# Texture Mapping



## Reading

Required

- Angel, 7.6-7.8.

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)*

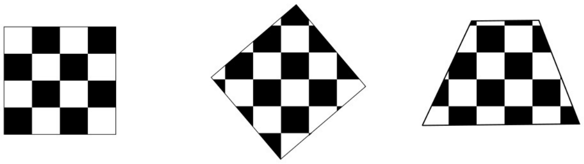
Texture mapping allows you to take a simple polygon and give it the appearance of something much more complex.

- 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.



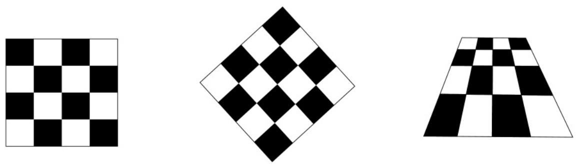
## Non-parametric texture mapping



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>:

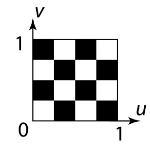
- Separate “texture space” and “screen space”
- Texture the polygon as before, but in texture space
- Deform (render) the textured polygon into screen space

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

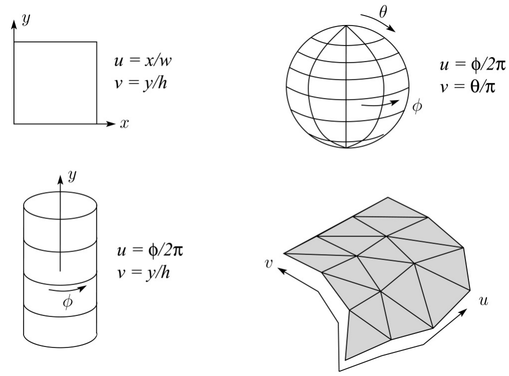


# Implementing texture mapping

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.



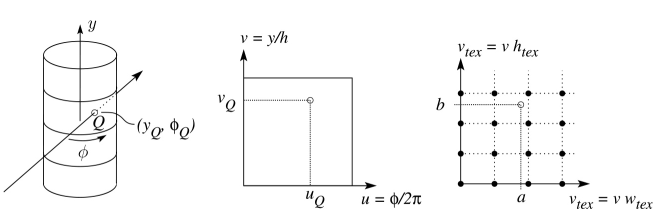
# Mapping to texture image coords

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

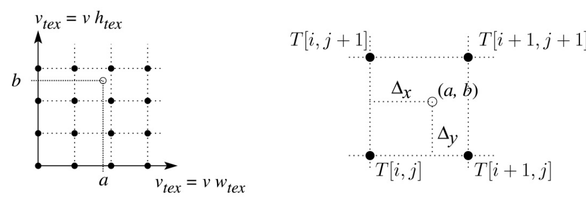
Mapping to texture pixel coords

**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**:

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

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

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

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

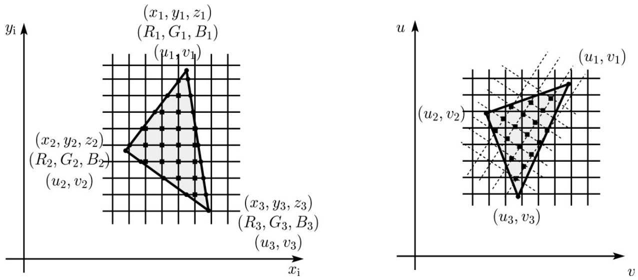
$$\underline{\qquad\qquad}\ \mathrm{T}[i+1,j+1]$$

# Texture mapping and the z-buffer

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

<u>Method</u>:

- 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

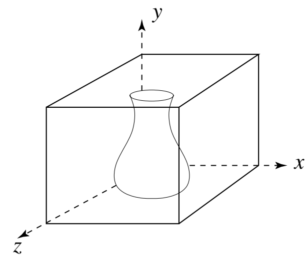



<u>Note</u>: Mapping is more complicated if you want to do perspective right!



# 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:

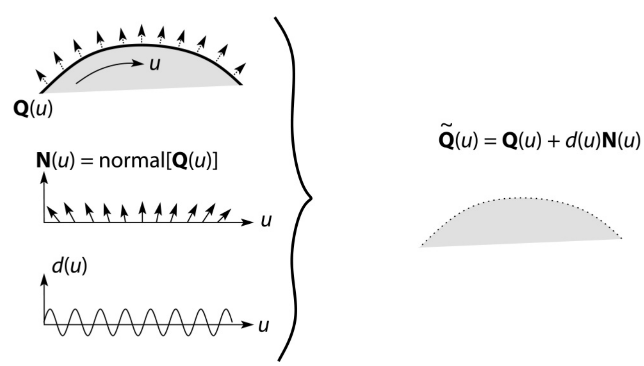
*Solid marble texture by Ken Perlin, (Foley, IV-21)*



# 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

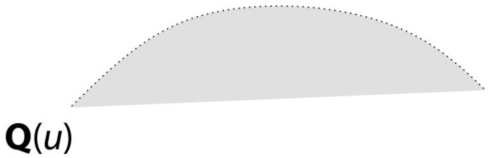
**Q**: Do you have to do hidden surface calculations on $\tilde{\mathbf{Q}}$?

## 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:

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

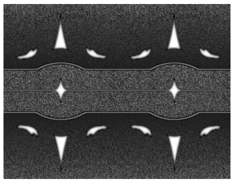



**Q**: What artifacts in the images would reveal that bump mapping is a fake?

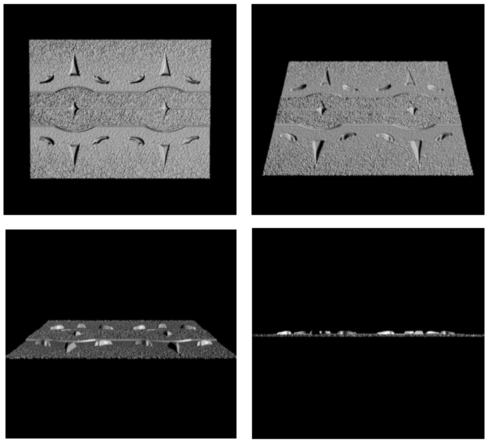


## Displacement vs. bump mapping

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*



## Environment mapping

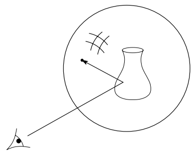


Image of gazing sphere (taken in a pub)

Environment-mapped rendering

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

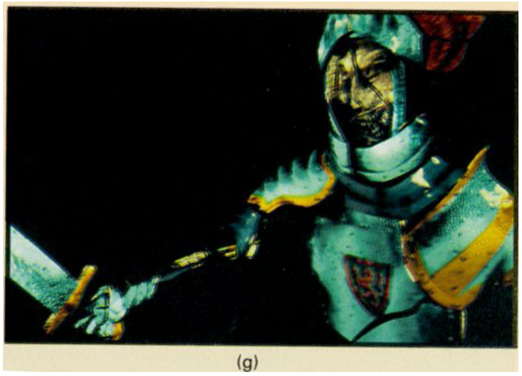
- Rays are bounced off objects into environment
- Color of the environment used to determine color of the illumination
- Really, a simplified form of ray tracing
- Environment mapping works well when there is just a single object – or in conjunction with ray tracing

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

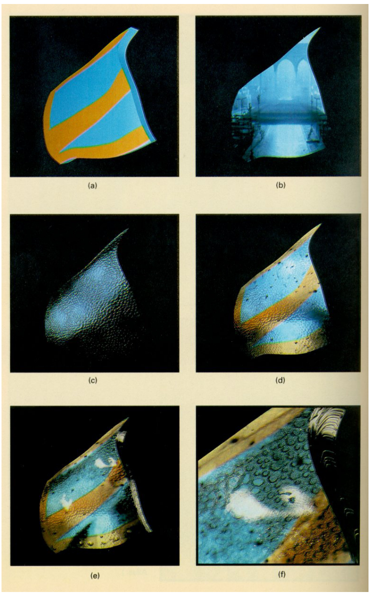
Using texture maps in combination gives even better effects, as *Young Sherlock Holmes* demonstrated …




*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. The meaning of the boldfaced terms.
2. Familiarity with the various kinds of texture mapping, including their strengths and limitations.
3. Understanding of the various approaches to antialiased texture mapping:
   - Brute force
   - Mip maps
   - Summed area tables