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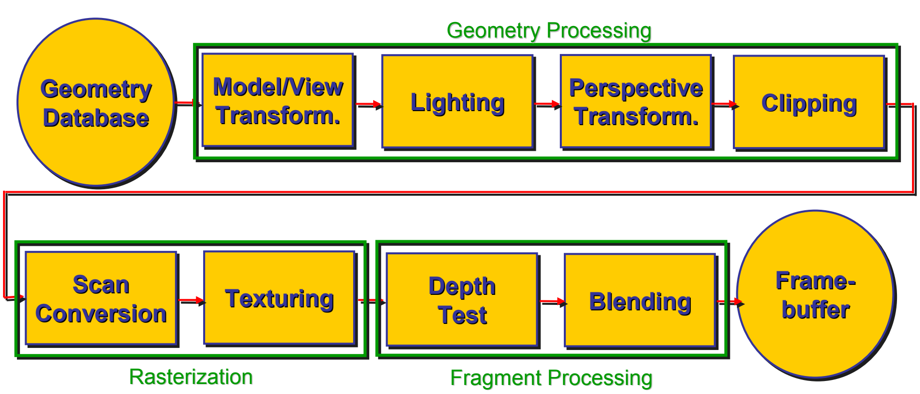
Chapter 9

Texture Mapping

The Rendering Pipeline



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Texture Mapping

- Real life objects non uniform in terms of color & normal
- To generate realistic objects - reproduce coloring & normal variations = **Texture**
- Can often replace complex geometric details

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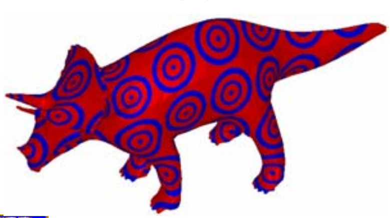
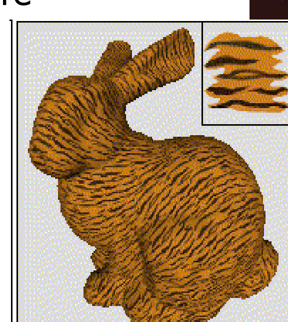
Color Texture Mapping

- Define color (RGB) for each point on object surface
- Two approaches
  - Surface texture map
  - Volumetric texture





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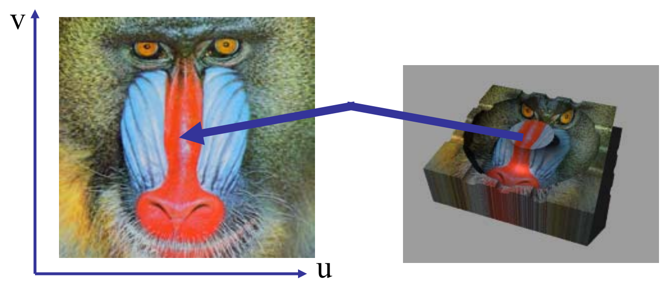
Surface texture

- Define texture pattern over (u,v) domain (Image)
  - Image – 2D array of "texels"
- Assign (u,v) coordinates to each point on object surface
- For free-form – use inverse of surface function
- For polygons (triangle)
  - Inside – use barycentric coordinates
  - For vertices need mapping function



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Texture Mapping - OpenGL

- Texture Coordinates
  - generation at vertices
    - specified by programmer or artist

```
glTexCoord2f(s,t)
glVertexf(x,y,z)
```

    - generate as a function of vertex coords
  - interpolated across triangle (like R,G,B,Z) (well, not quite...)

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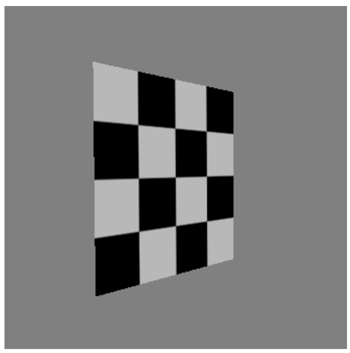
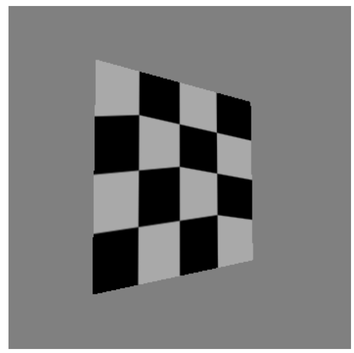
Texture Mapping

- Texture coordinate interpolation
  - Perspective foreshortening problem
  - Also problematic for color interpolation, etc.





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Perspective - Reminder

- Matrix formulation

$$(x, y, z, 1)\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \frac{d}{d-\alpha} & \frac{1}{d} \\ 0 & 0 & \frac{-\alpha d}{d-\alpha} & 0 \end{bmatrix} = \left(x, y, \frac{(z-\alpha)d}{d-\alpha}, \frac{z}{d}\right),$$

$$\begin{pmatrix} x' & y' & z' & w' \end{pmatrix} = \left(x, y, \frac{(z-\alpha)d}{d-\alpha}, \frac{z}{d}\right)$$

$$(x_p, y_p, z_p) = \left(\frac{x}{z/d}, \frac{y}{z/d}, \frac{d^2}{d-\alpha}\left(1 - \frac{\alpha}{z}\right)\right)$$

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Texture Coordinate Interpolation

- Perspective Correct Interpolation
  - α, β, γ :
    Barycentric coordinates of point **P**
  - s_0, s_1, s_2 : texture coordinates of vertices
  - w_0, w_1, w_2 : homogenous coordinate of vertices

$$s = \frac{\alpha \cdot s_0 / w_0 + \beta \cdot s_1 / w_1 + \gamma \cdot s_2 / w_2}{\alpha / w_0 + \beta / w_1 + \gamma / w_2}$$

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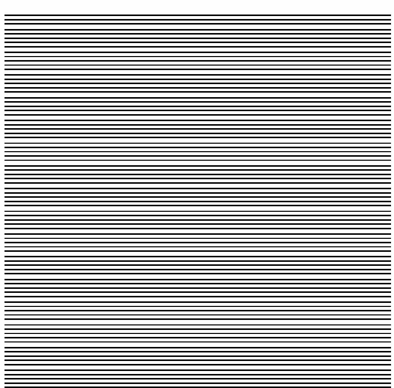
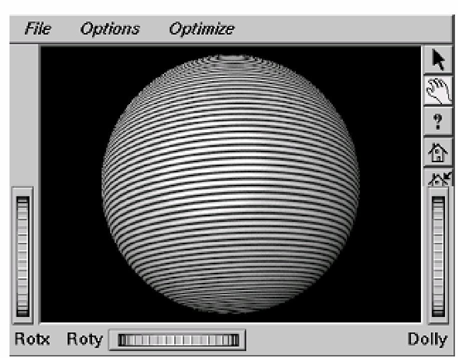
Reconstruction





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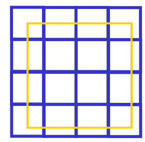
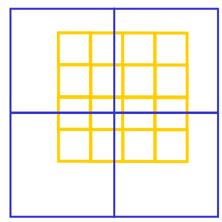
(image courtesy of Kiriakos Kutulakos, U Rochester)

Reconstruction

- How to deal with:
  - pixels that are much larger than texels ?
    (apply filtering, "averaging")



  - pixels that are much smaller than texels ?
    (interpolate)



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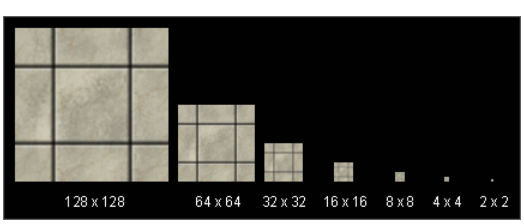
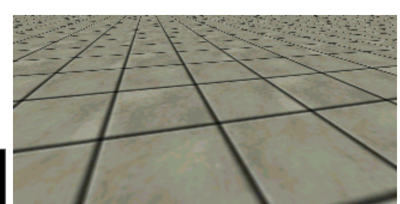
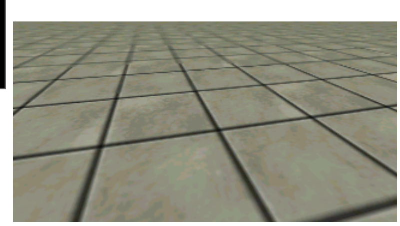
MIP-mapping

Use "image pyramid" to precompute averaged versions of the texture





Without MIP-mapping



With MIP-mapping

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Volumetric Texture

- Define texture pattern over 3D domain - 3D space containing the object
  - Texture function can be digitized or procedural
  - For each point on object compute texture from point location in space
- Common for natural material/irregular textures (stone, wood,etc…)

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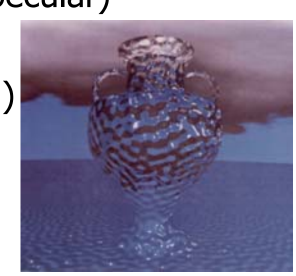
Texture Parameters

- In addition to color can control other material/object properties
  - Reflectance (either diffuse or specular)
  - Surface normal (bump mapping)
  - Transparency
  - Reflected color (environment mapping)



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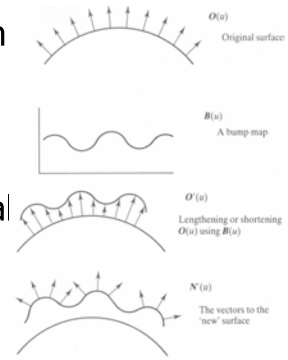
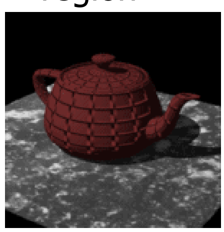
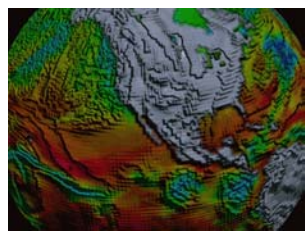
Normal – Bump Mapping

- Object surface often not smooth – to recreate correctly need complex geometry model
- Can control shape "effect" by locally perturbing surface normal
  - Random perturbation
  - Directional change over region







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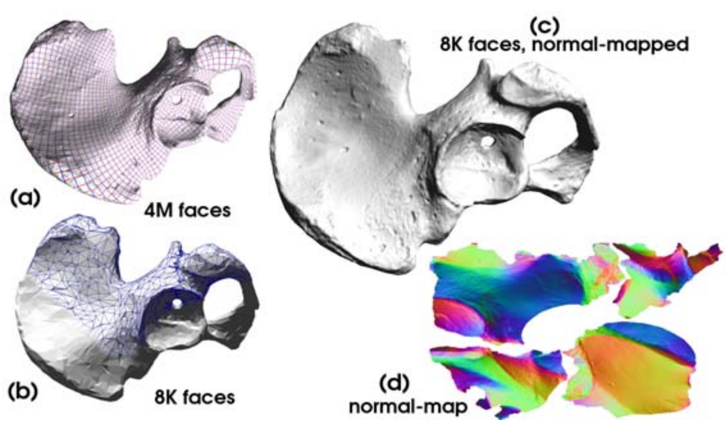
Normal map



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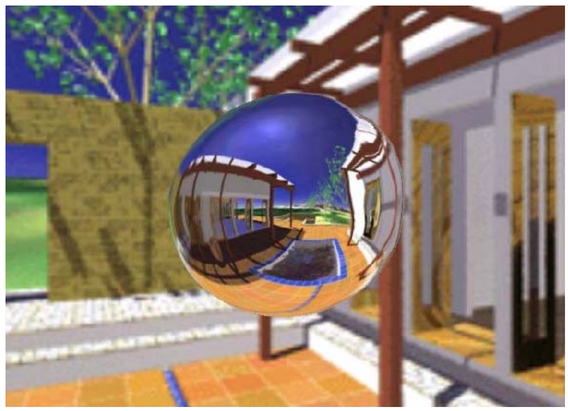
Environmental Mapping

- Cheap way to achieve reflective effect
  - Generate image of surrounding
  - Map to object as texture



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