

9. Texture Mapping

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Reading

Required

- ♦ Watt, intro to Chapter 8 and intros to 8.1, 8.4, 8.6, 8.8.

Recommended

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

Optional

- ♦ Watt, the rest of Chapter 8
- ♦ 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.

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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.

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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

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Parametric texture mapping



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

Idea:

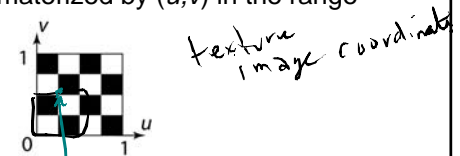
- ◆ Separate “texture space” and “screen space”
- ◆ Texture the polygon as before, but in texture space
- ◆ Deform (render) the textured polygon into screen space

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

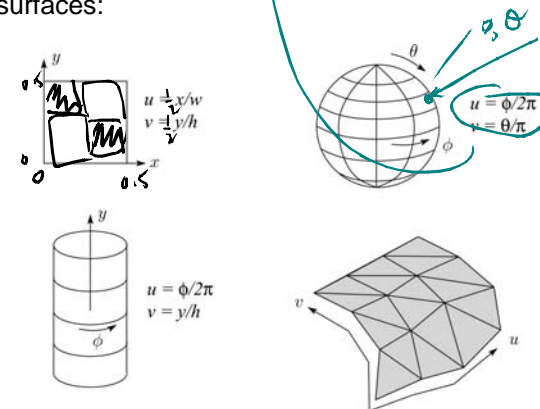
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Implementing texture mapping

A texture lives in its own abstract image coordinates parameterized 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

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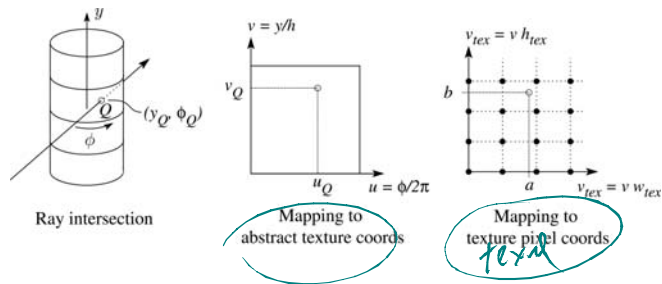
Mapping to texture image coords

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 $([0.. w_{tex}], [0.. h_{tex}])$

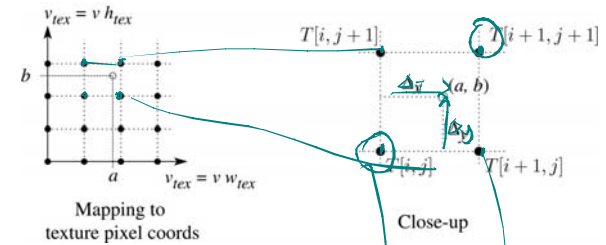


Q: What do you do when the texture sample you need lands between texture pixels?

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Texture resampling

We need to resample the texture:



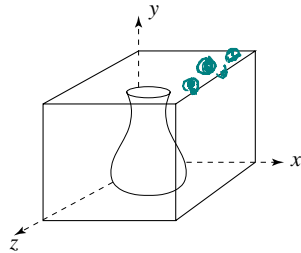
A common choice is **bilinear interpolation**:

$$\begin{aligned}
 T(a, b) &= T(i + \Delta_x, j + \Delta_y) \\
 &= \frac{(1 - \Delta_x)(1 - \Delta_y)}{\Delta x \Delta y} T[i, j] + \\
 &\quad \frac{\Delta x (1 - \Delta_y)}{\Delta x \Delta y} T[i + 1, j] + \\
 &\quad \frac{(1 - \Delta_x) \Delta y}{\Delta x \Delta y} T[i, j + 1] + \\
 &\quad \frac{\Delta x \Delta y}{\Delta x \Delta y} T[i + 1, j + 1]
 \end{aligned}$$

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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.

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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)

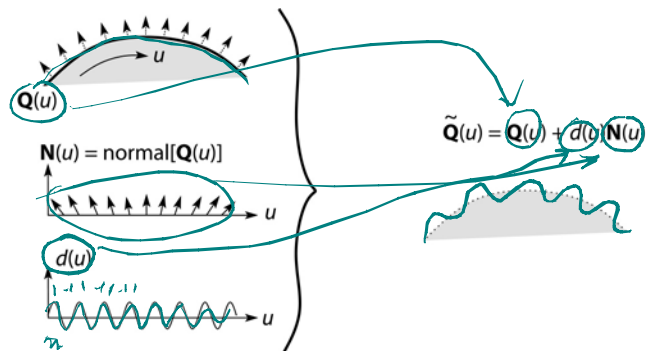
Ken Perlin

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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

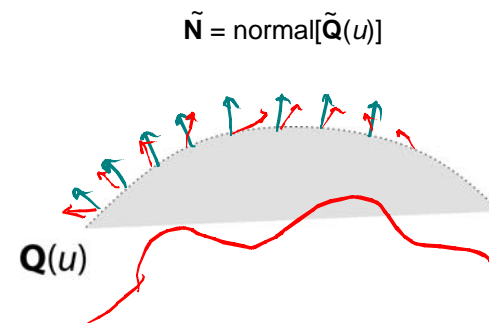
Q: Do you have to do hidden surface calculations on Q ?

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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:

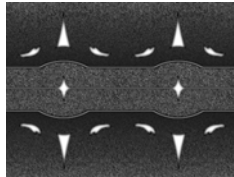


Q: What artifacts in the images would reveal that bump mapping is a fake?

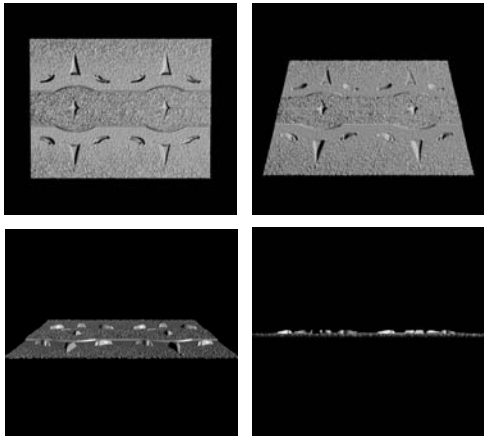
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Displacement vs. bump mapping

Input texture



Rendered as displacement map over a rectangular surface



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Displacement vs. bump mapping (cont'd)



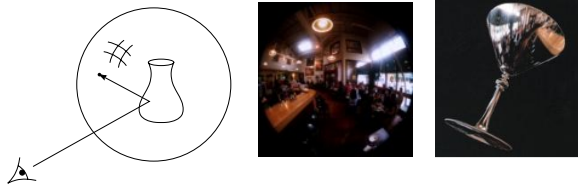
Original rendering

Rendering with bump map wrapped around a cylinder

Bump map and rendering by Wyvern Aldinger

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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.

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Combining texture maps

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

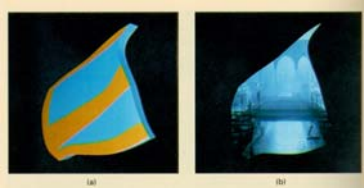


Construction of the glass knight, (Foley, IV-24)

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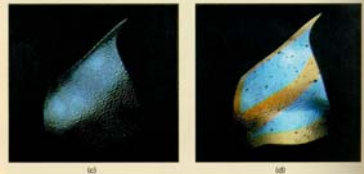
Combining texture maps (cont'd)

Phong lighting
with
diffuse texture



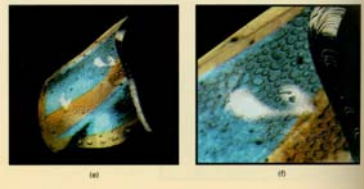
Environment-
mapped
mirror reflection

Bump mapping +
textures
Glossy reflection



Combine
and add dirt

Rivet stains +
Shinier reflections



Close-up

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