CSE-170 Computer Graphics

Lecture 11

Textures and Other Mappings

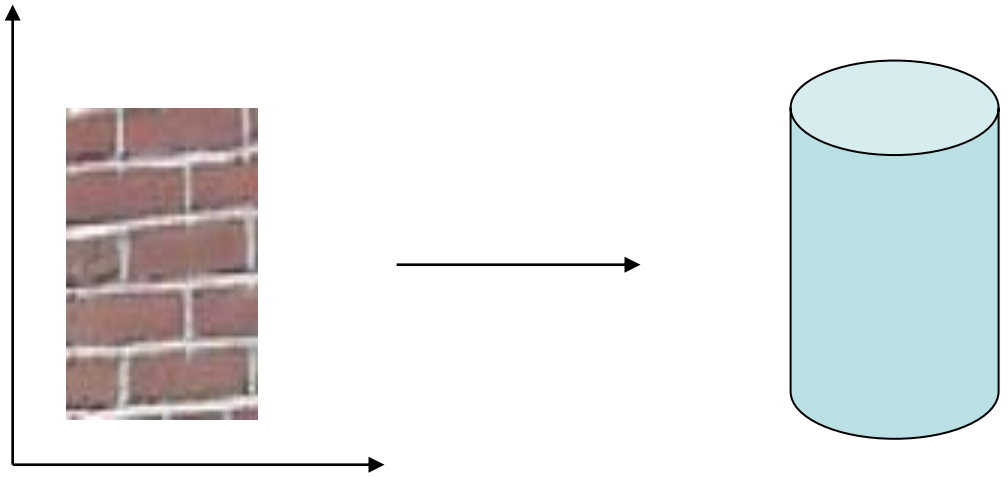
Dr. Renato Farias
rfarias2@ucmerced.edu

Mapping Techniques

- Texture mapping
  - used to improve realism
  - extremely common
- Reflection mappings
  - A way to display reflections in real-time, for ex. computed from ray tracing
- Light maps
  - Lighting effects from texture mapping
- Bump maps and Displacement maps
  - To improve geometry detail appearance
- etc.

Mapping Techniques

- Mapping techniques usually involves mapping a 2D data array onto the surface of a 3D object
  - Ex: map a height field or an image to a surface



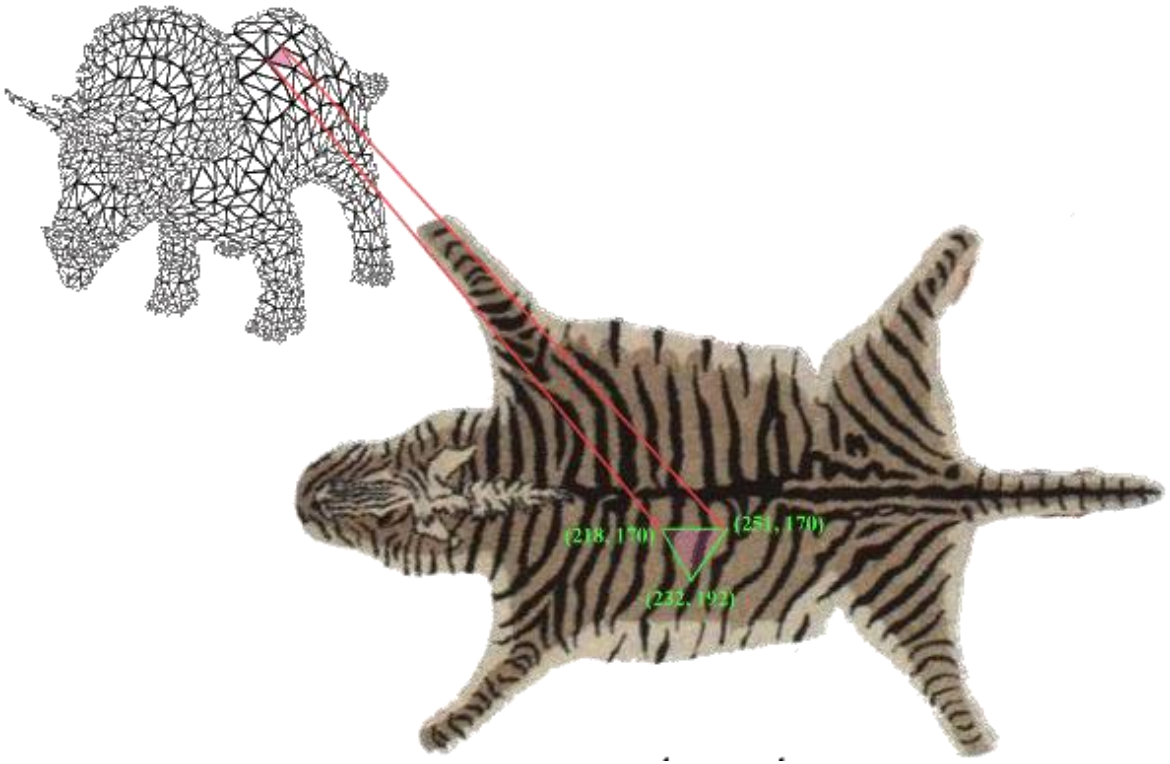
Texture Mapping

Texture Mapping

- Can be seen as extension to Phong's model
  - Rewrite the diffuse component I_d as a function of the texture map
  - Better name would be “color mapping”
- Powerful effects

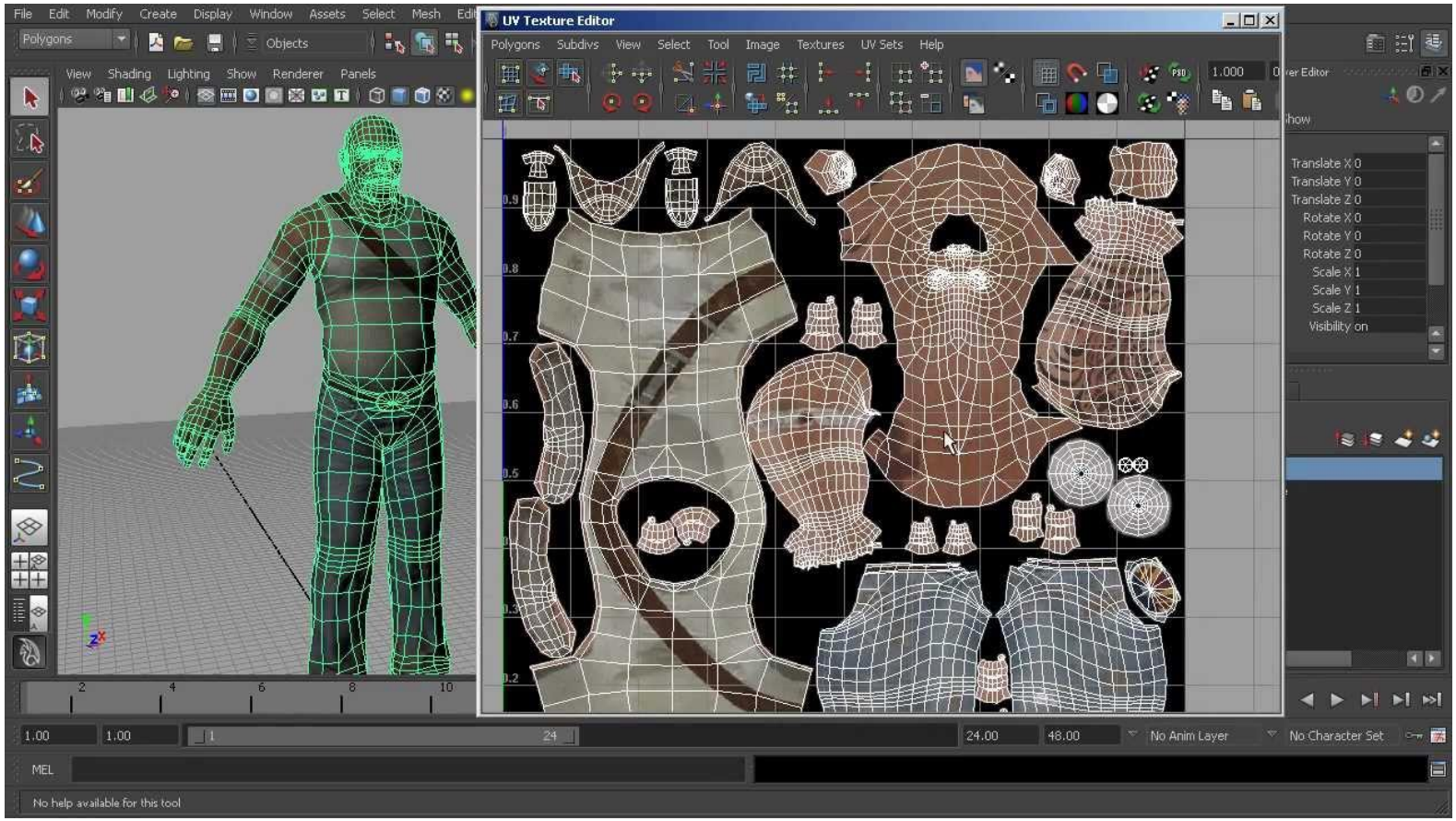
Texture Mapping

- Main problem: the mapping
  - For every triangle to be rendered, we have to define how to map the triangle to the texture image



Texture Mapping

- Main problem: the mapping
  - Many tools exist to help “design” the mapping

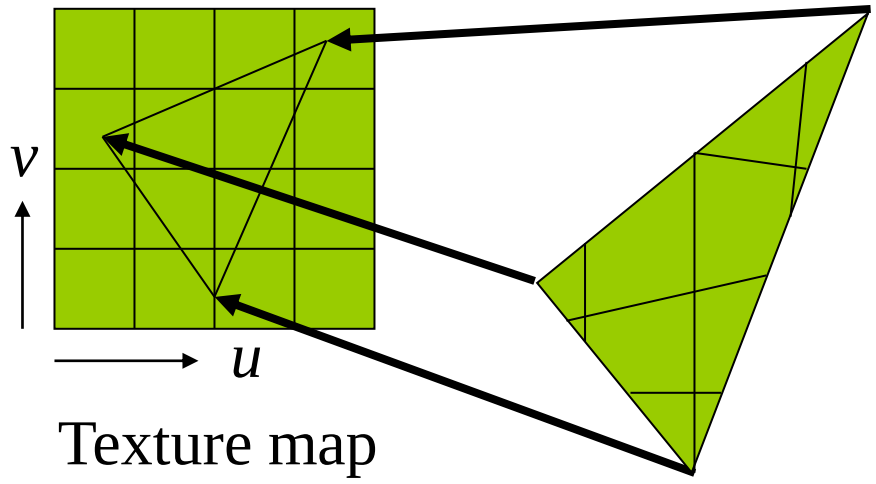


Texture Mapping

- Textures can become rather complex

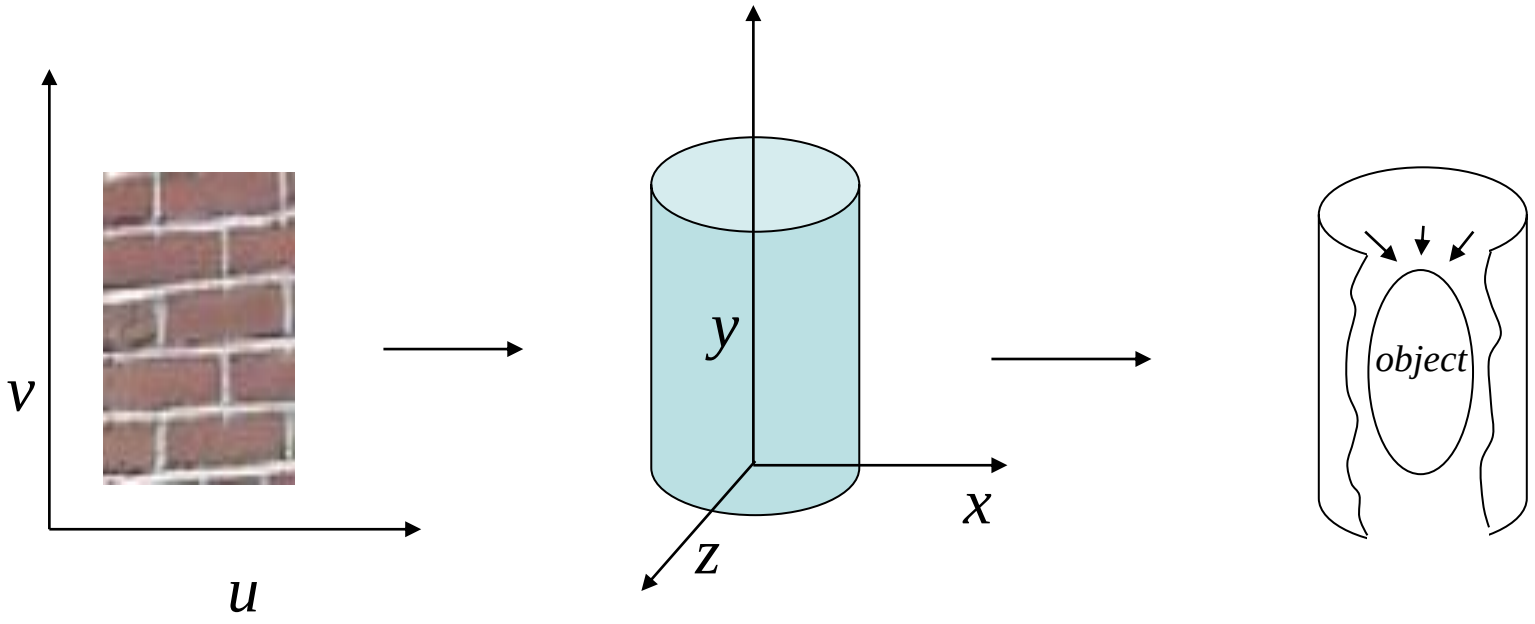
Texture Mapping

- In OpenGL
  - Each vertex will be associated with `(u,v)` texture coordinates:
    - Texture coordinates are ***always in [0,1]***



Texture Mapping

- Mapping using intermediate surface
  - First map to an “easy” surface
  - Then, map to the final object
  - ex: cylinder mapping



Texture Mapping

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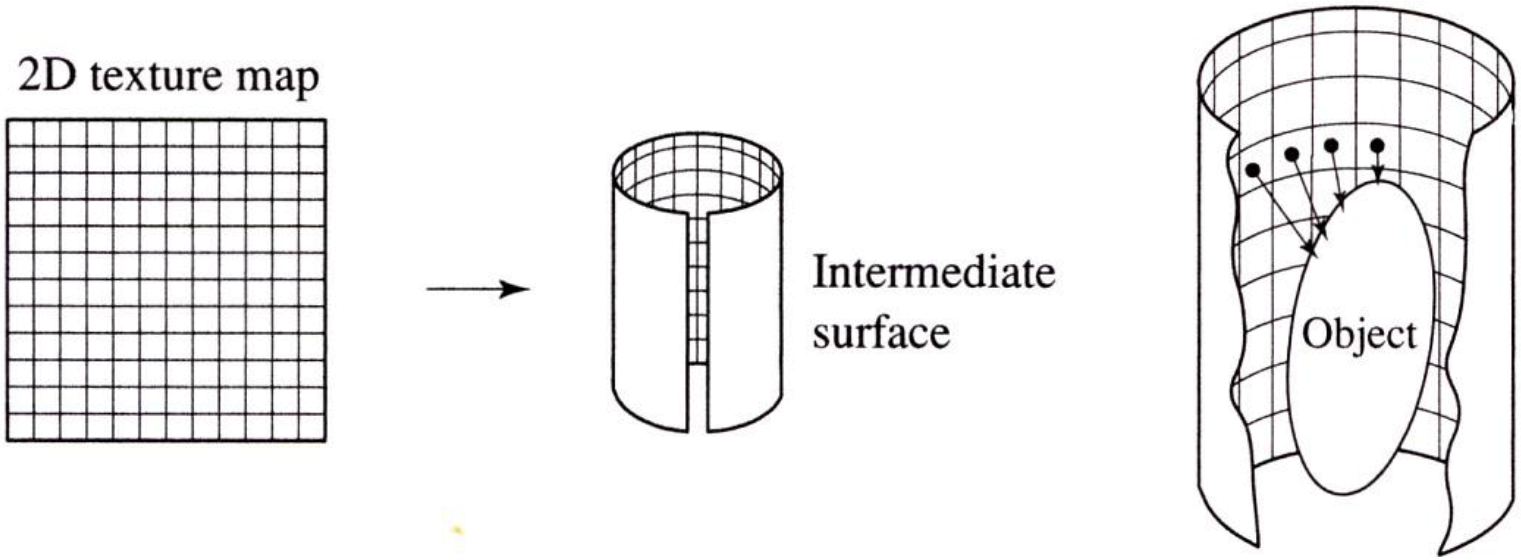
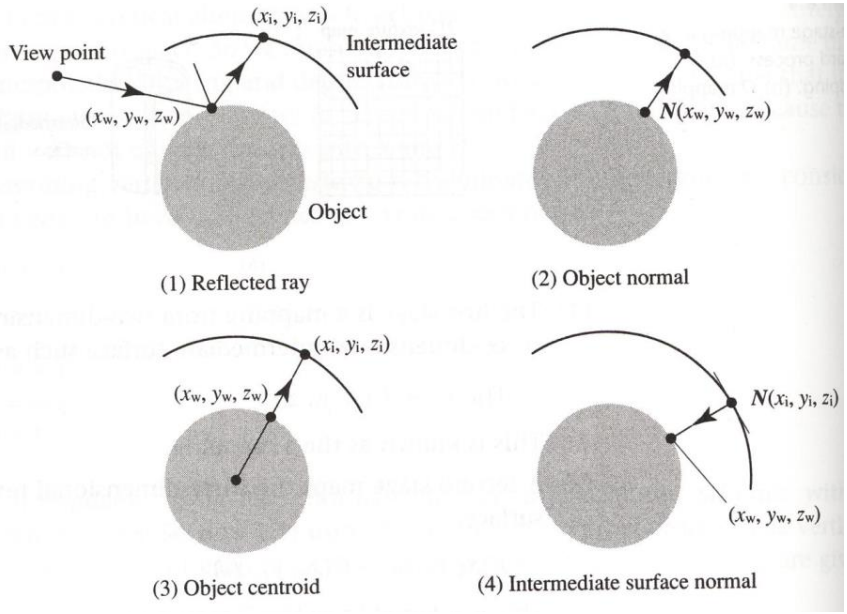
  - ex: cylinder mapping

    $(\theta,h) \rightarrow (u,v) : (u,v) = (\theta / \theta_{max}, h / h_{max})$



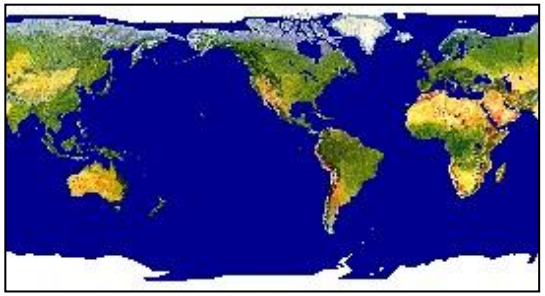
Texture Mapping

- Mapping using intermediate surface
  - Several possibilities for the final mapping:
    - intersection of reflected view ray
    - intersection of surface normal
    - intersection of a line from object center
    - intermediate surface normal



Texture Mappings

- Common intermediate mappings
  - Cylindrical
  - Spherical
  - Projection
  - Orthogonal
  - etc.

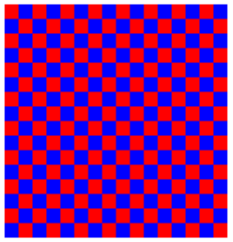


Texture Mappings

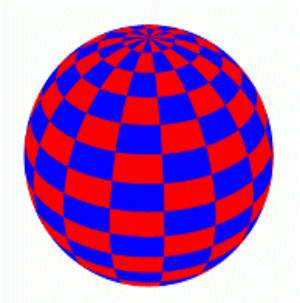
- Spherical mappings
  - Texture mapping can be used to alter some or all of the constants in the illumination equation: diffuse color, alter the normal, etc.
  - GLSL uses keyword *sampler* to access the colors in the texture:

```
uniform sampler2D texId;
```

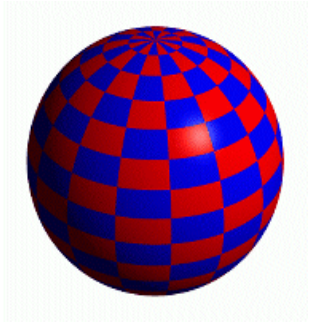
Diffuse Color



Diffuse Texture Color



Texture used as Label



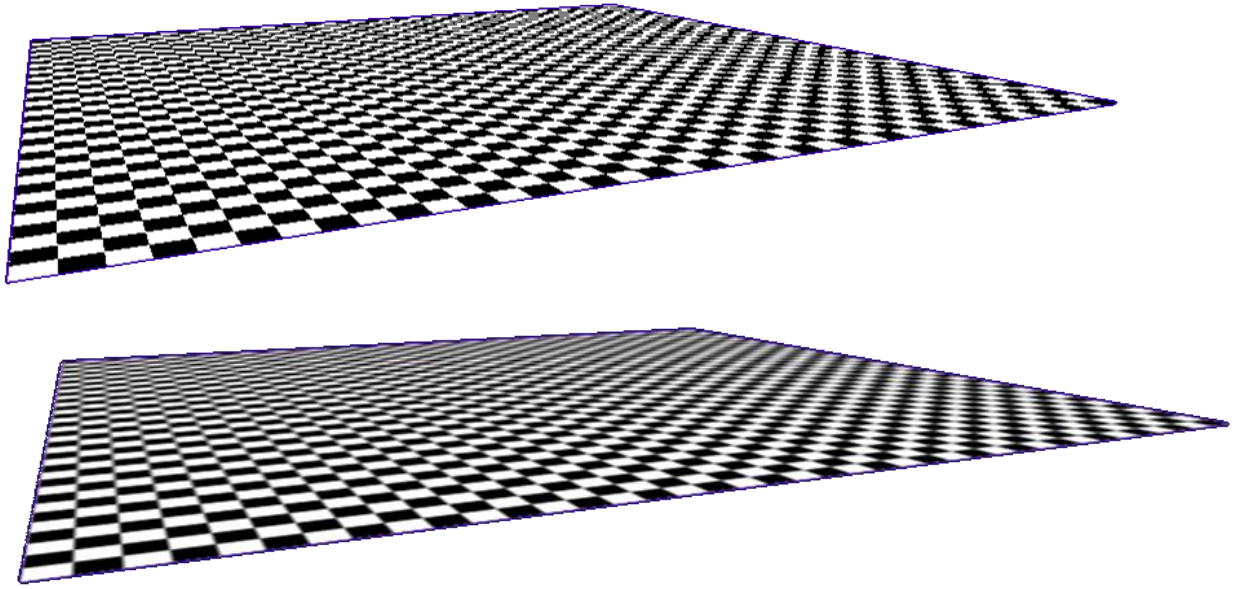
Texture used as Diffuse Color

Texture Mappings

- Difficulties
  - Textures do not define geometry
    - should really be thought as color mappings
  - Lighting may not appear correctly
  - Aliasing effects

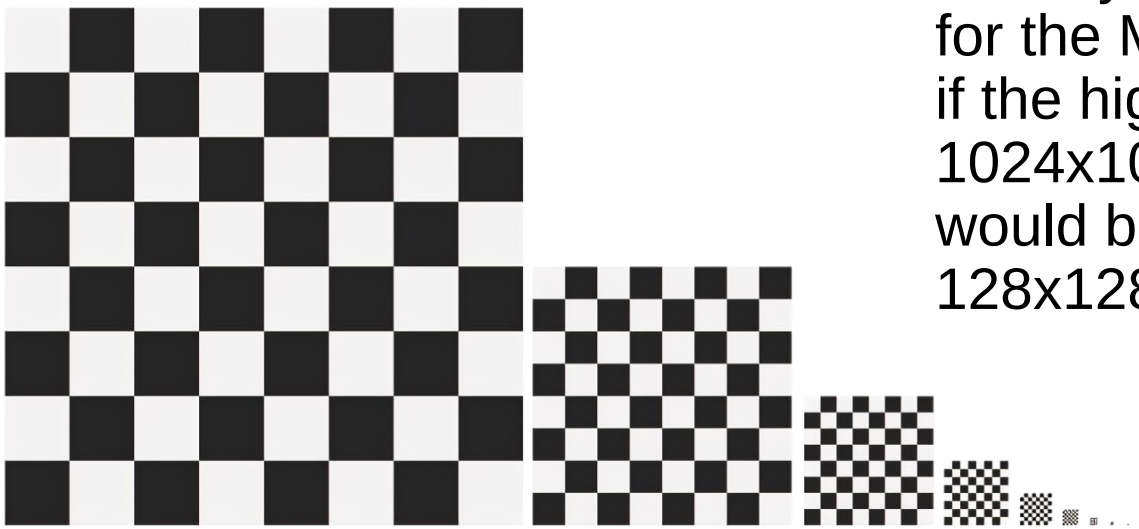
Texture Mappings

- Aliasing is the under-sampling of a signal, and it's especially noticeable during animation
  - Details may pop in and out of view
  - Solution: mipmapping



Texture Mappings

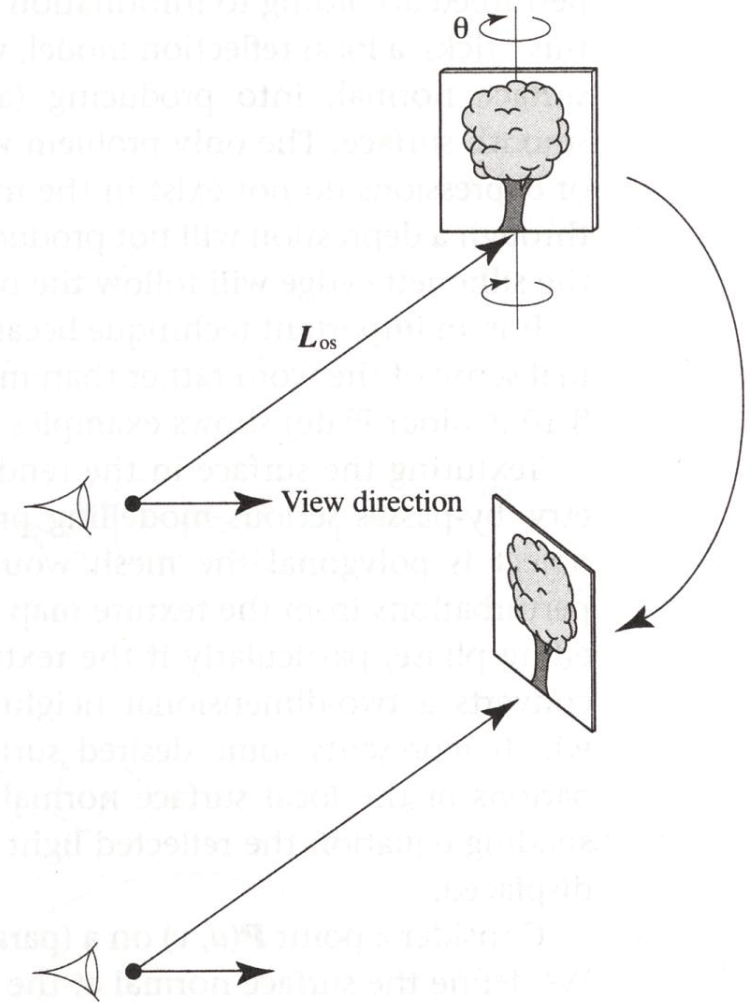
- Mipmapping
  - Original high-resolution texture map is scaled and filtered into multiple resolutions before it is applied to a surface
    - *multum in parvo:* "many things in a small space.“
  - The texture can appear in full detail if it is seen in a close-up, or can be rendered quickly and smoothly from a lower MIP level when the object appears smaller or further away
  - Usually, powers of 2 are used for the MIP Map levels (for ex. if the highest resolution is 1024x1024, the next levels would be 512x512, 256x256, 128x128, etc.)



Billboards

Billboards

- Texture map is treated as a 3D object in a scene
  - it is not mapped to a solid object surface
  - it is just a plane with the image
  - the plane rotates to always face the viewer
  - parts of the texture can be transparent
  - ex: trees

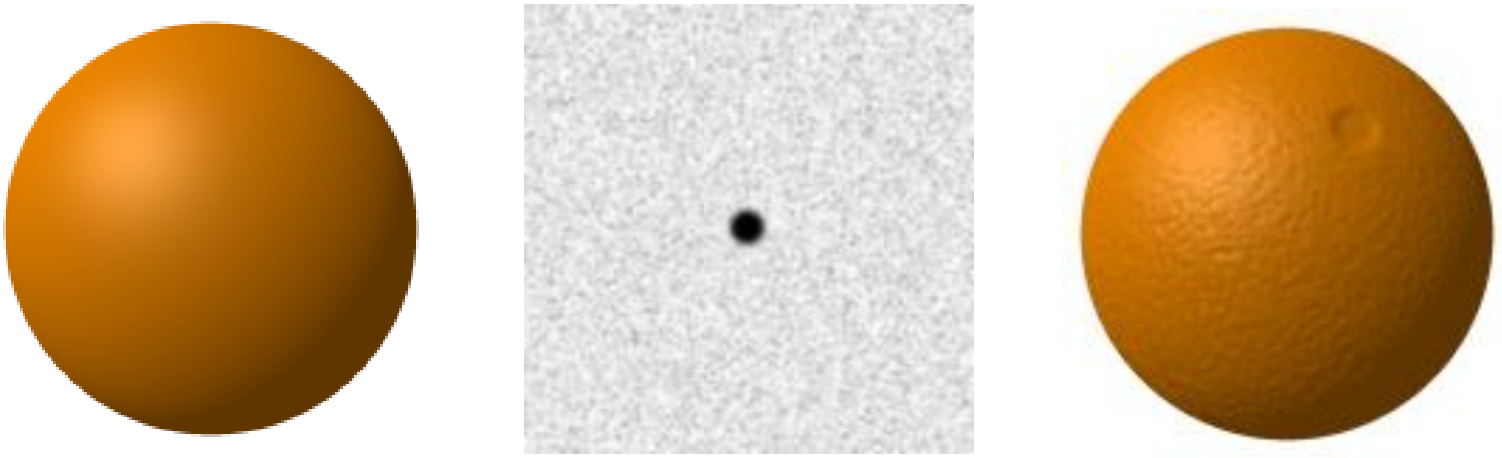


Bump Mapping

Bumps by Normal Vector Perturbation

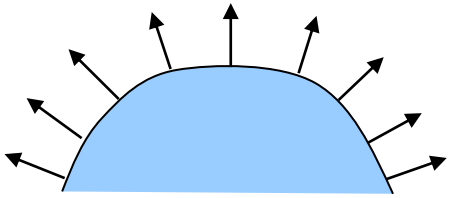
- Bump mapping
  - Heightmap buffer with perturbations to be applied to the surface normals, creating the effect of a different surface
  - New normals are used for illumination

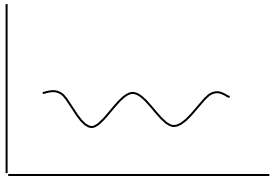
    (contrary to simple textures)
  - The geometry does not actually change!

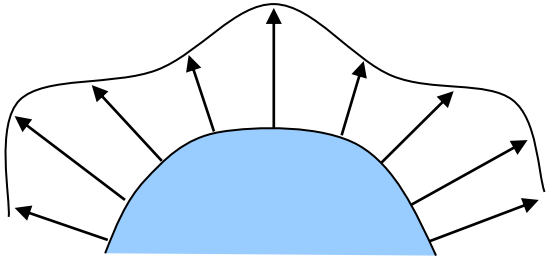


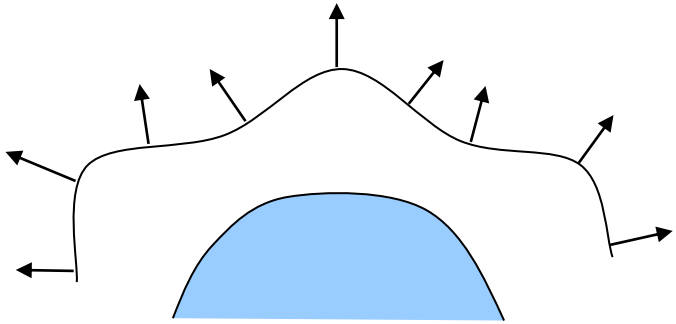
Bump Mapping

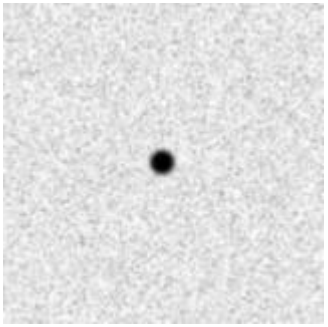
- Bump mapping



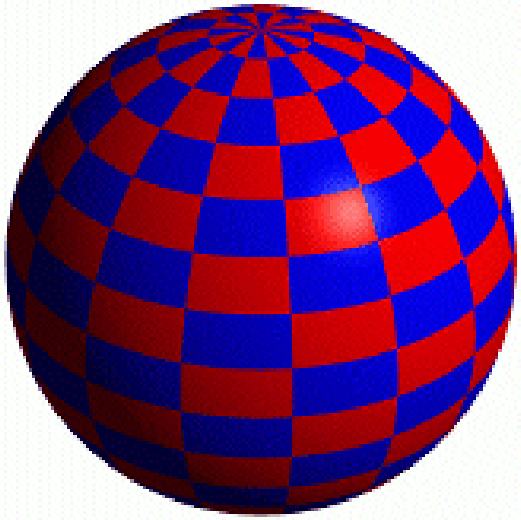






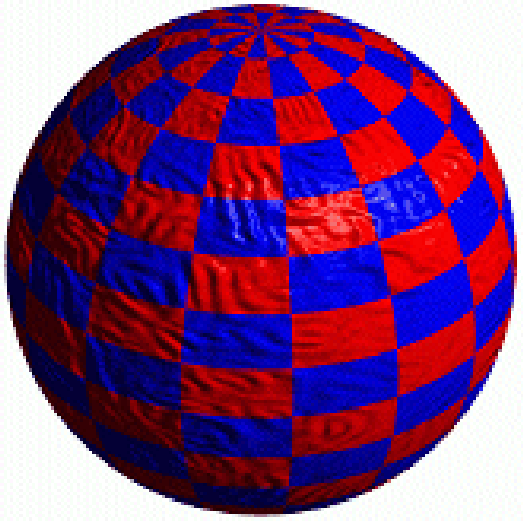


Bump Mapping

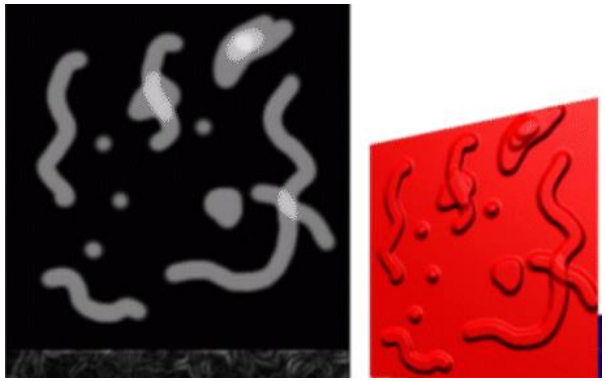


Sphere w/Diffuse Texture

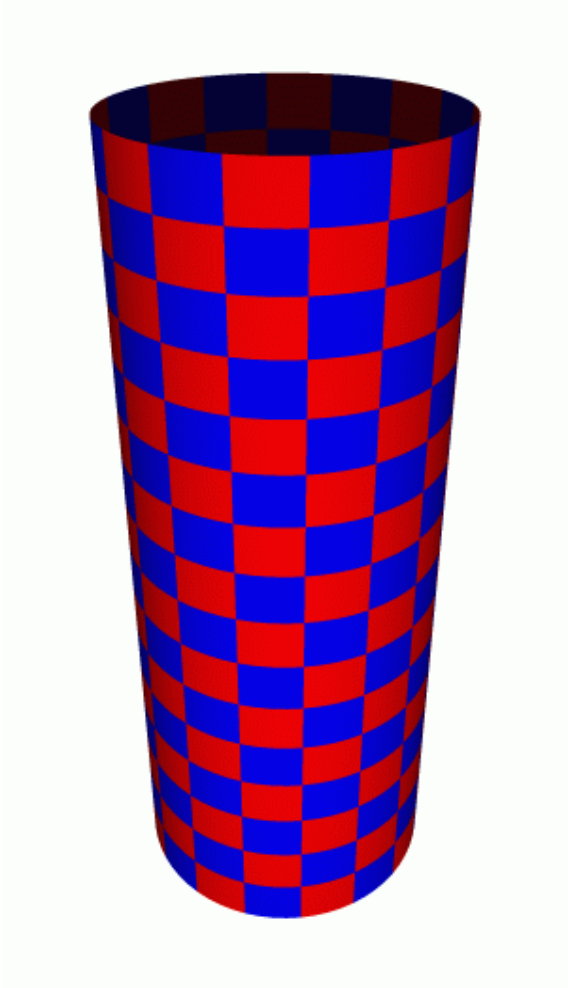
Bump Map

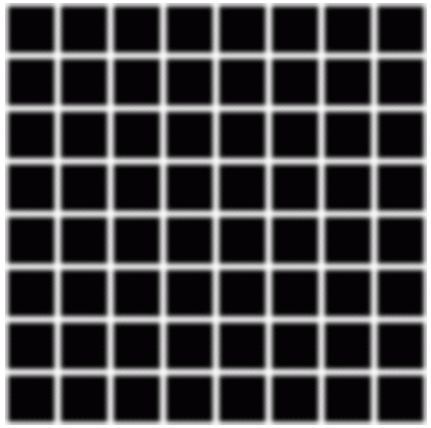


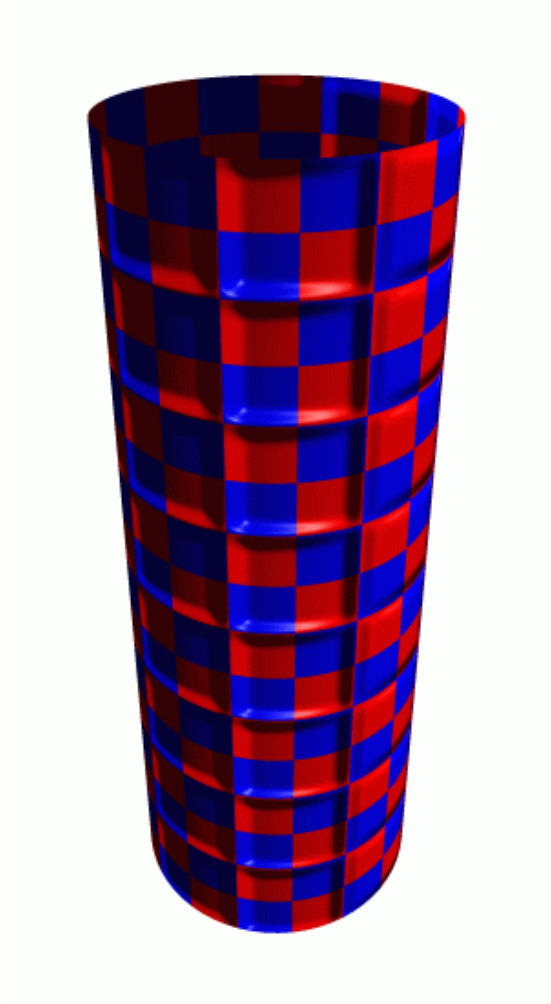
Sphere w/Diffuse Texture & Bump Map



Bump Mapping

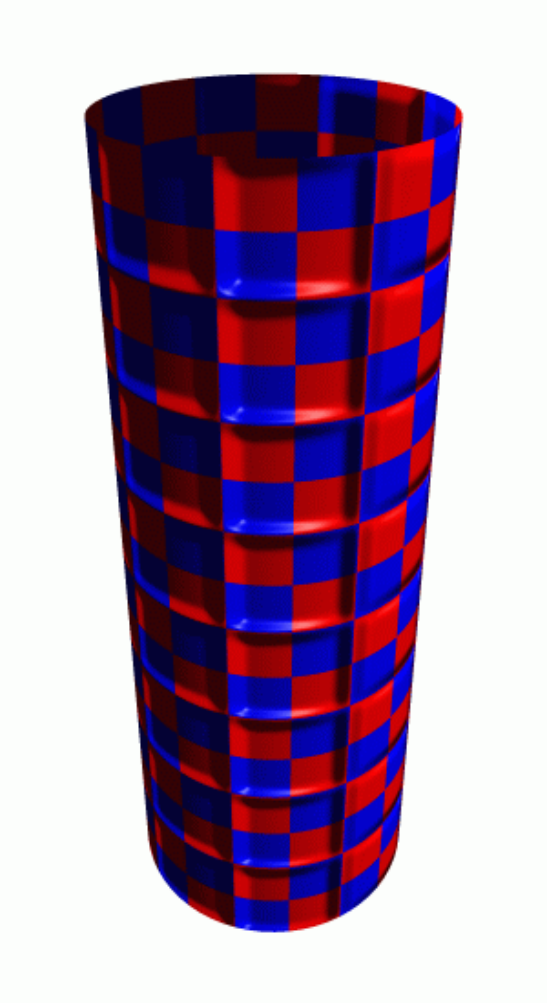






Bump Mapping

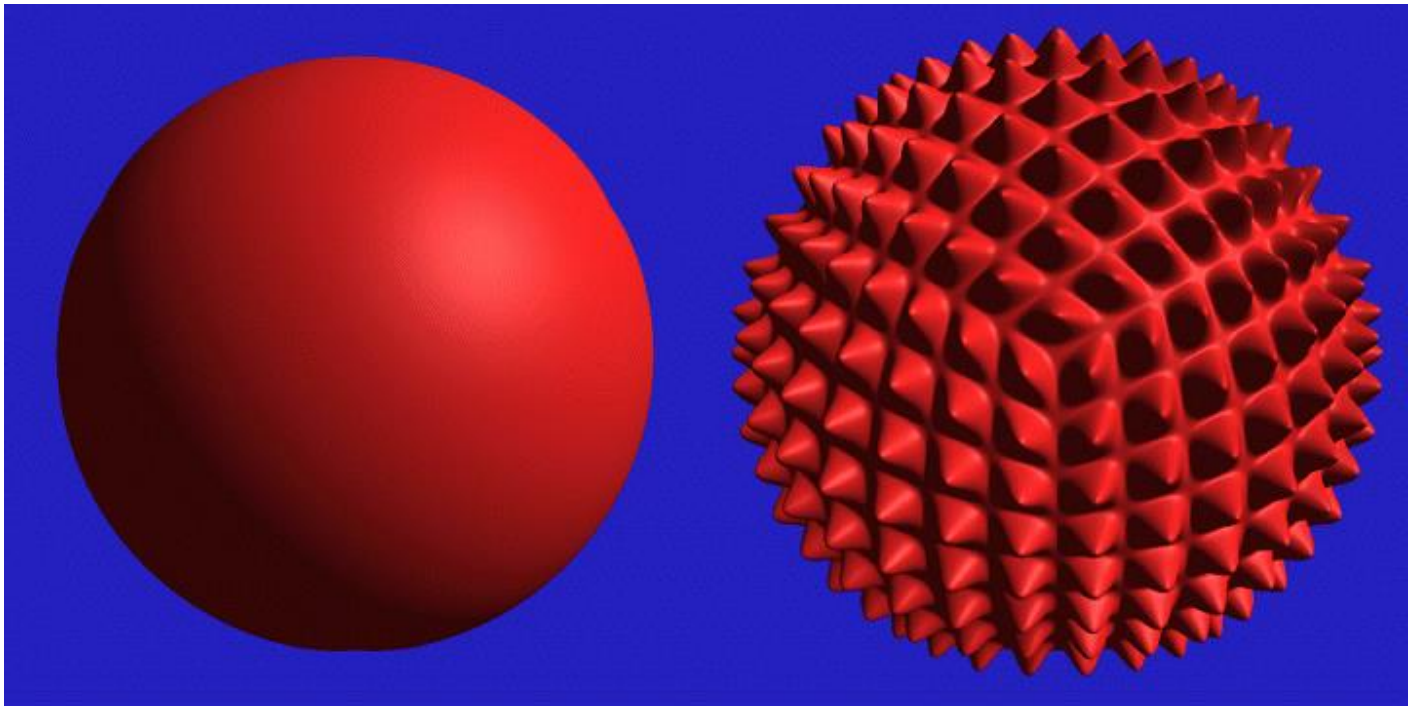
- Limitations
  - It is not possible to create bumps on the silhouette of a bump-mapped object
  - Bump maps do not resolve self-occlusion



Displacement Mapping

Displacement maps

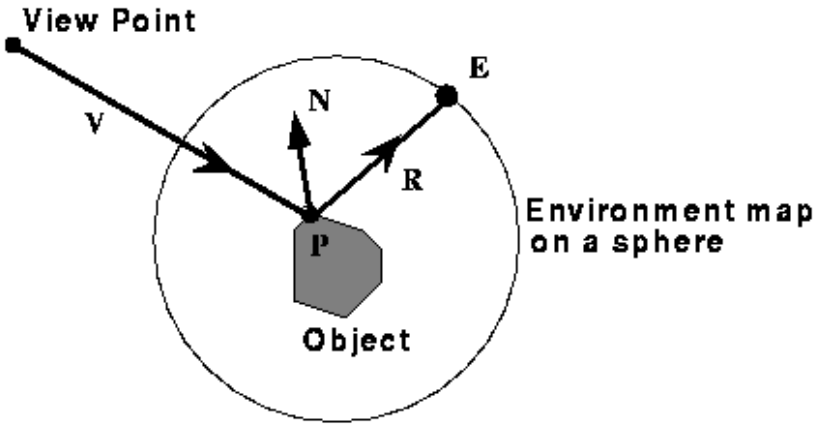
- Use the texture map to actually move the surface point
- The geometry must be displaced before visibility is determined



Environment Mapping

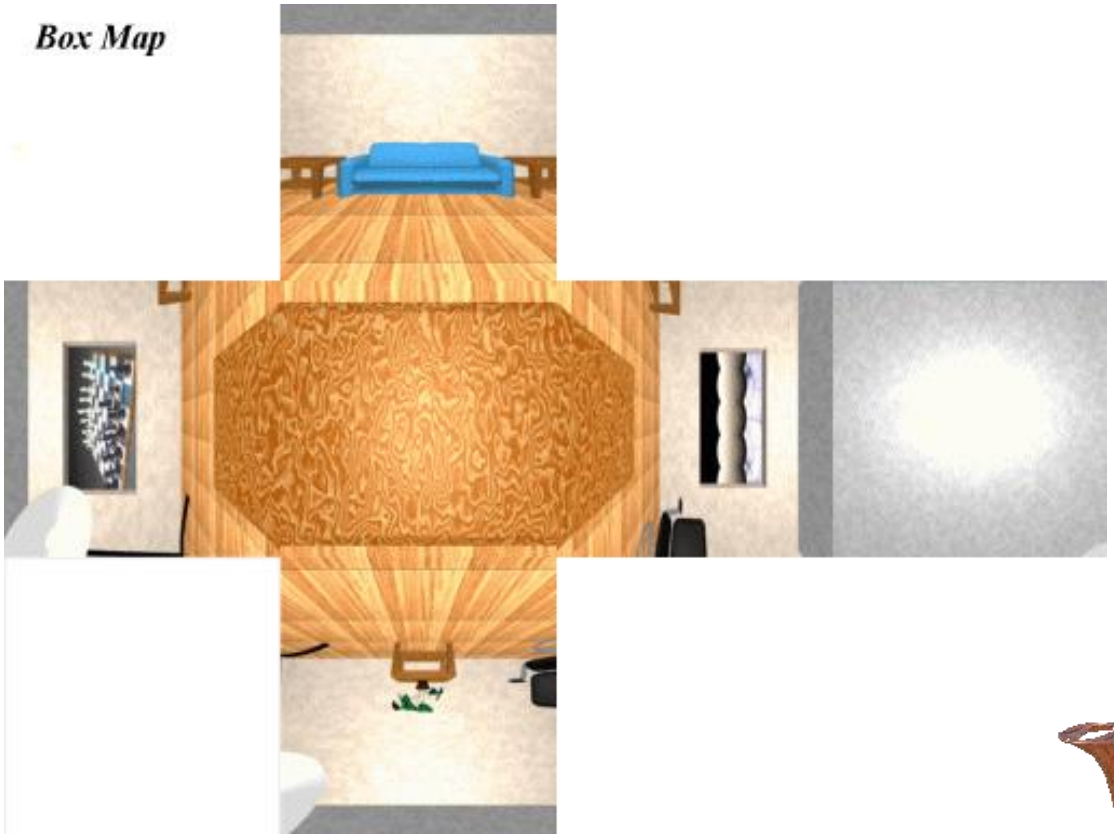
Environment Maps

- We can simulate reflections by using the direction of the reflected ray to index a spherical texture map at "infinity".



Environment Maps

- Ex:



Environment Maps

- Ex:

Light Maps

Light Maps

- First use a global renderer to realistically render the scene with lights, shadows, etc.
- Then use the image as a color map in the illumination of real-time environments
  - popular in games