Texture Mapping

Reading

Foley 16.3

Optional

- Paul S. Heckbert. Survey of texture mapping. *IEEE Computer Graphics and Applications* 6(11): 56-67, November 1986

  http://www.cs.cmu.edu/afs/cs/user/ph/www/texsurv.ps.gz

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, PhD thesis, 1974

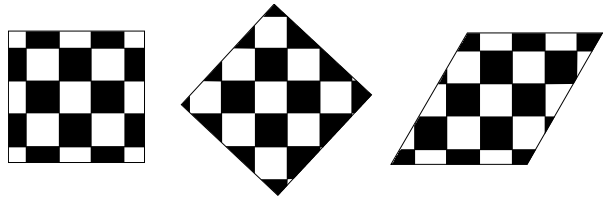- ensures that "all the right things" happen as a texture polygon is transformed and rendered

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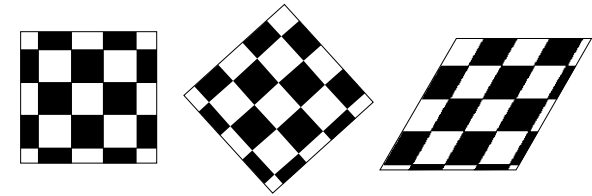# Non-parametric texture mapping

With non parametric texture mapping:

- Texture size and orientation are fixed
- Unrelated to size and orientation of polygon
- Gives a 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
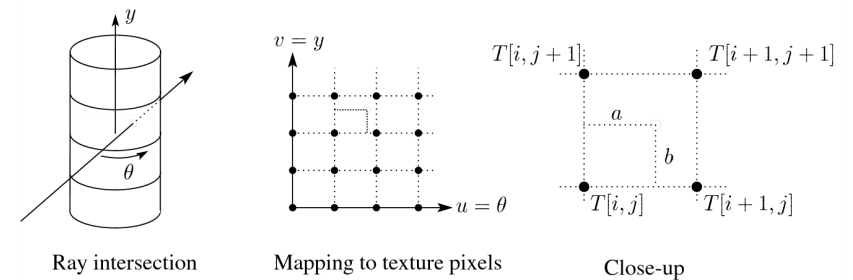
Textures can be warped around many different surfaces:
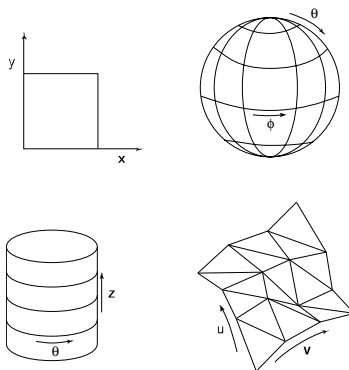
Computing (u,v) coordinates in a ray tracer is fairly straightforward

Texture resampling

What do we do when the texture sample lands between the texture pixels?

$v = y$

$T[i, j+1]$ $T[i+1, j+1]$

a

b

$u = \theta$ $T[i, j]$ $T[i+1, j]$

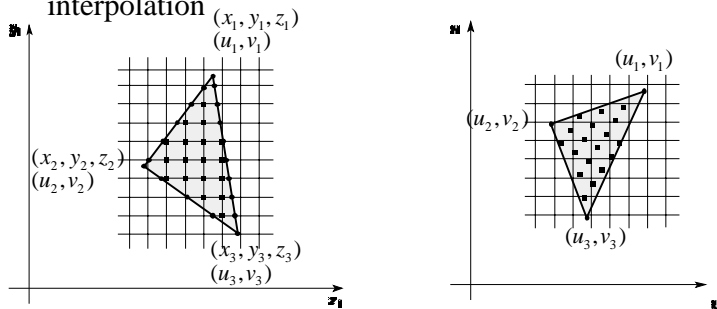Ray intersection   Mapping to texture pixels   Close-up

We resample. Common choice is **bilinear resampling**.
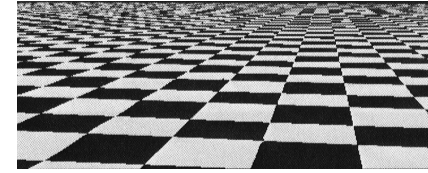
Implementing, cont.

- 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
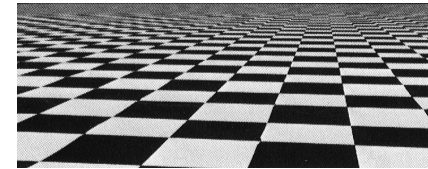- Texture coordinates are found by Gouraud-style interpolation

Antialiasing

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

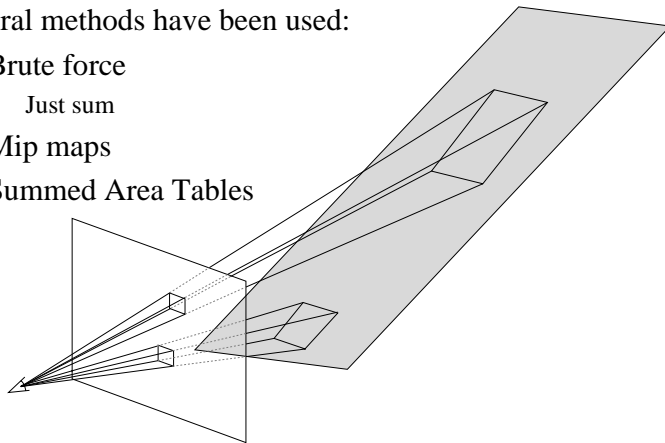- Proper antialiasing requires area averaging in the texture:

Computing average color

Computationally difficult part is summing over the covered pixels:

Several methods have been used:

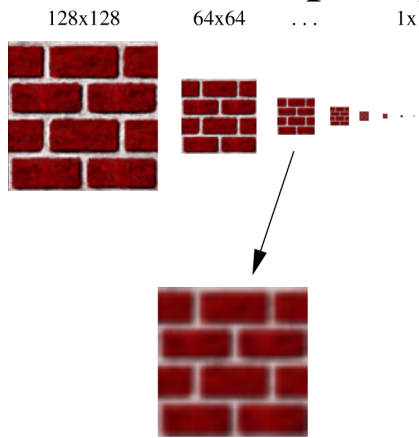1. Brute force
   - Just sum
2. Mip maps
3. Summed Area Tables

Mip Maps

- Lance Williams, 1983
- "multum in parvo" – many things in a small place
- Keep textures prefiltered at multiple resolutions

Mip maps, cont'd

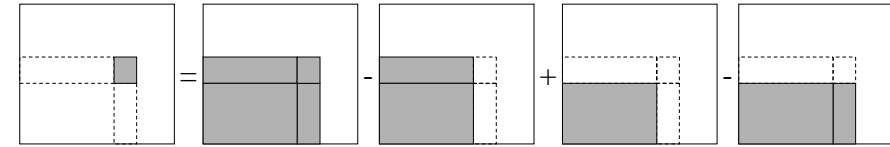128x128   64x64   . . .   1x1

1. Figure out two closest levels
2. Linear interpolate between the two

Q: What would the mip map return for an average over a 65x65 neighborhood at (u,v)?
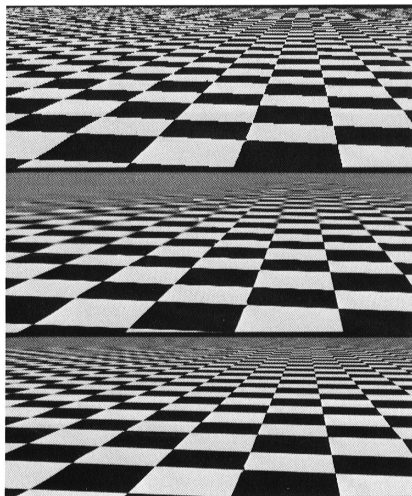
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Summed area tables

- Due to Frank Crow, 1984
- Keep sum of everything below and to the left
- Use four table lookups
- Requires more memory (2-4 times the original image)
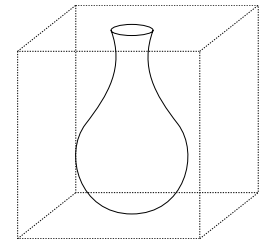- Gives less blurry textures

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Comparison of techniques

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Solid textures

Q: what kinds of artifacts might you see from using a marble veneer instead of a 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…
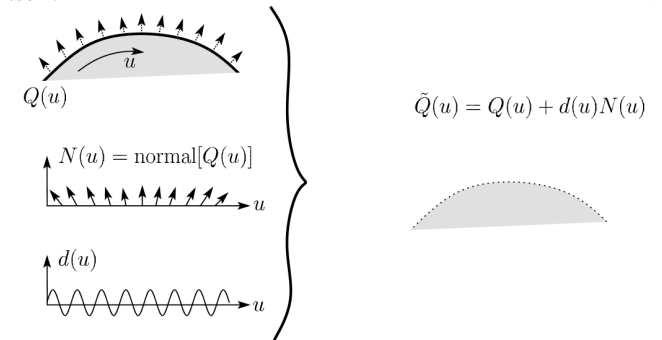
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Solid textures, cont.

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

Displacement mapping

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

$$\tilde{Q}(u) = Q(u) + d(u)N(u)$$
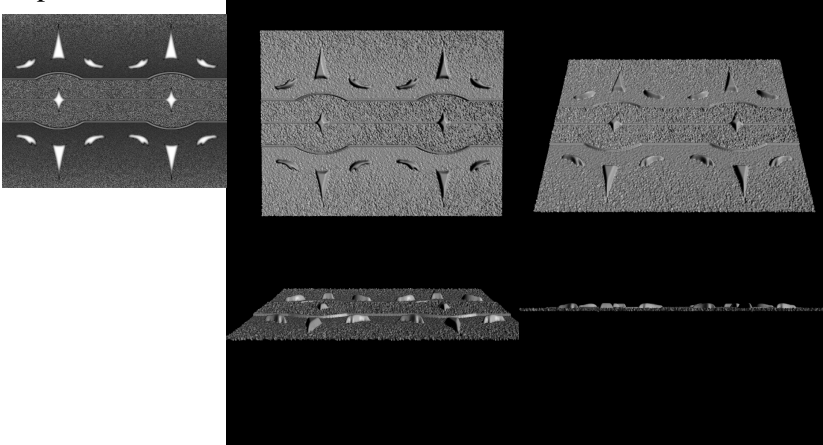
$Q(u)$

$N(u) = \text{normal}[Q(u)]$

$d(u)$

- Silhouettes are correct
- Requires doing additional hidden surface calculations

Displacement mapping, cont.

Input texture:

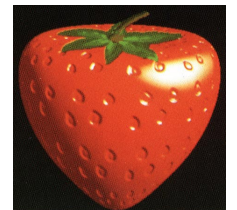Displacement map over rectangular surface:

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 fake?

Bump mapping example
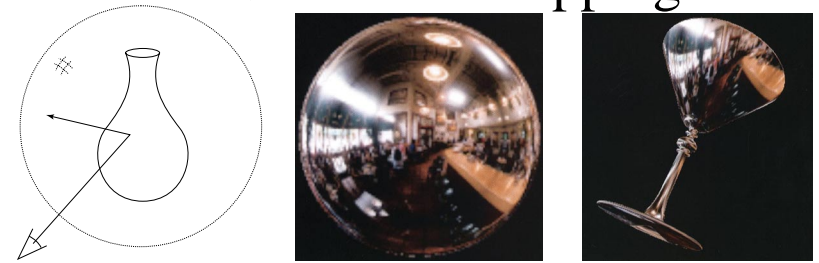

Original rendering   Rendering with bump map
wrapped around a cylinder

Environment mapping

- A.k.a. reflection mapping
- Use texture to model object's environment
- Rays are bounced off objects into environment to determine color of illumination
- Works well when there is just a single object
- With some simplifications can be implemented in hardware
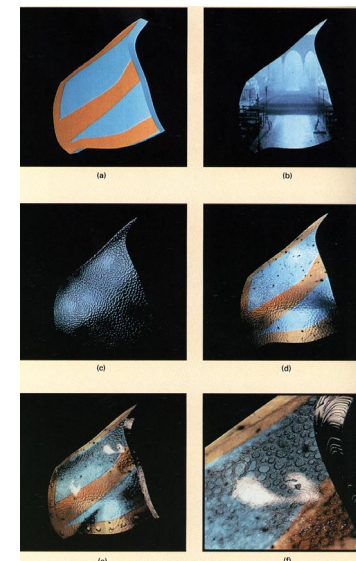- Raytracer can be extended to handle refractions as well

Combining texture maps

- Using texture maps in combination give even better effects

Combining texture maps, cont.

Summary

What to take from this lecture:

- What texture mapping is and what is it good for
- Understanding the various approaches to antialiased textured mapping
  - Brute force
  - Mip maps
  - Summed area tables
- Additional effect with texture mapping techniques
  - Bump mapping
  - Displacement mapping
  - Environment mapping

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