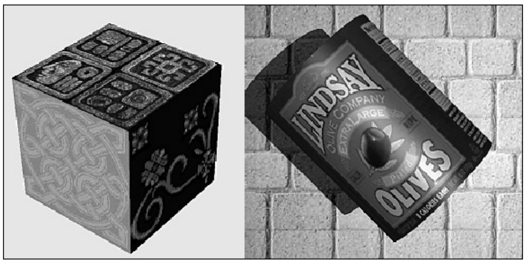
Texturing

Outline

- Texture mapping
  - Going from 3-D to 2-D
  - Rasterization issues

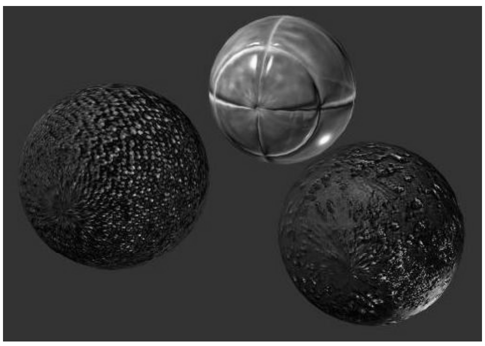
What is Texture Mapping?

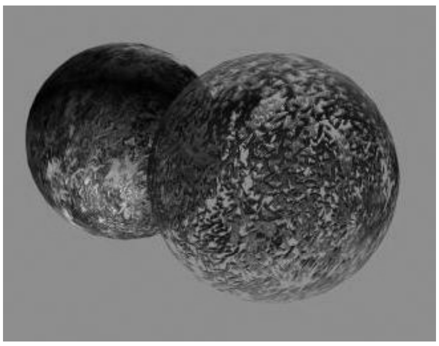
- Spatially-varying modification of surface appearance
- Characteristics
  - Bumpiness
  - Shininess
  - Transparency
  - Etc.



from Hill

Texture mapping: Examples



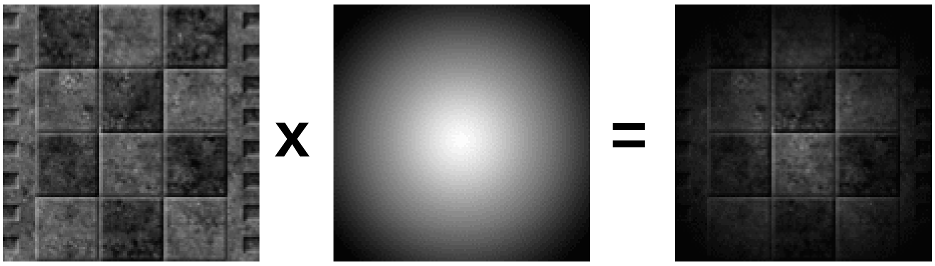


Examples of bumpiness, shininess, transparency
with identical sphere geometry

Why use texture mapping?

- More detail without the cost of more complicated geometry
  - Modeling
  - Display
- "Lookup table" for precomputed quantities
  - Lighting
  - Shadows

Texture mapping applications: Lightmaps



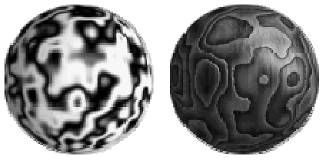
courtesy of K. Miller

Texture mapping: Steps

- **Creation**: Where does the texture image come from?
- **Geometry**: Transformation from 3-D shape locations to 2-D texture image coordinates
- **Rasterization**: What to draw at each pixel

Texturing: Creation

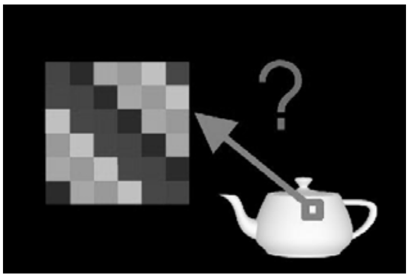
- Photographs, or handpainted
- Synthesis
  - Lightmaps
  - Procedurally-built
    - Randomness, pattern-generating rules, etc.



courtesy of H. Elias

Texturing: Geometry

1. Compute object space location (x, y, z) from screen space location (i, j)
2. Use **projector** function to obtain (u, v)
3. **Corresponder** function to find texel coordinates (s, t)

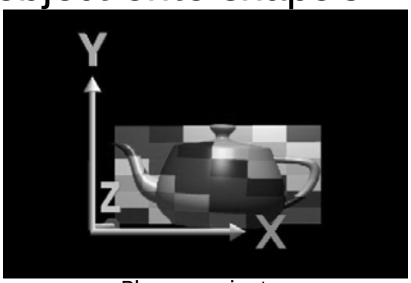


courtesy of R. Wolfe

list adapted from Akenine-Moller & Haines

Projector Functions

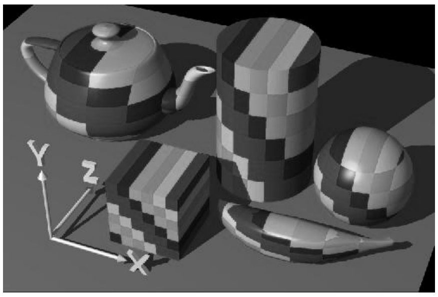
- Idea: Way to get from 3-D point to 2-D surface coordinates as an intermediate step
- Project from **inside** object onto shape's surface
  - Plane
  - Cylinder
  - Sphere
  - Cube

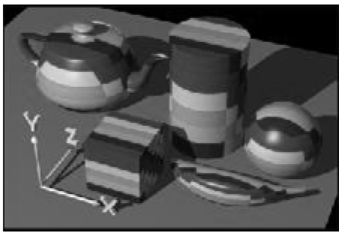


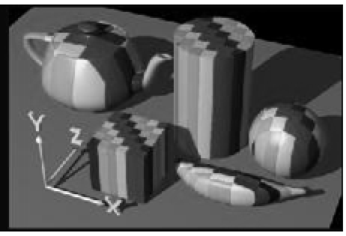
Planar projector

Planar projector

Orthographic projection
onto XY plane:
u = x, v = y







courtesy of
R. Wolfe

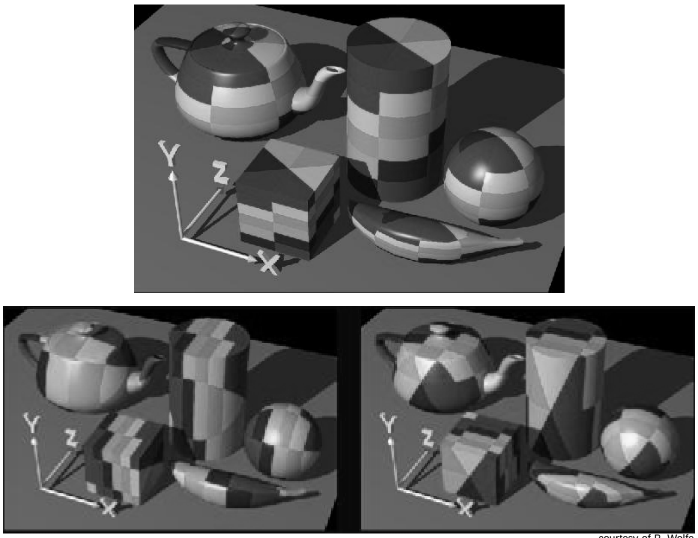
...onto YZ plane ...onto XZ plane

Cylindrical projector

- Convert rectangular coordinates (x, y, z) to cylindrical (r, θ, h), use only (θ , h) to index texture image

courtesy of
R. Wolfe

Cylindrical projectors with different axes



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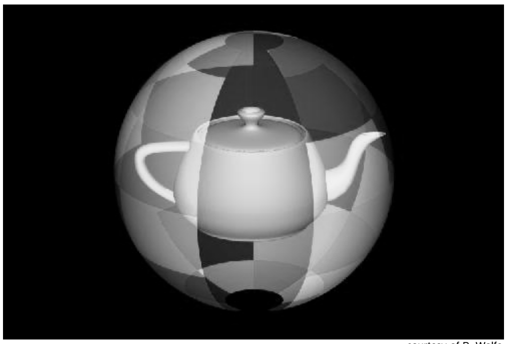
Spherical projector

- Convert rectangular coordinates (x, y, z) to spherical (θ, φ)



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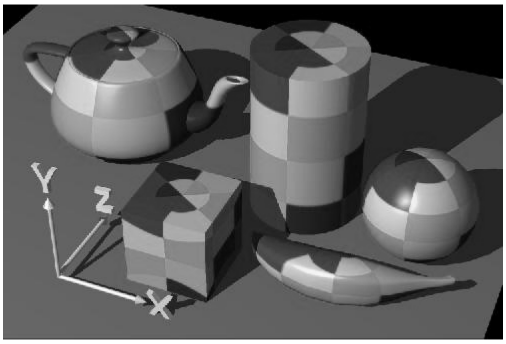
Spherical projectors



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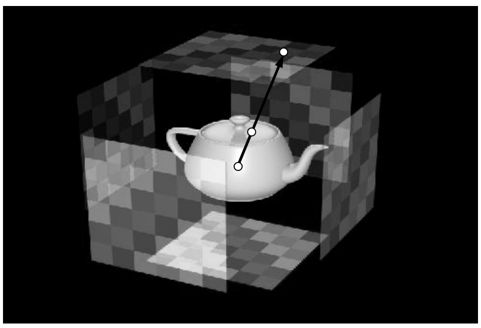
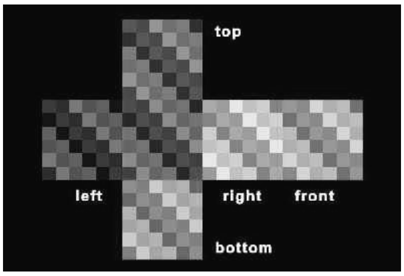
Cube projector

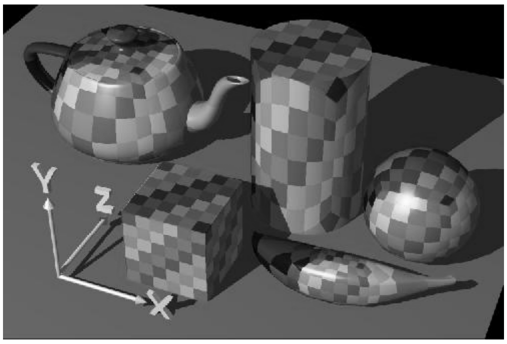
- Use intersection with cube of ray from center of shape through (x, y, z) on shape surface to pick one of six side textures



courtesy of
R. Wolfe

Cube projector

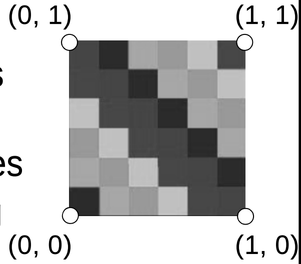




courtesy of R. Wolfe

Corresponder function

- Maps from (u, v) to texture image coordinates (s, t) in units of pixels
- (u, v) in range [0, 1] are displayed; corresponder decides:
  - What part of texture image this references (all or only part)
  - Wrapping: How to handle values outside range [0, 1] (including negative)



for example, a 256 x 256 texture image

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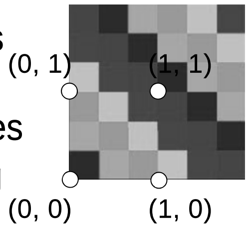
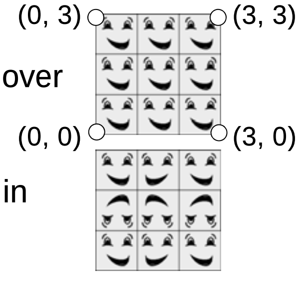


for example, a 256 x 256 texture image

Wrapping modes

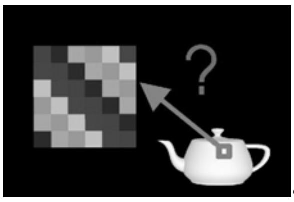
- **repeat**: Start entire texture over
- **mirror**: Flip copy of texture in each direction
  - Get continuity of pattern



courtesy of Microsoft

Texturing: Rasterization

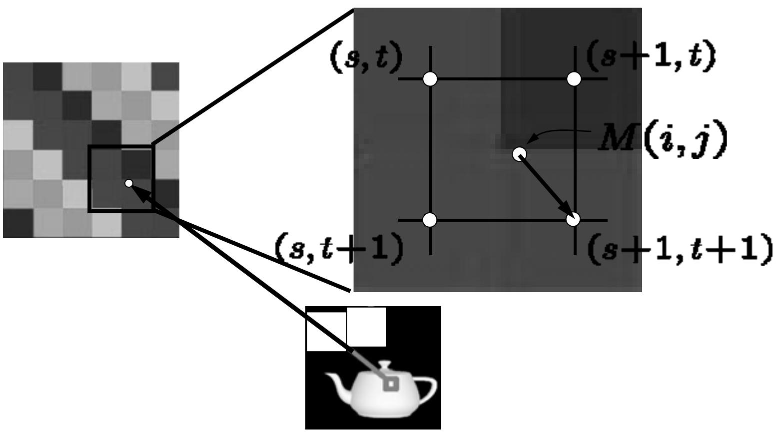
- Assume we can compose the previous steps (projector, corresponder, etc.) to define a transformation function M from integer screen coordinates (i, j) to real-valued texture coordinates (s, t) such that M (i, j) = (s, t)



courtesy of R. Wolfe

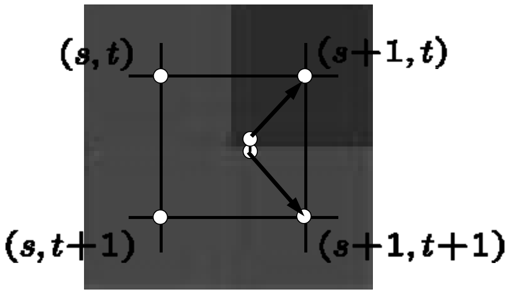
Nearest neighbor interpolation (NN)

- Idea: Just use closest integer-valued texel



NN issues

- Problem is that it can cause big **aliasing** effects
- Why? Because the **`round()`** function causes discontinuous switches in which texel is nearest and hence is the color drawn

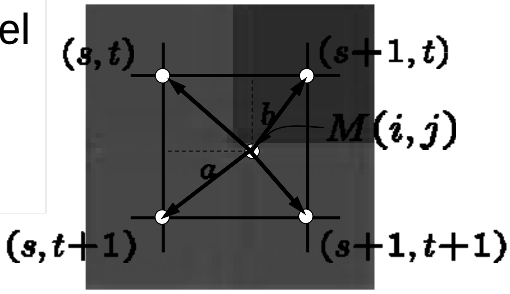


NN aliasing

rotate 45º, scale 1.5

Bilinear Interpolation (BLI)

- Idea: Blend four texel values surrounding source, weighted by nearness



$$\mathbf{I}(i,j) = (1-b, b)\begin{bmatrix} \mathbf{I}_{tex}(s,t) & \mathbf{I}_{tex}(s+1,t) \\ \mathbf{I}_{tex}(s,t+1) & \mathbf{I}_{tex}(s+1,t+1) \end{bmatrix}\begin{pmatrix} 1-a \\ a \end{pmatrix}$$

Vertical blend Horizontal blend

Bilinear interpolation

- Blending eliminates abrupt color changes, reducing aliasing artifacts

rotate 45±, scale 1.5

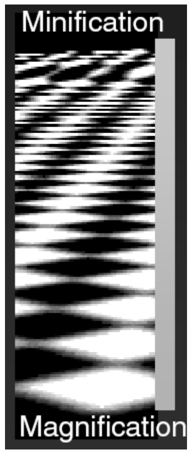
Texel Interpolation approaches: NN vs. BLI

More rasterization techniques

- Filtering
- Interpolation

Magnification and minification

- **Magnification**: Single screen pixel maps to area less than or equal to one texel
- **Minification**: Single screen pixel area maps to area greater than one texel



courtesy of H. Pfister

Filtering for minification

- Aliasing problem much like line rasterization
  - Pixel maps to quadrilateral (**pre-image**) in texel space

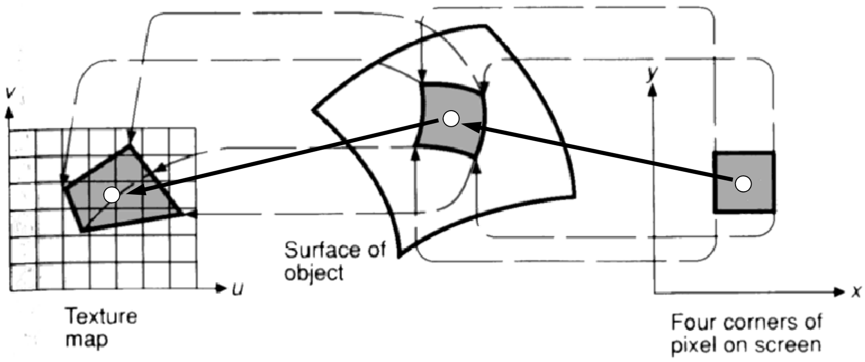
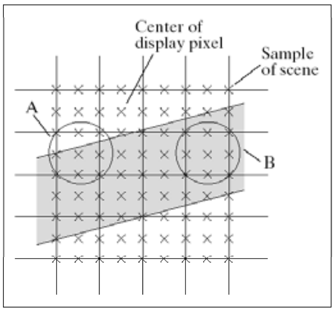


image courtesy of D. Cohen-Or

Supersampling

- Rasterize at higher resolution
  - Regular grid pattern around each "normal" image pixel
- Combine multiple samples into one pixel via **weighted average**
  - "Box" filter: All samples associated with a pixel have equal weight (i.e., directly take their average)
  - Gaussian filter: Sample weights inversely proportional to distance from associated pixel

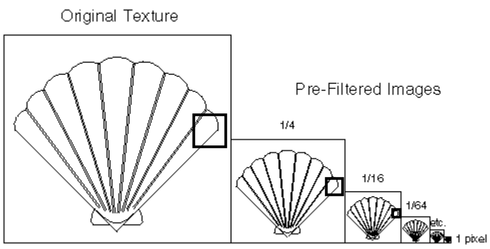


from Hill

Regular supersampling with 2x frequency

Mipmaps

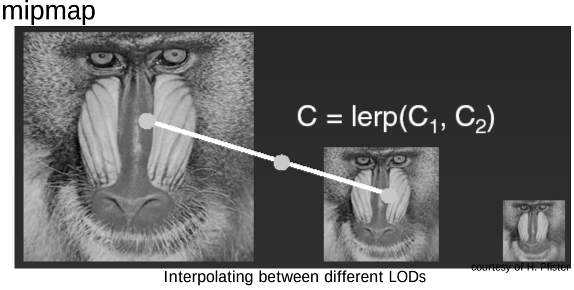
- Filtering for minification is expensive
- Idea:
  - Prefilter entire texture image at different resolutions
  - For each screen pixel, pick texture in mipmap at **level of detail (LOD)** that minimizes minification (i.e., pre-image area closest to pixel area)
  - Do nearest or linear filtering in appropriate LOD texture image



from Woo, *et al.*

Mipmaps in OpenGL

- Create with **`gluBuild2DMipmaps()`**
- Use by calling **`glTexParameter(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, param)`**, where **`param`** is:
  - **`GL_NEAREST_MIPMAP_NEAREST`**: **`GL_NEAREST`** filtering in closest LOD mipmap
  - **`GL_LINEAR_MIPMAP_NEAREST`**: **`GL_LINEAR`** filtering in closest LOD mipmap



Interpolating between different LODs

courtesy of H. Pfister