11. Texture Mapping

Reading

- Angel, sections 10.2 - 10.4
- Hearn & Baker, 14.8 - 14.9
- Woo, Neider, & Davis, chapter 9

- 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.

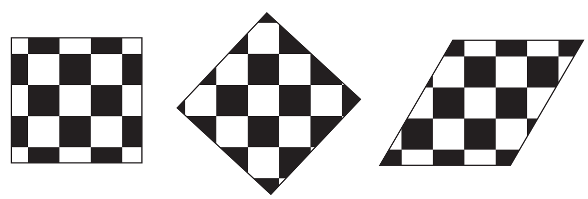
Texture mapping

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

- Due to Ed Catmull, Ph.D. thesis, 1974
- Refined by Blinn & Newell, 1976

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

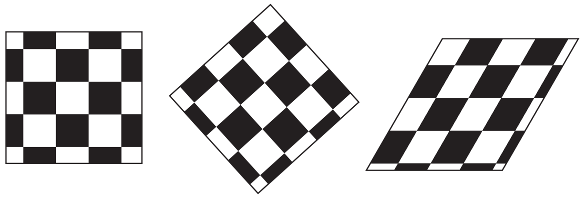
Non-parametric texture mapping



With **non-parametric texture mapping**:

- texture size and orientation are fixed
- unrelated to size and orientation of polygon
- gives cookie-cutter effect

Parametric texture mapping

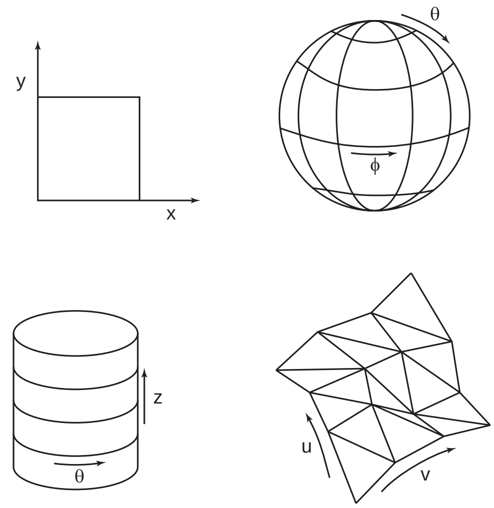


With **parametric texture mapping**, texture size and orientation are tied to the polygon:

- separate **texture space** and **screen space**
- texture the polygon as before, but in texture space
- deform (render) the textured polygon into screen space

Implementing texture mapping

Textures can be wrapped around many different surfaces:

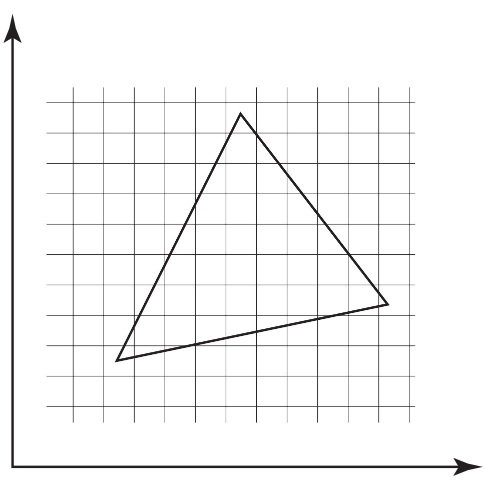


Computing (*u*,*v*) coordinates in a ray tracer is fairly straightforward.

Implementing, cont.

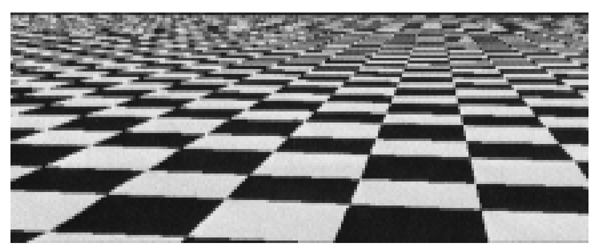
Texture mapping can also be handled in z-buffer algorithms.

- 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

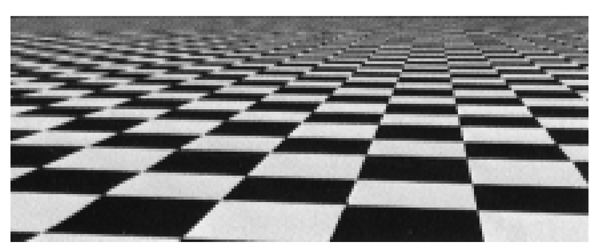


Antialiasing

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



Proper antialiasing requires area averaging in the texture:



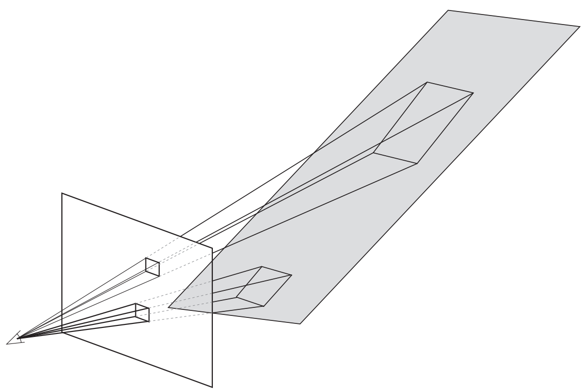
Computing the average color

The computationally difficult part is summing over the covered pixels:

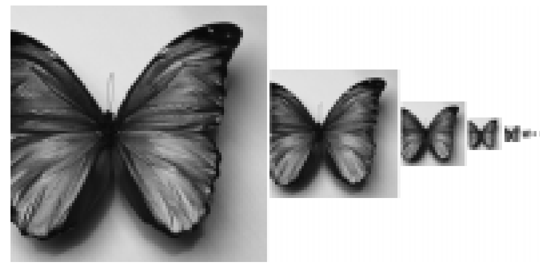
Several methods have been used:

1. Brute force

- just sum



Computing the average color, cont.



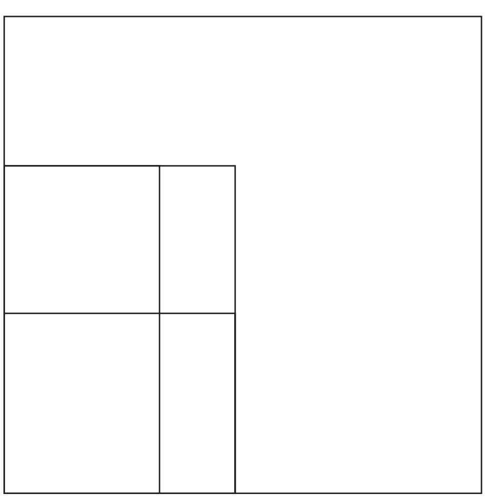
2. **Mip maps**

- Lance Williams, 1983
- stands for "multum in parvo" — "many things in a small place"
- keep textures prefiltered at multiple resolutions
- figure out two closest levels
- linear interpolate between the two

Computing the average color, cont.

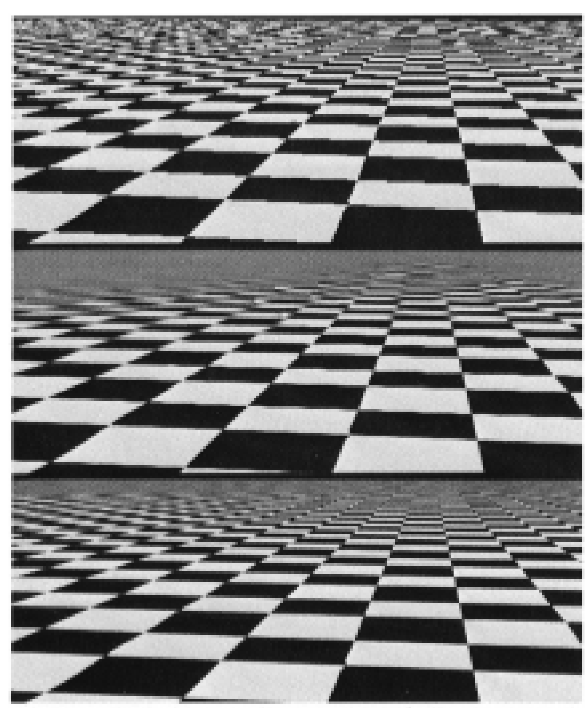
3. **Summed area tables**

- Frank Crow, 1984
- keep sum of everything below and to the left
- use four table lookups



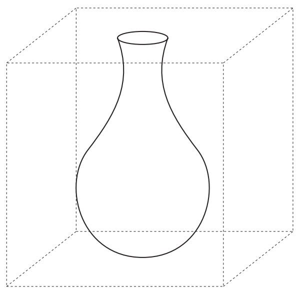
- requires more memory
- gives less blurry textures

Comparison of techniques



Solid textures

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



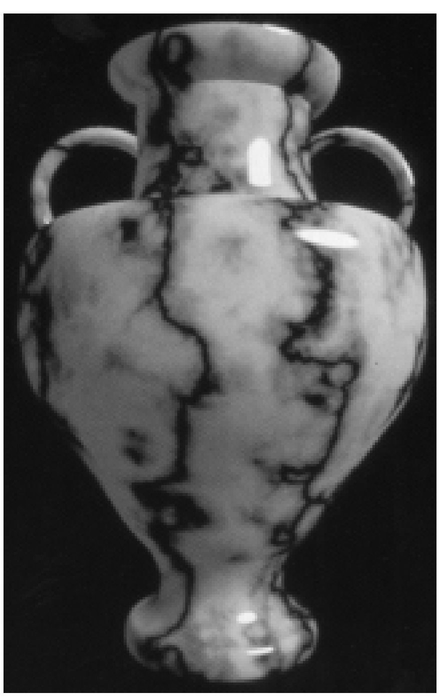
One solution is to use **solid textures**.

- 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.

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



Procedural texture mapping

Instead of using texture coordinates to index into an image, use them to compute a function that defines the texture.

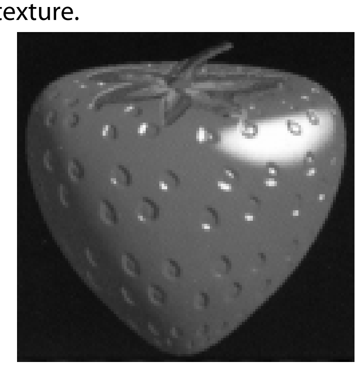
Bump mapping

Textures can be used for more than just color.

$$I = k_a I_a + \sum_i f(d_i) I_{li} \left[k_d (\mathbf{N} \cdot \mathbf{L}_i)_+ + k_s (\mathbf{V} \cdot \mathbf{R})_+^{n_s} \right]$$

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

- the normal is perturbed in each parametric direction according to the partial derivatives of the texture.



- these bumps "animate" with the surface

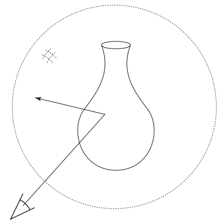
Q: What artifacts in the images would reveal that bump mapping is a fake?

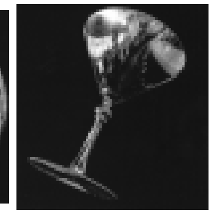
Displacement mapping

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

- silhouettes are correct
- requires doing additional hidden surface calculations

Environment mapping





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

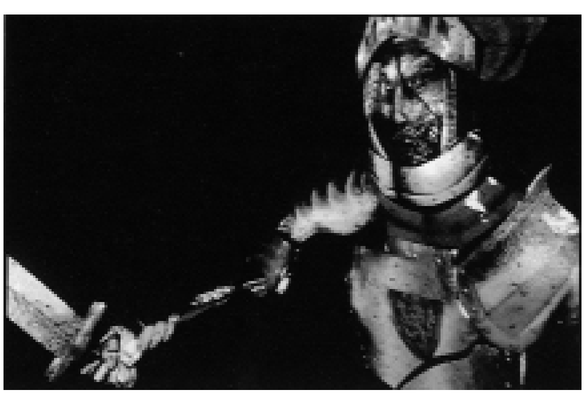
- rays are bounced off objects into environment
- color of the environment used to determine color of the illumination
- really, a simplified form of ray tracing
- environment mapping works well when there is just a single object — or in conjunction with ray tracing

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

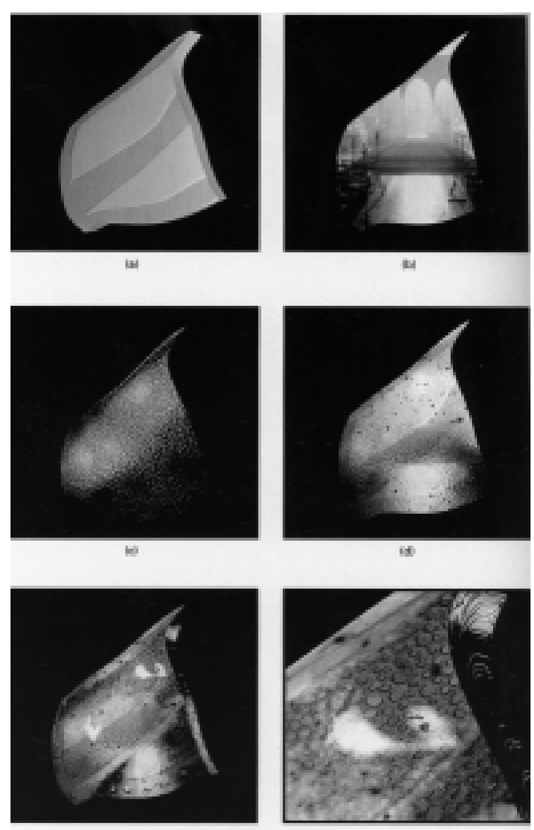
With a ray tracer, the concept is easily extended to handle refraction as well as reflection.

Combining texture maps

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



Combining texture maps, cont.



Summary

What to take home from this lecture:

- What texture mapping is, and what it's good for.
- Understanding of the various approaches to antialiased texture mapping:
  - brute force
  - mip maps
  - summed area tables