Texture Mapping

Reading

Angel, pages 373-386

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

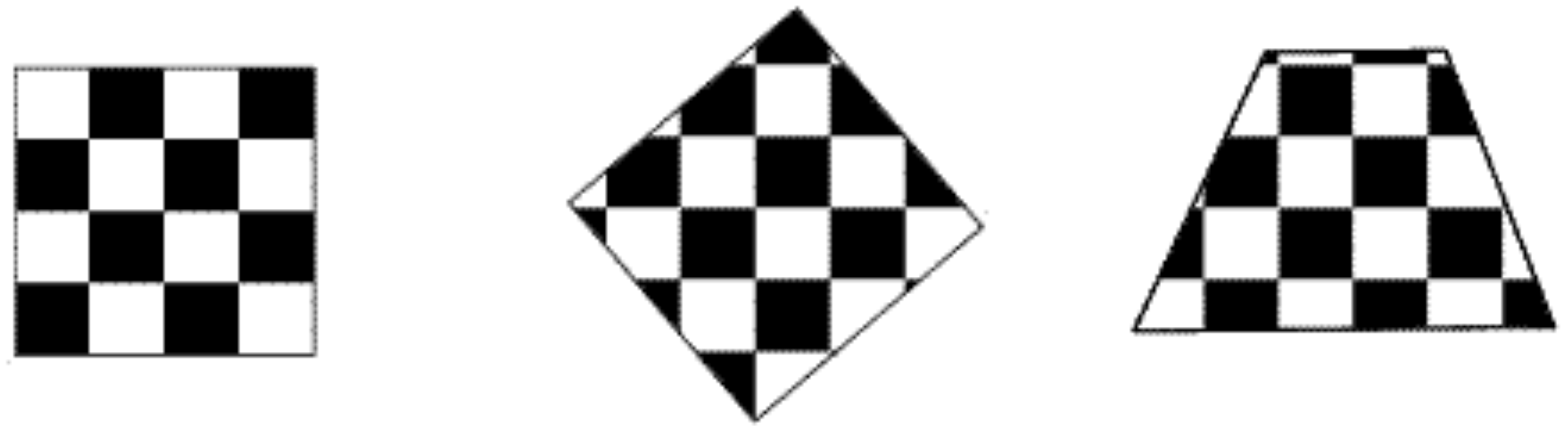
Texture mapping

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


IRIS Performer

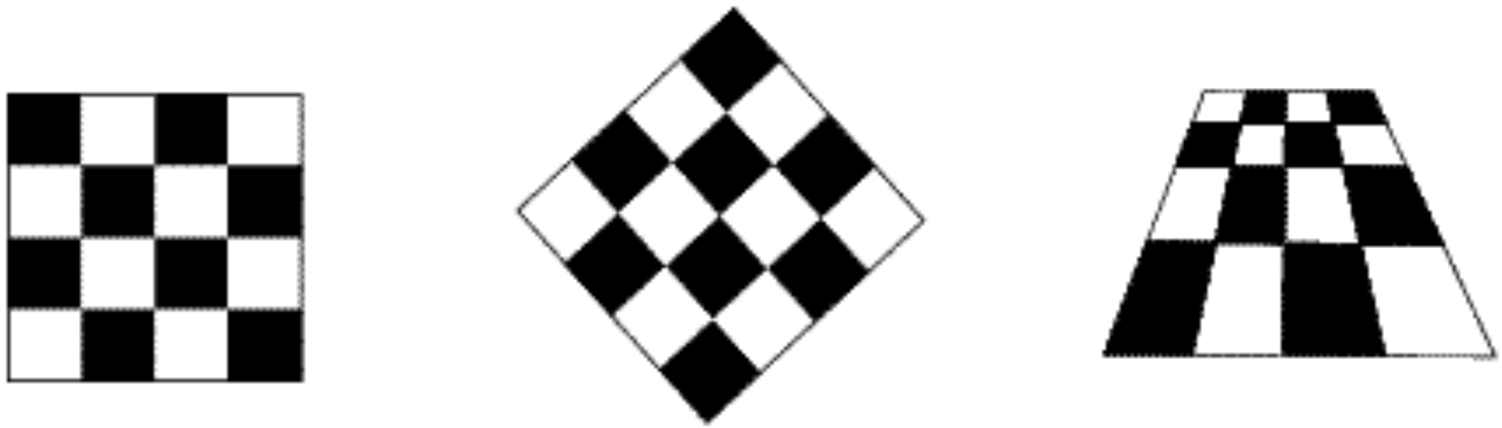
Non-parametric texture mapping



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

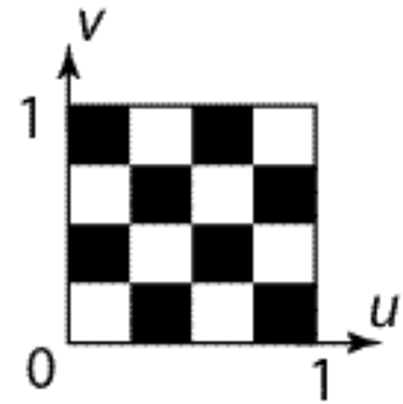


With parametric texture mapping, texture size and orientation are tied to the polygon:

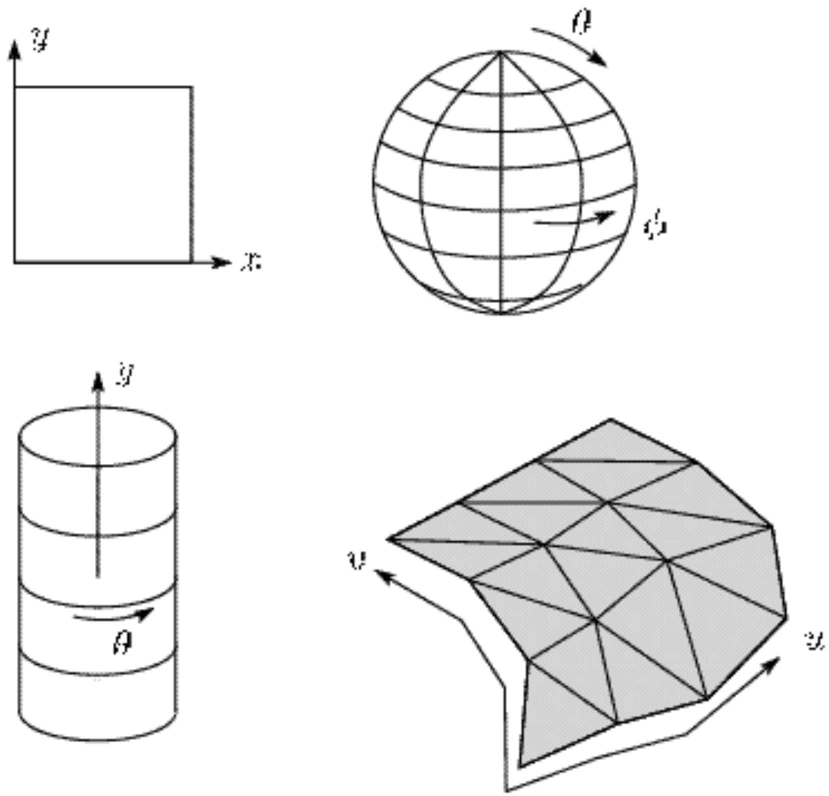
- Separate texture space and screen space
- Texture the polygon as before but in texture space
- Deform (render) the textured polygon into screen space

Implementing texture mapping

A texture lives in it own image coordinates paramaterized by (*u,v*):

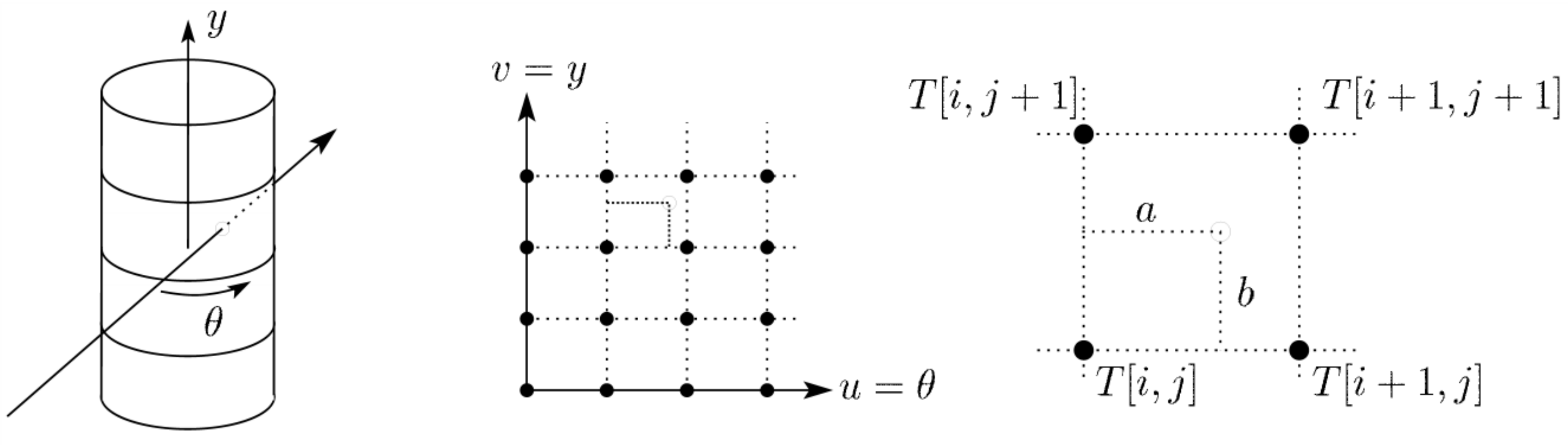


It can be wrapped around many different surfaces:



Texture resampling

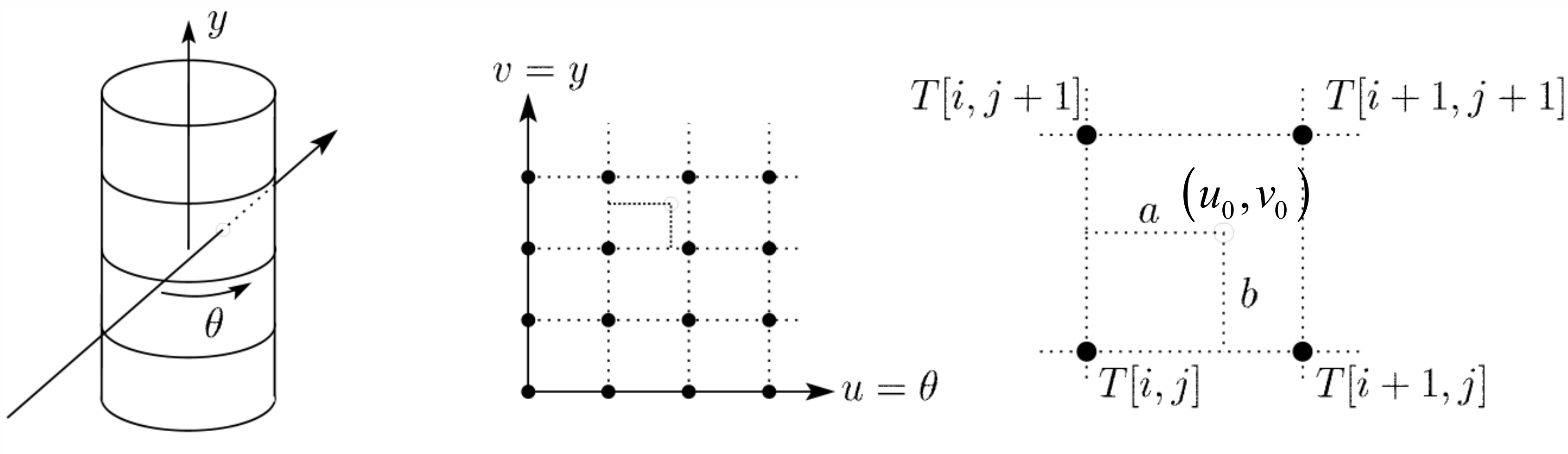
What do we do when the texture sample lands between the texture pixels?



Ray intersection   Mapping to texture pixels   Close-up

We resample. Common choice is **bilinear resampling**.

Bilinear Resampling



Ray intersection   Mapping to texture pixels   Close-up

$T(u_0, v_0) =$

$T(i\Delta + a, j\Delta + b)$ = ____________T[*i*,*j*] +

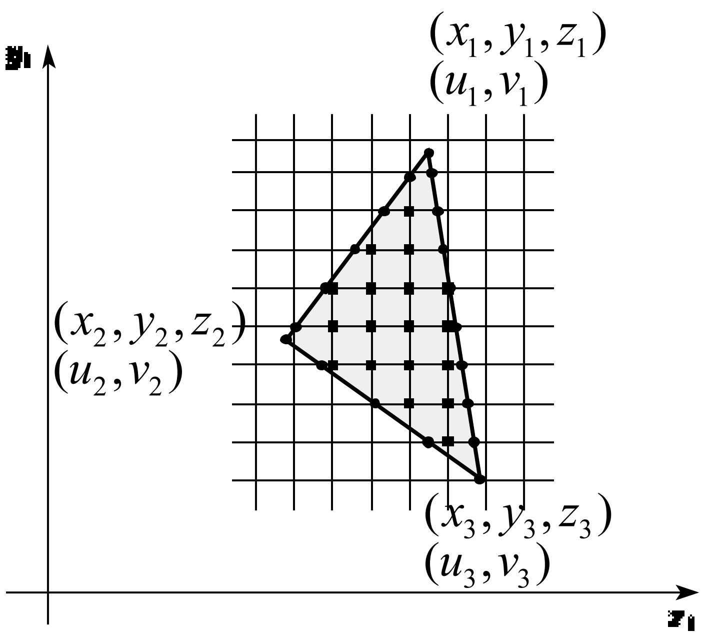
____________T[*i*+1,*j*] +

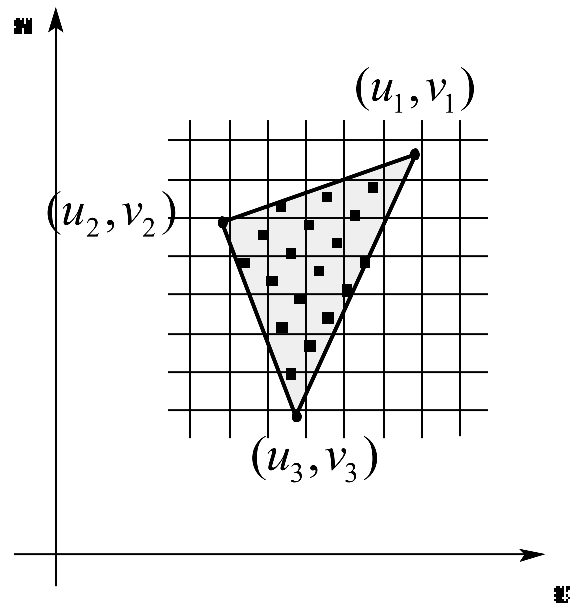
____________T[*i*,*j*+1] +

____________T[*i*+1,*j*+1]

Implementing, cont.

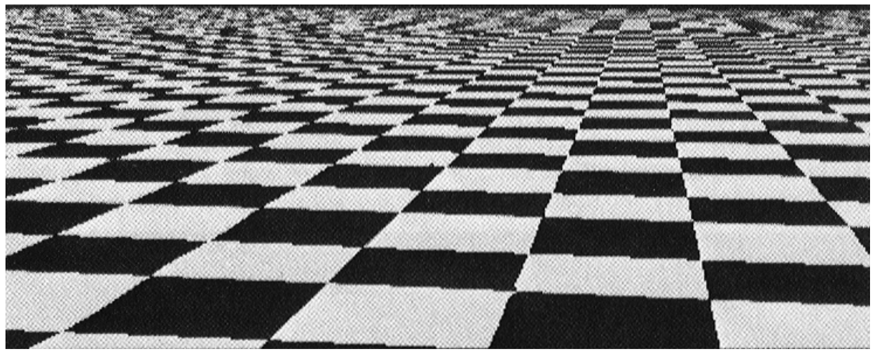
- Texture mapping can also be handled in z-buffer algorithms:
  - Scan conversion is done in screen space, as usual
  - Each pixel is colored according to the texture
  - Texture coordinates are found by Gouraud-style interpolation



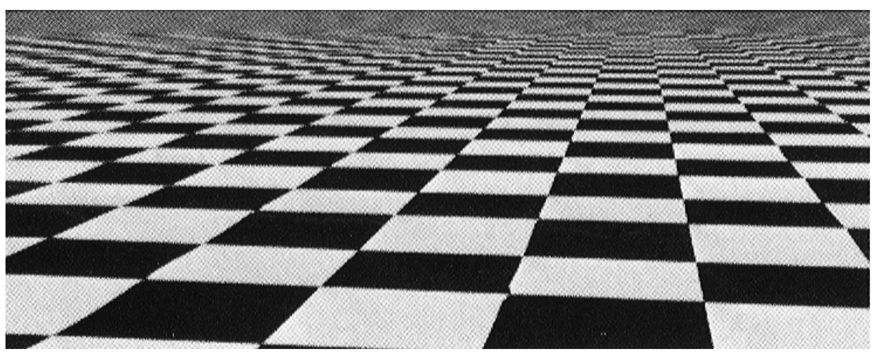


Antialiasing

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



- Proper antialiasing requires area averaging in the texture:

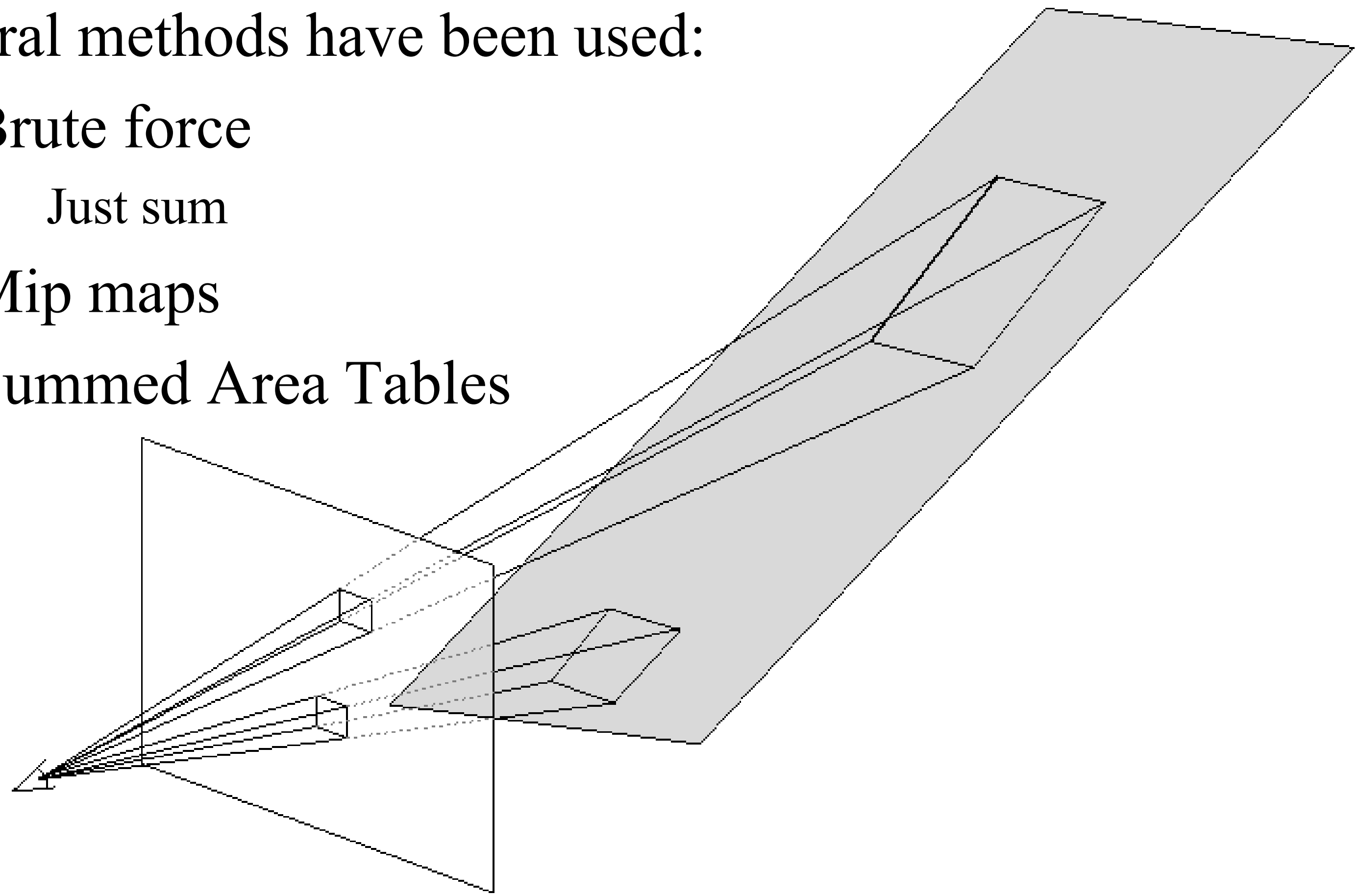


Computing average color

Computationally difficult part is summing over the covered pixels:

Several methods have been used:

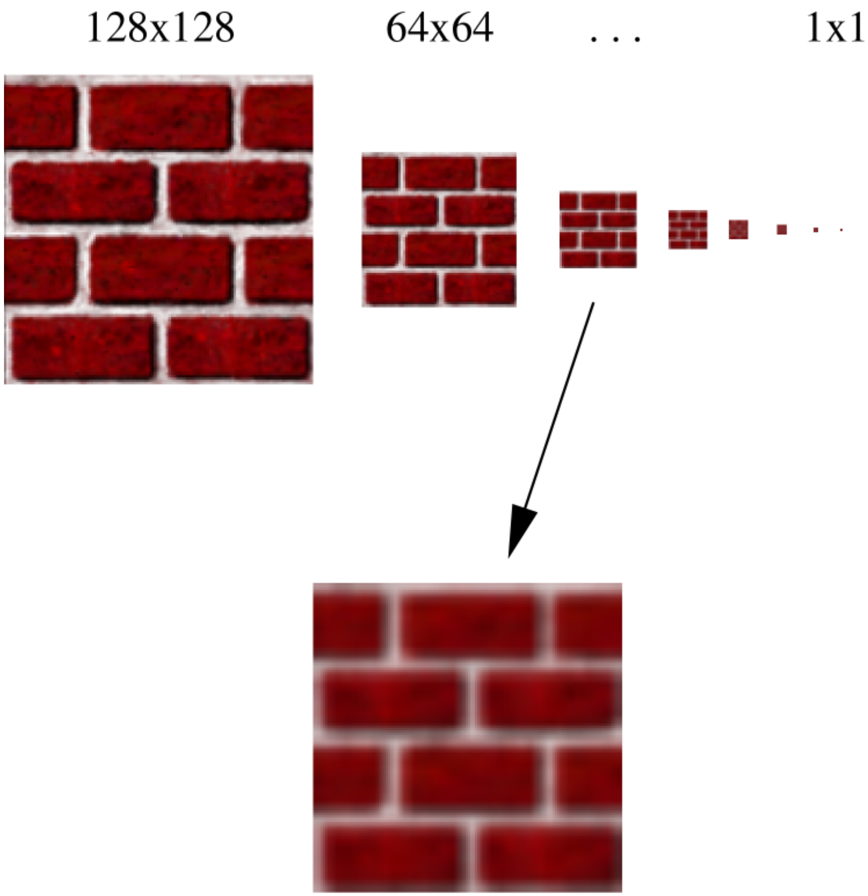
1. Brute force
   – Just sum
2. Mip maps
3. Summed Area Tables



Mip Maps

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

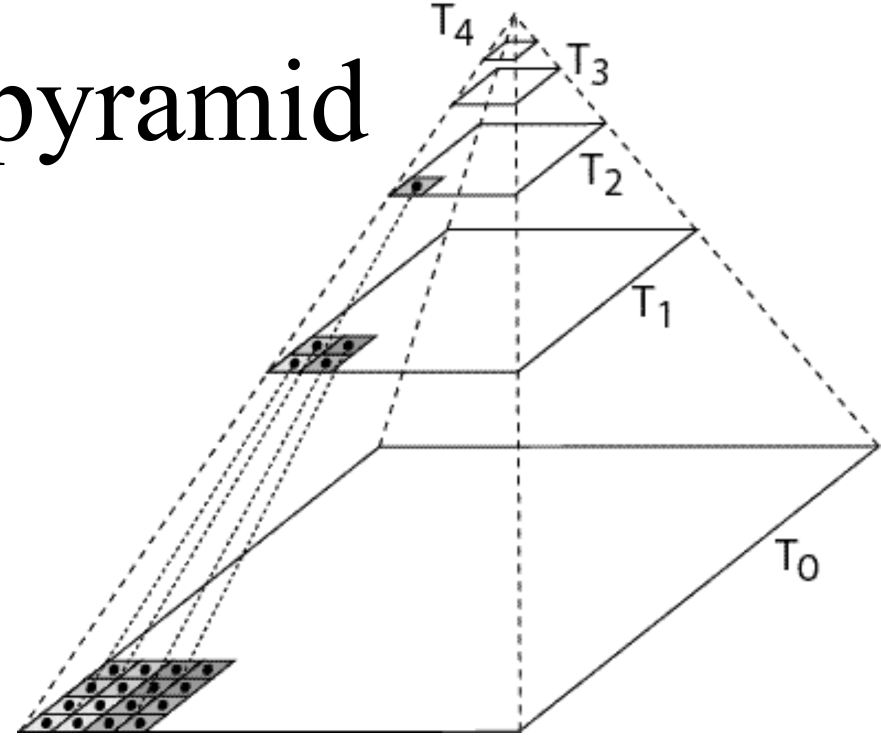
Mip maps, cont' d



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)?

Mip map pyramid

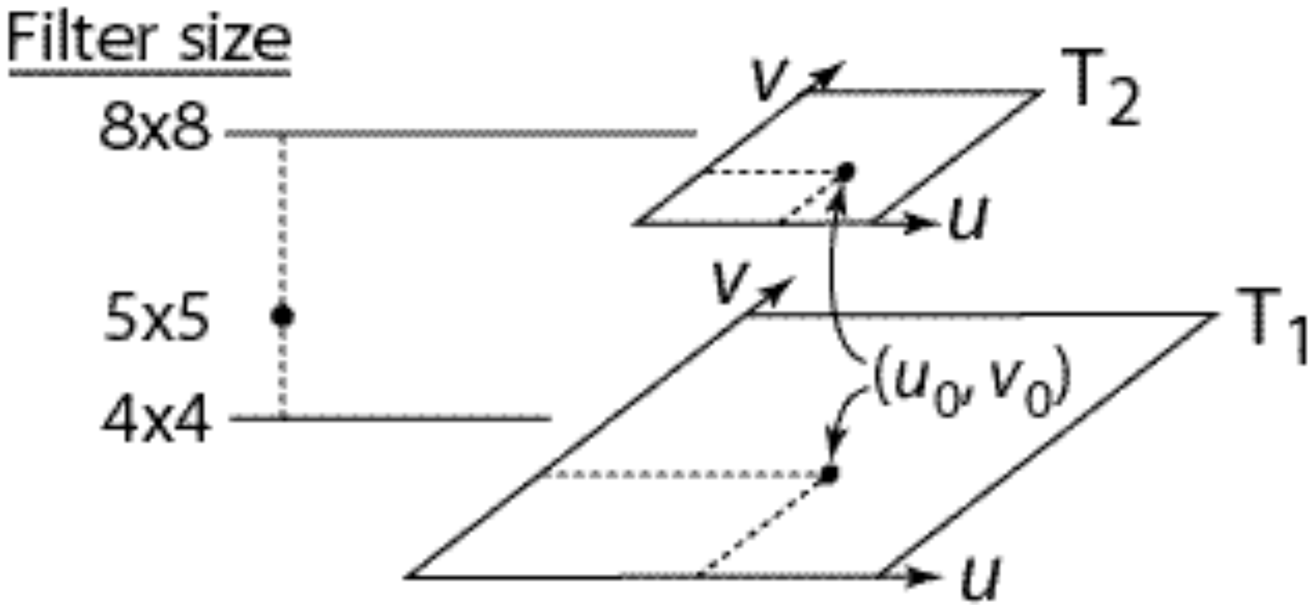


- The mip map hierarchy can be thought of as an image pyramid:
  - Level 0 ($T_0[i,j]$) is the original image.
  - Level 1 ($T_1[i,j]$) averages over 2x2 neighborhoods of original.
  - Level 2 ($T_2[i,j]$) averages over 4x4 neighborhoods of original
  - Level 3 ($T_3[i,j]$) averages over 8x8 neighborhoods of original

- What's a fast way to pre-compute the texture map for each level?

Mip map resampling

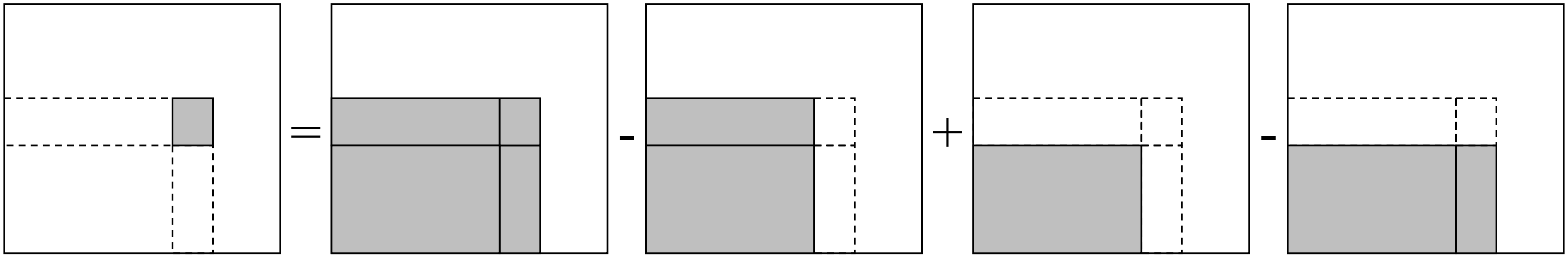
- What would the mip-map return for an average over a 5x5 neighborhood at location (u_0, v_0)?



- How do we measure the fractional distance between levels?

- What if you need to average over a non-square region?

Summed area tables

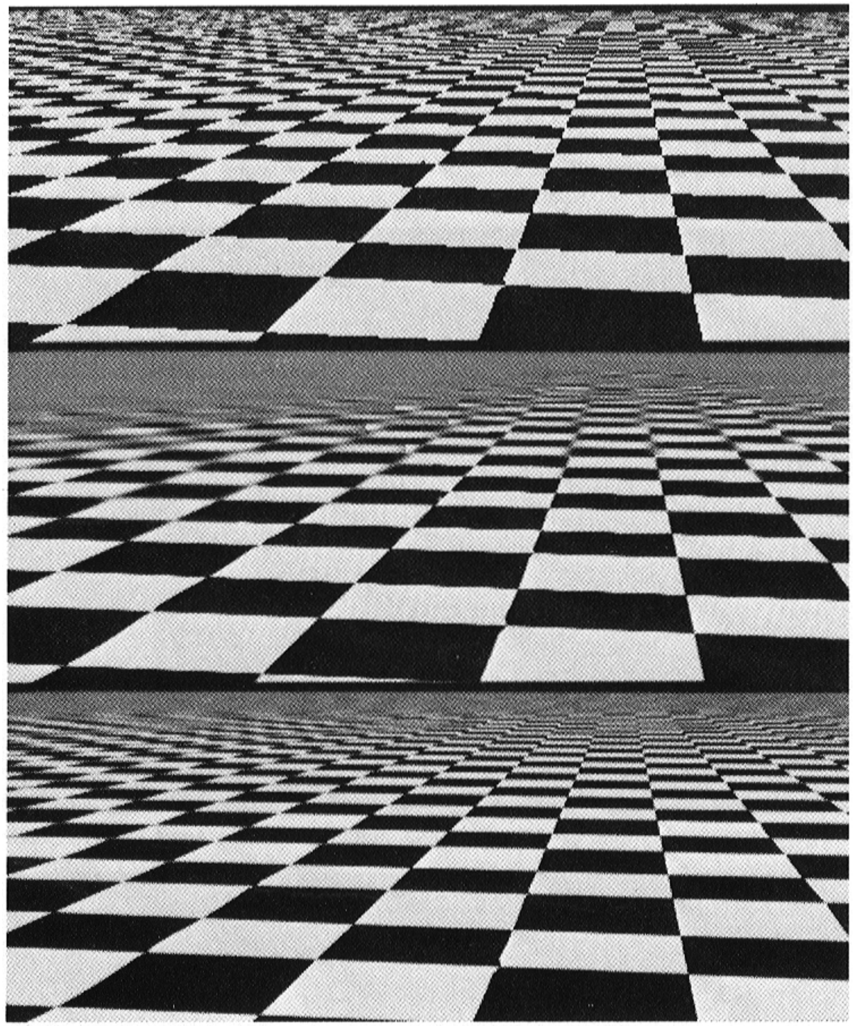


- Recall from calculus: $$\int_a^b f(x)dx = \int_{-\infty}^b f(x)dx - \int_{-\infty}^a f(x)dx$$

  Or in discrete form: $$\sum_{i=k}^{m} f[i] = \sum_{i=0}^{m} f[i] - \sum_{i=0}^{k} f[i]$$

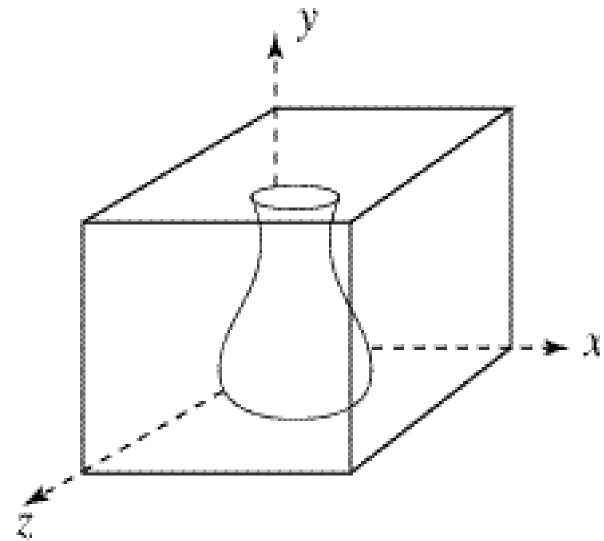
- Due to Frank Crow, 1984
- Keep sum of everything below and to the left
- Use four table lookups
- Requires more memory (2-4 times the original image)
- Gives less blurry textures

Comparison of techniques



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

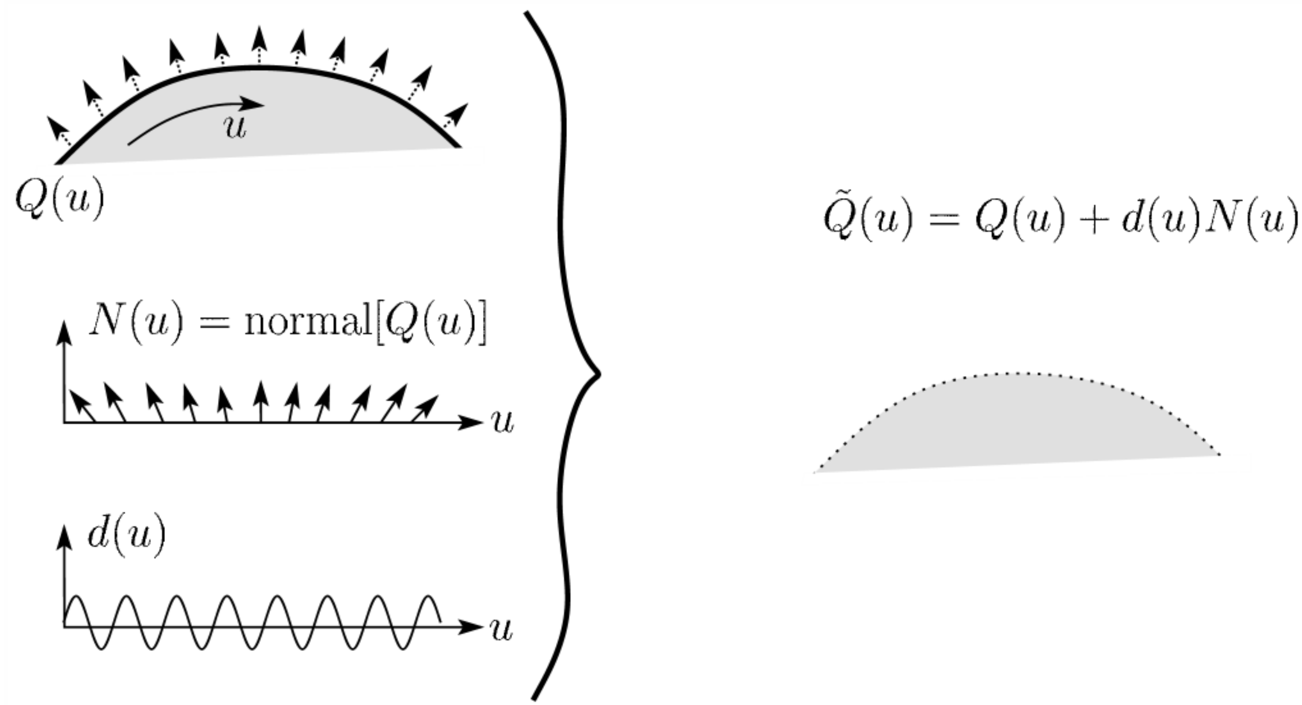
One difficulty of solid texturing is coming up with the textures…

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

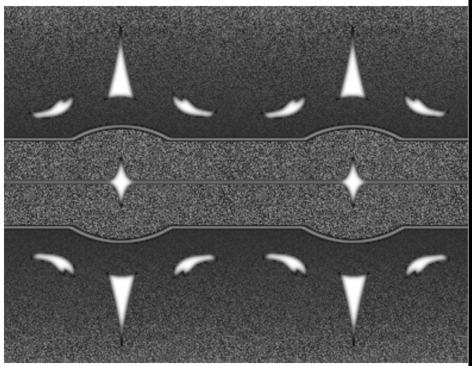
In displacement mapping, a texture is used to preturb the surface geometry itself:



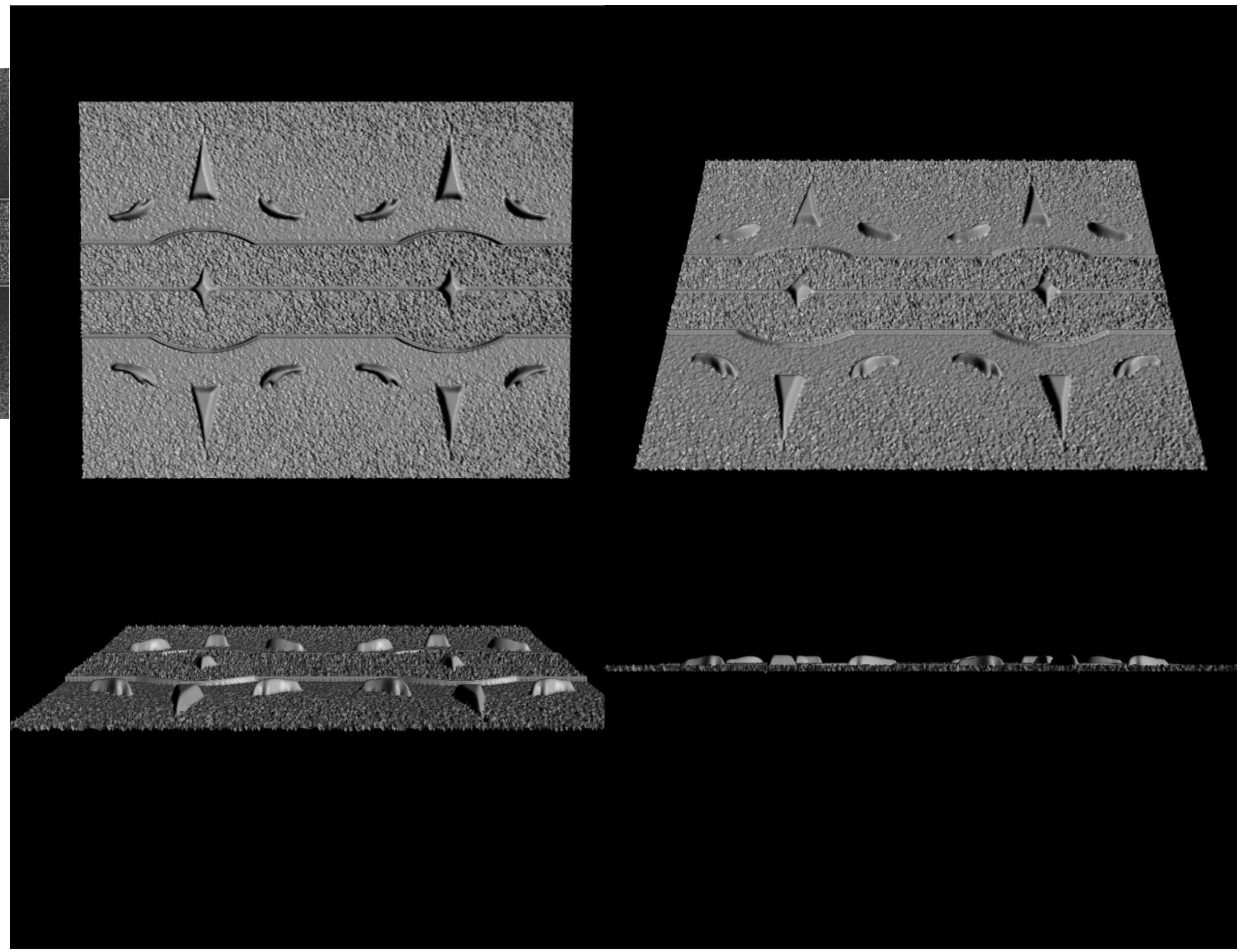
- Silhouettes are correct
- Requires doing additional hidden surface calculations

Displacement mapping, cont.

Input texture:



Displacement map over rectangular surface:



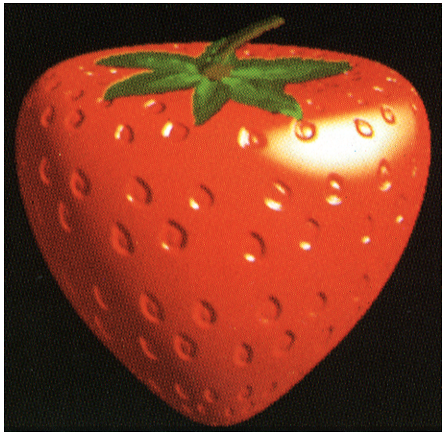
Bump mapping

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

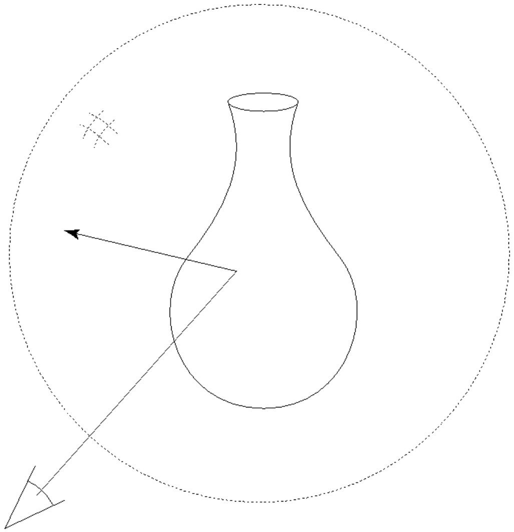
Q: What artifacts in the images would reveal that bump mapping is fake?

Bump mapping example

Original rendering

Rendering with bump map wrapped around a cylinder

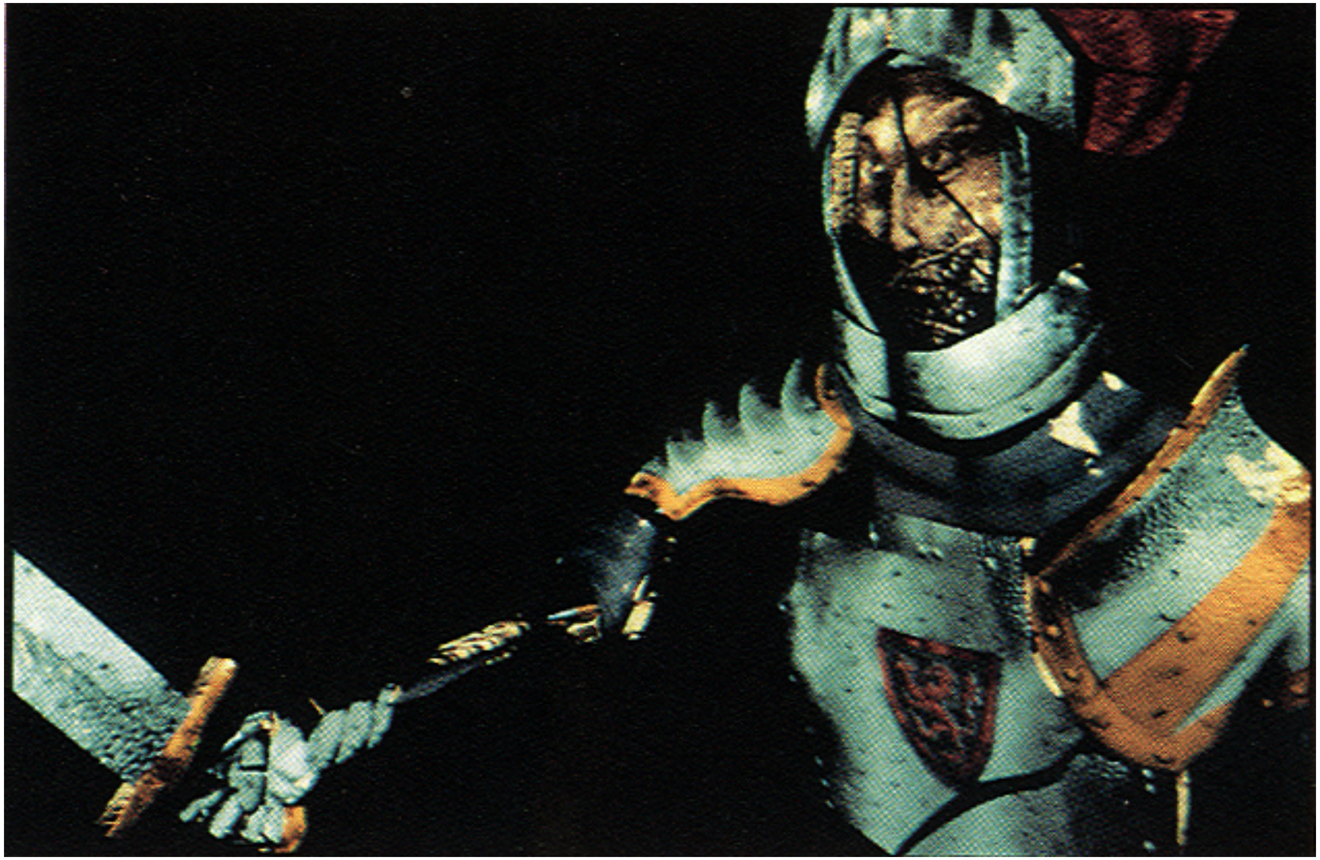
Environment mapping



- 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.

Phong lighting with diffuse texture

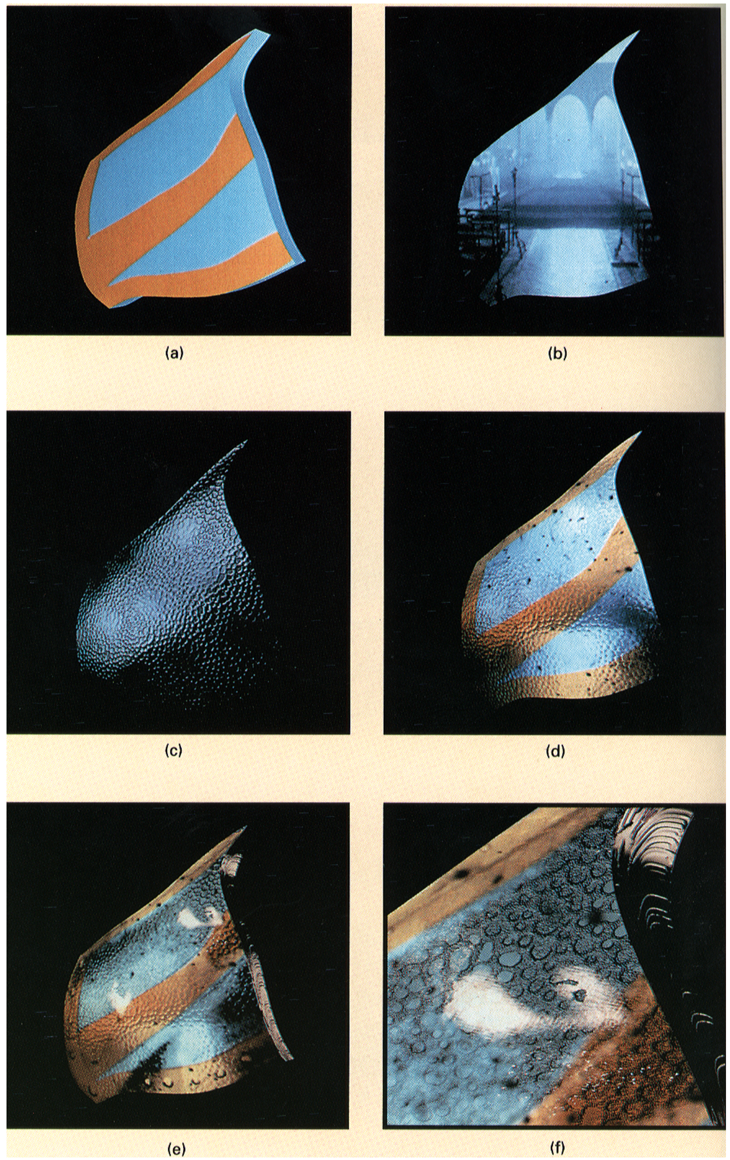
Environment-mapped mirror reflection

Bump mapping + Glossy reflection

Combine textures and add dirt

Rivet stains + Shinier reflections

Close-up



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