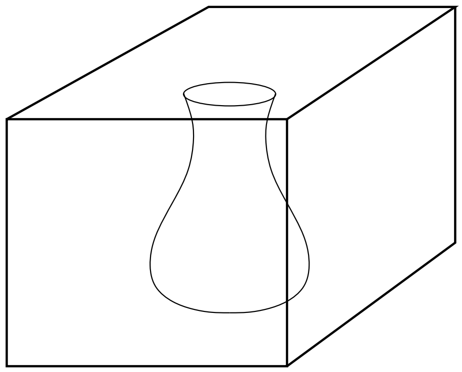
Summed
area table

Figure 5: CheckerBoards mapped onto a square showing vertically compressed texture.

From Crow, SIGGRAPH '84

Solid textures

Q: What kinds of artifacts might you see from using a marble veneer instead of real marble?



One solution is to use “solid textures”:

- Use model-space coordinates to index into a 3D texture
- Like “carving” the object from the material

One difficulty of solid texturing is coming up with the textures. . . .

Solid textures, cont'd

Here's an example for a vase cut from a solid marble texture:

Solid marble texture by Ken Perlin, (Foley, IV-21)

Bump mapping

Textures can be used for more than just color.

In "bump mapping," a texture is used to perturb the normal:

- The normal is perturbed in each parametric direction according to the partial derivates of the texture:

- These bumps "animate" with the surface

Q: What artifacts in the images would reveal that bump mapping is a fake?

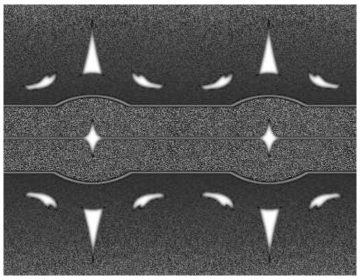
Displacement mapping

In "displacement mapping," a texture is used to perturb the surface geometry itself:

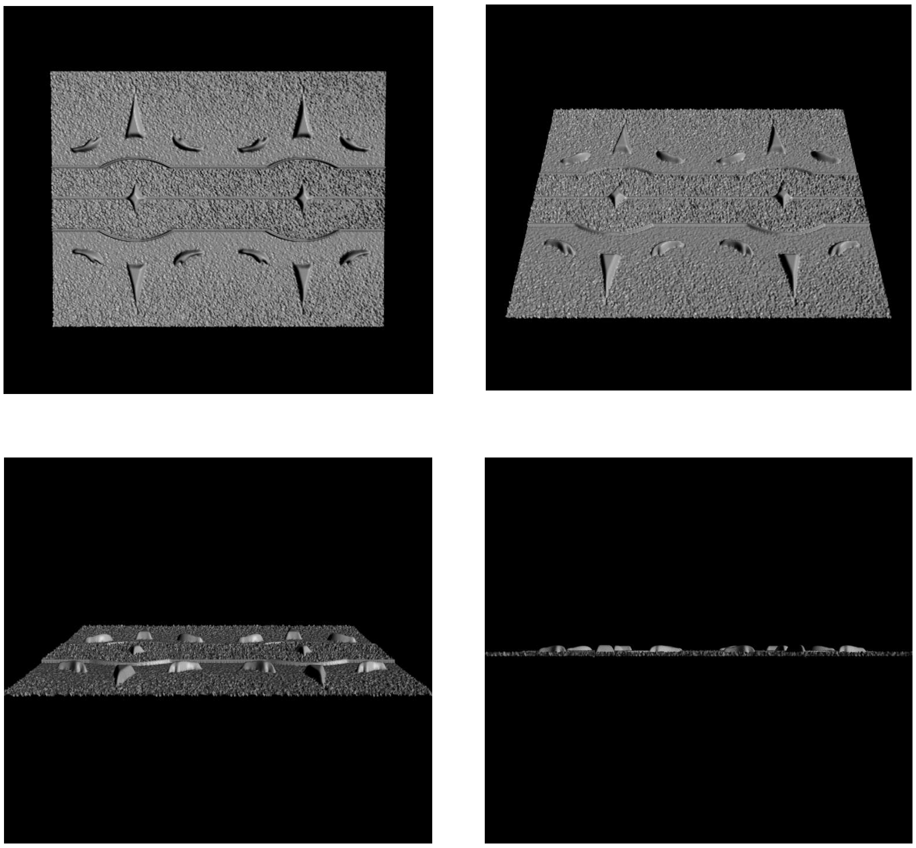
- Silhouettes are correct
- Requires doing additional hidden surface calculations

Displacement vs. bump mapping

Input texture



Rendered as displacement map over a rectangular surface



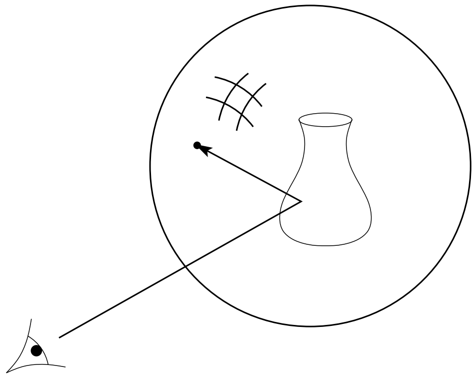
Displacement vs. bump mapping, cont'd

Original rendering

Rendering with bump map
wrapped around a cylinder

Bump map and rendering by Wyvern Aldinger

Environment mapping



In “environment mapping” (also known as “reflection mapping”), a texture is used to model an object’s environment:

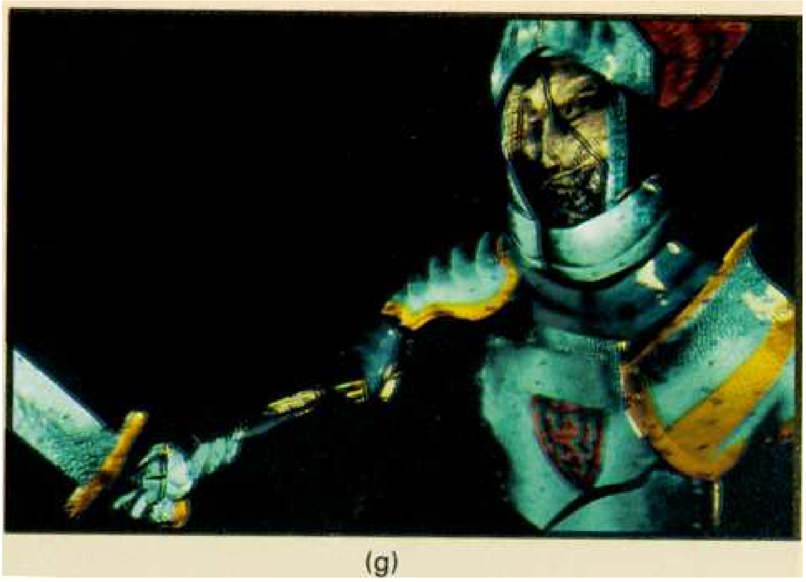
- Rays are bounced off objects into environment
- Color of the environment used to determine color of the illumination
- Really, a simplified form of ray tracing
- Environment mapping works well when there is just a single object — or in conjunction with ray tracing

Under simplifying assumptions, environment mapping can be implemented in hardware.

With a ray tracer, the concept is easily extended to handle refraction as well as reflection.

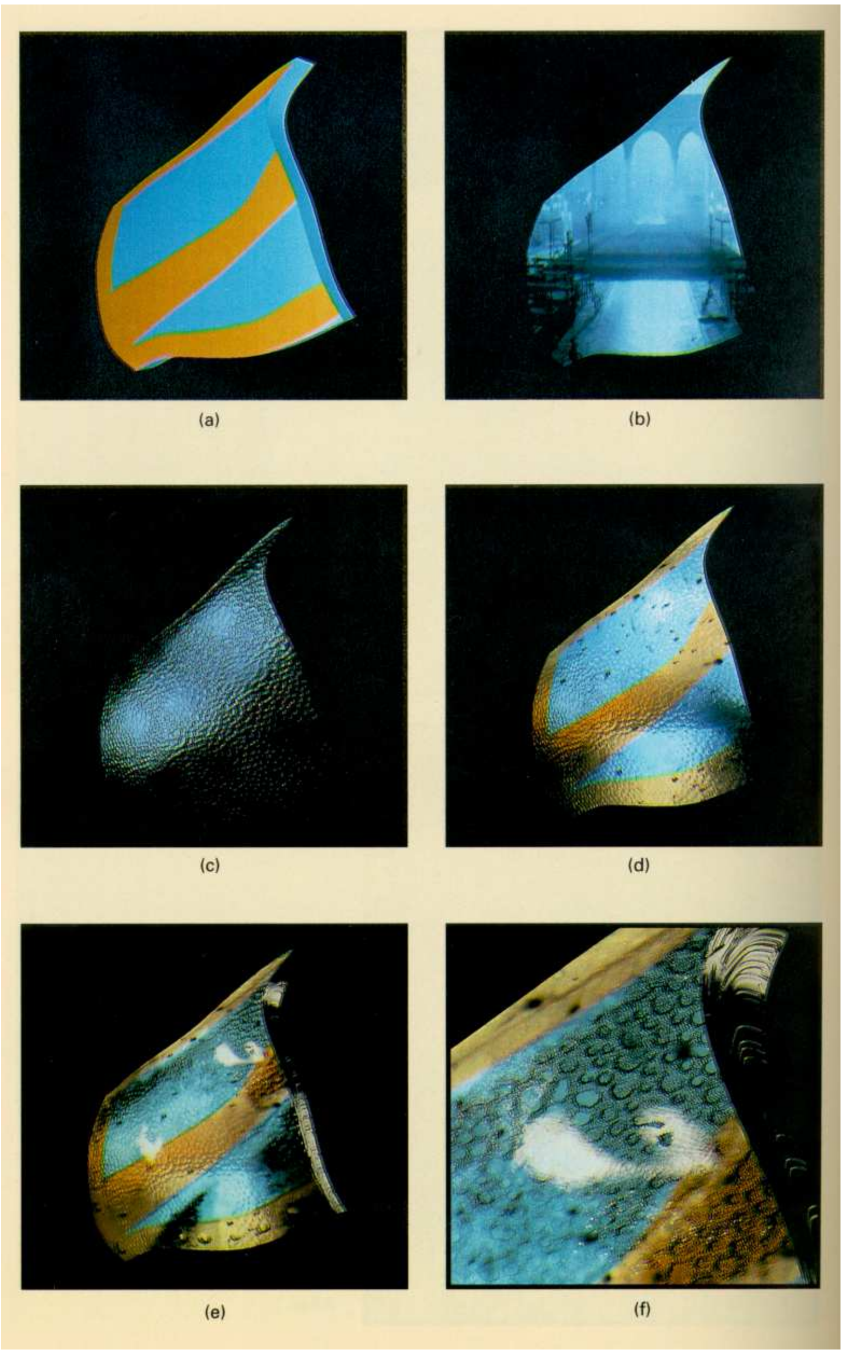
Combining texture maps

Using texture maps in combination gives even better effects, as *Young Sherlock Holmes* demonstrated. . . .



Construction of the glass knight, (Foley, IV-24)

Combining texture maps, cont'd



Construction of the glass knight, (Foley, IV-24)

Summary

What to take home from this lecture:

1. What texture mapping is, and what it's good for.
2. Understanding of the various approaches to antialiased texture mapping:
   - Brute force
   - Mip maps
   - Summed area tables