Texture Mapping

Reading

Required

- Shirley, 11.1-11.3, 11.5-11.7

Recommended

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

Optional

- 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.

Texture mapping

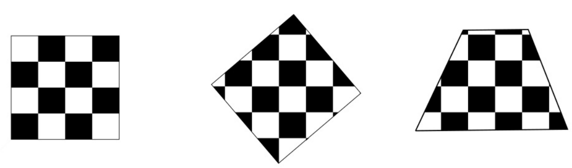
Texture mapping (Woo et al., fig. 9-1)

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.

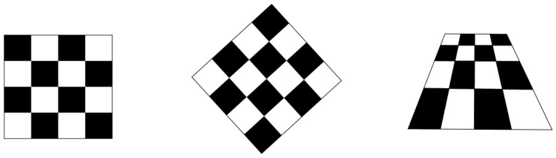
Non-parametric texture mapping



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.

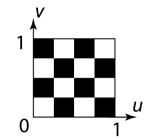
<u>Idea</u>:

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

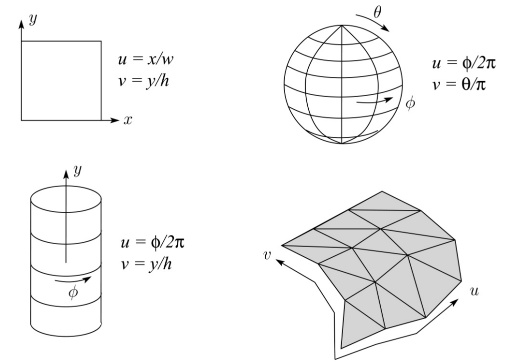
A texture can modulate just about any parameter – diffuse color, specular color, specular exponent, …

Implementing texture mapping

A texture lives in it own abstract image coordinates paramaterized by (u,v) in the range ([0..1], [0..1]):



It can be wrapped around many different surfaces:



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

Note: if the surface moves/deforms, the texture goes with it.

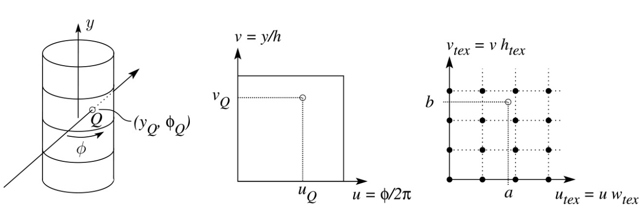
Mapping to texture image coords

The texture is usually stored as an image. Thus, we need to convert from abstract texture coordinate:

(u,v) in the range ([0..1], [0..1])

to texture image coordinates:

(u_{tex},v_{tex}) in the range ([0.. w_{tex}], [0.. h_{tex}])



Ray intersection

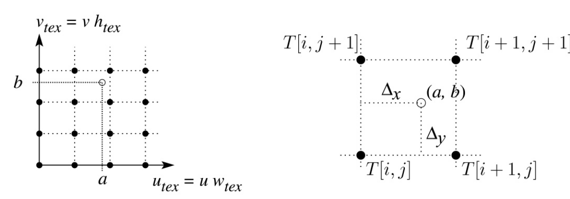
Mapping to abstract texture coords

Mapping to texture pixel coords

Q: What do you do when the texture sample you need lands between texture pixels?

Texture resampling

We need to resample the texture:



Mapping to texture pixel coords

Close-up

A common choice is **bilinear interpolation**:

$$\mathrm{T}(a,b) = \mathrm{T}\left(i+\Delta_x, j+\Delta_y\right)$$

$$= \underline{\qquad\qquad} \mathrm{T}[i,j] \;+$$

$$\underline{\qquad\qquad} \mathrm{T}[i+1,j] \;+$$

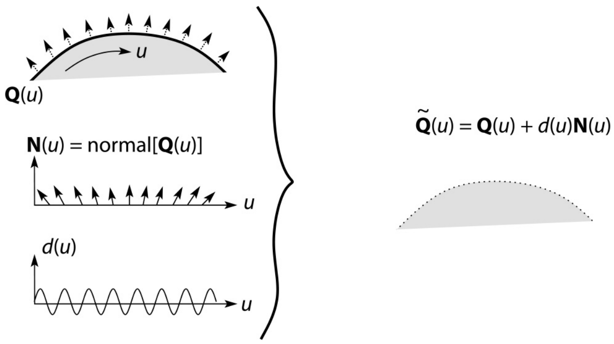
$$\underline{\qquad\qquad} \mathrm{T}[i,j+1] \;+$$

$$\underline{\qquad\qquad} \mathrm{T}[i+1,j+1]$$

Displacement mapping

Textures can be used for more than just color.

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



- These displacements "animate" with the surface

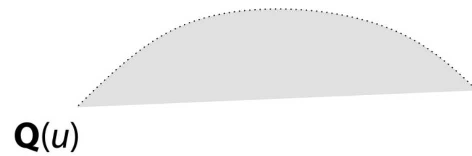
Q: Do you have to do hidden surface calculations on $\tilde{\mathbf{Q}}$?

Bump mapping

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

- Use the original, simpler geometry, **Q**(*u*), for hidden surfaces
- Use the normal from the displacement map for shading:

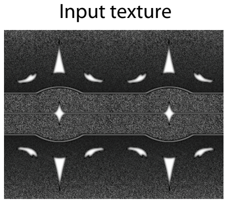
$$\tilde{\mathbf{N}} = \text{normal}[\tilde{\mathbf{Q}}(u)]$$



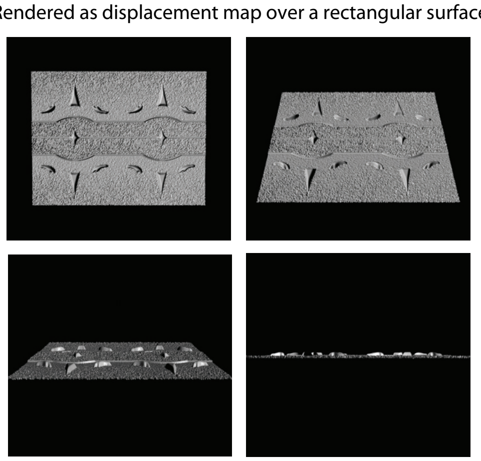
Q: What artifacts in the images would reveal that bump mapping is a fake?

Displacement vs. bump mapping

Input texture



Rendered as displacement map over a rectangular surface



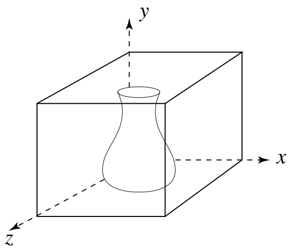
Displacement vs. bump mapping (cont'd)

Original rendering | Rendering with bump map wrapped around a cylinder

Bump map and rendering by Wyvern Aldinger

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.

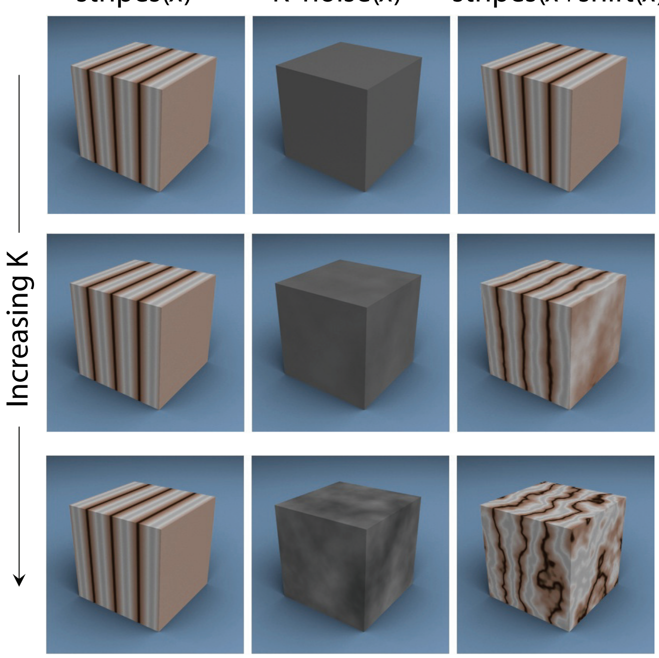
Solid textures (cont'd)

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

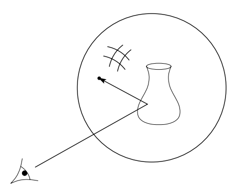
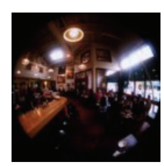
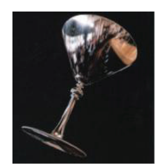
Solid marble texture by Ken Perlin, (Foley, IV-21)

Solid textures (cont'd)

in(x,y,z) = stripes(x)	shift(x,y,z) = K•noise(x)	out(x,y,z) = stripes(x+shift(x))



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.