Texture Mapping

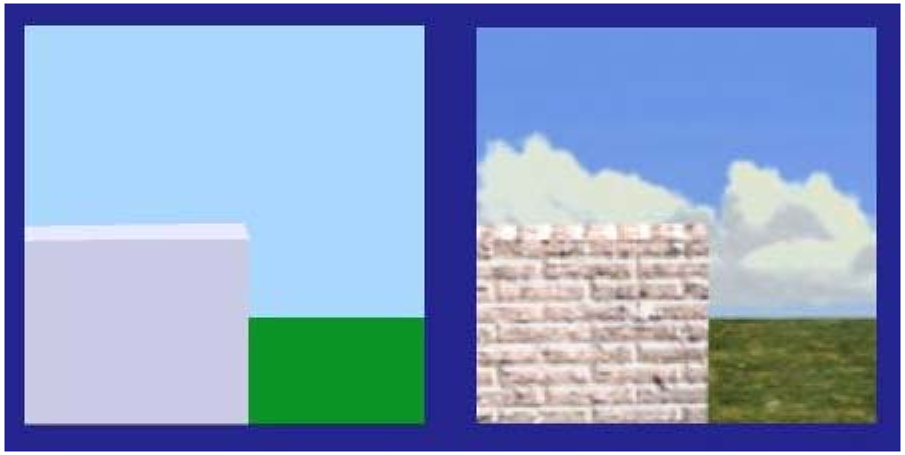
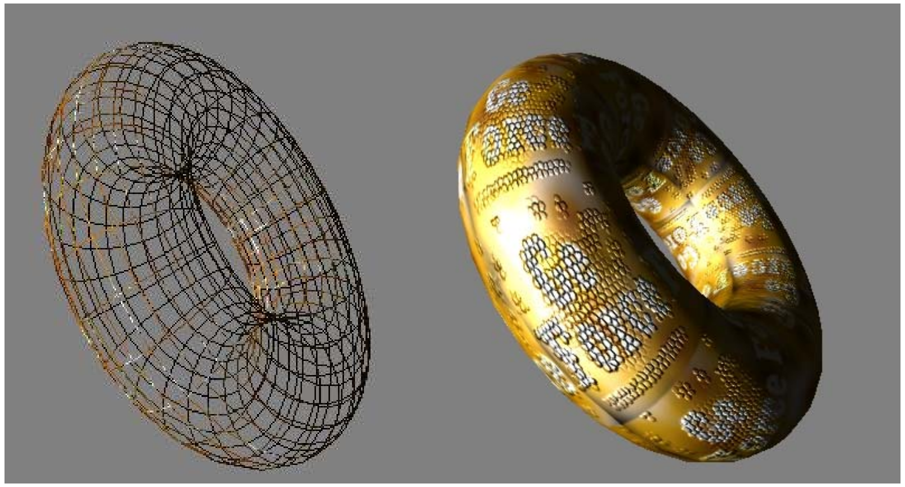
Texture Mapping

- To enhance the visual effect of an object, trade photo-realism for efficiency

  →**Texture Mapping:** texture wrapped on the object

- To add pseudo-realism to shiny animated objects by causing their surrounding environment to be reflected in them

  →**Environment mapping:** texture moved as the objects moved

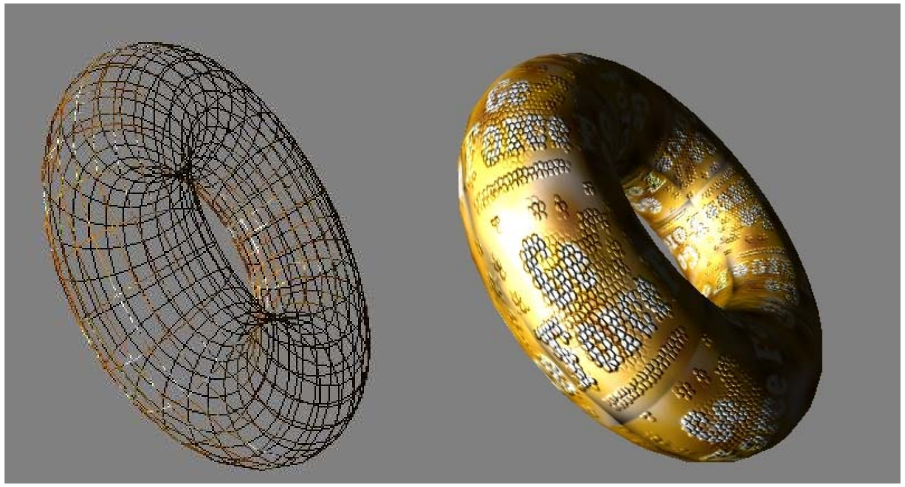



Various Mapping Techniques in CG

- 2D texture mapping
- Bump mapping
- Light maps
- Environment or reflection mapping

Store information in a domain → for the (later) rendering

- ❑ Texture Mapping is cheap, while global illumination computation is totally different and much more expensive

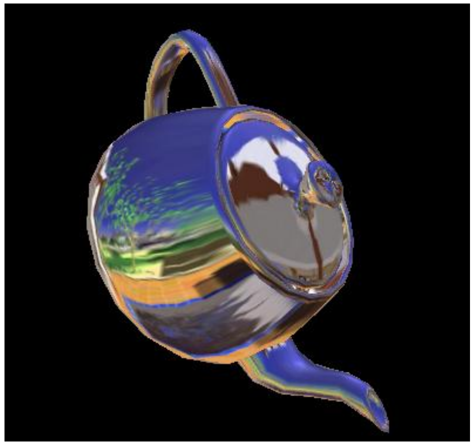


Texture Properties

What can be texture? What can be modulated with texture mapping?

- Color
- Specular Color
  - for environment reflection mapping
- Normal Vector Perturbation
  - Bump mapping
- Displacement along surface normal
  - Displacement mapping
- Transparency
  - Etched glass where a shiny surface is roughened (to cause opacity) with some decorative pattern

BUMP
MAPPING



Mapping Among Different Spaces

Texture Space

(u,v)

Surface Parameterization

$\longrightarrow$

Geometry Space

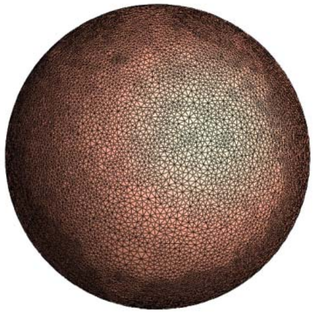
(x,y,z)

Projection

$\longrightarrow$

Screen Space

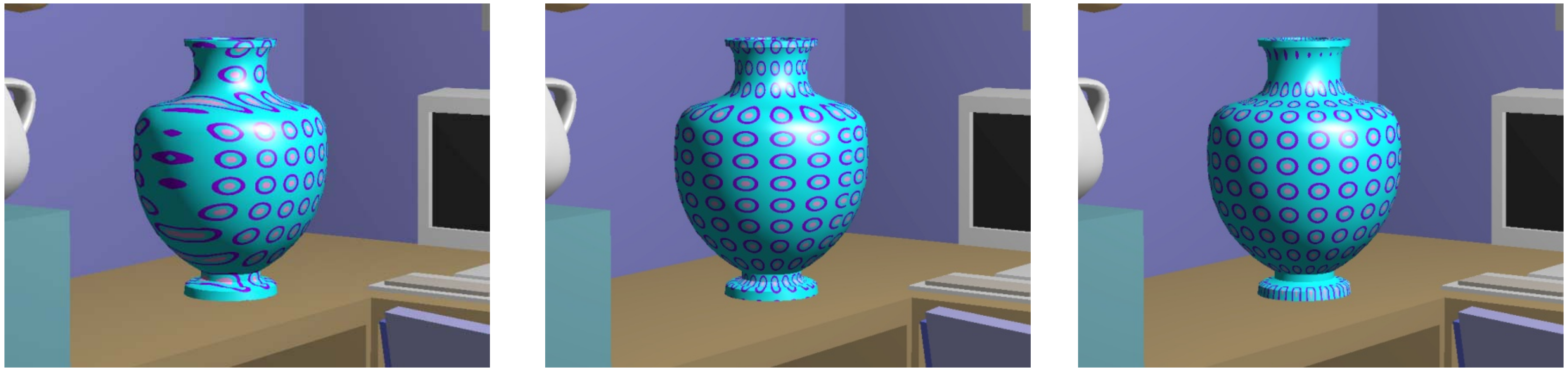
(x,y)



Intermediate Mapping Methods

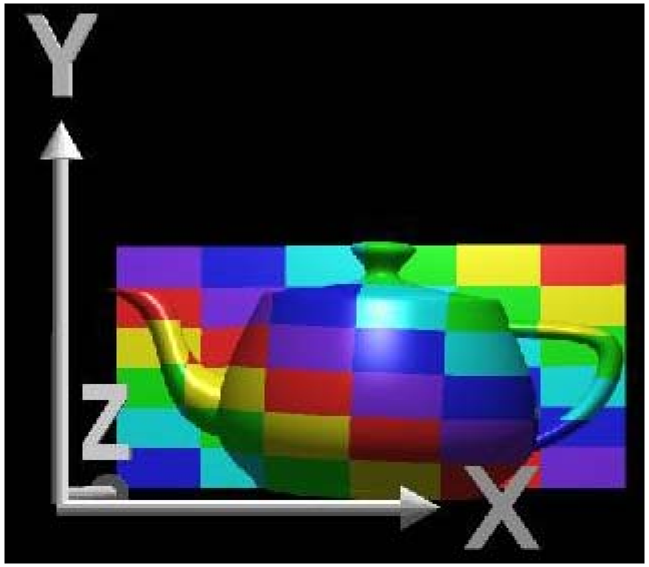
❑Based on projection

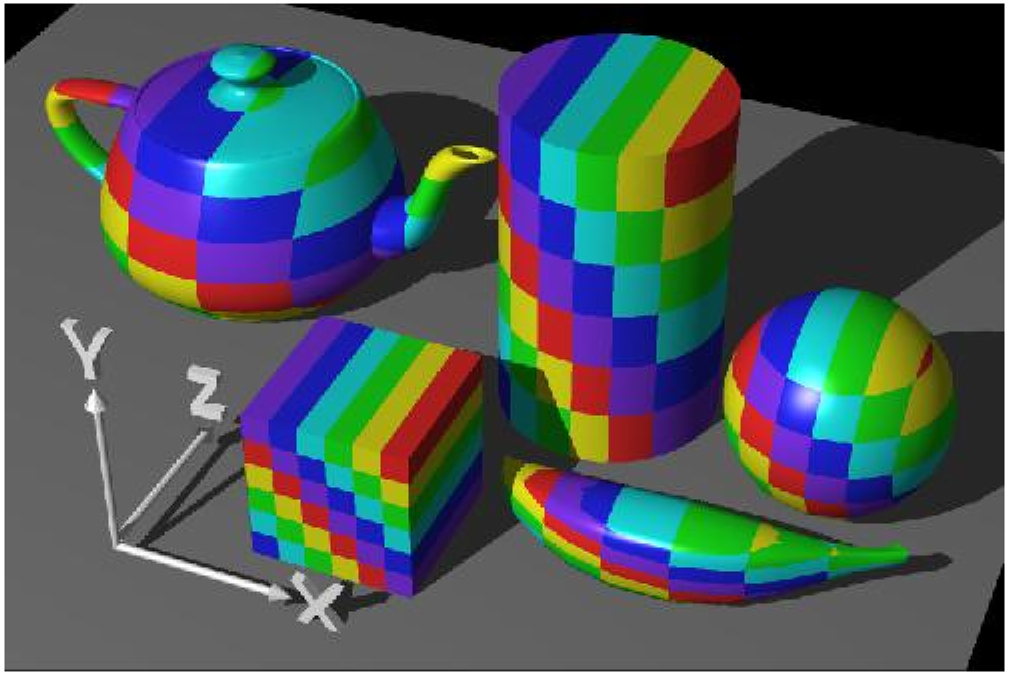
❑Project both the model and the texture image onto an intermediate surface



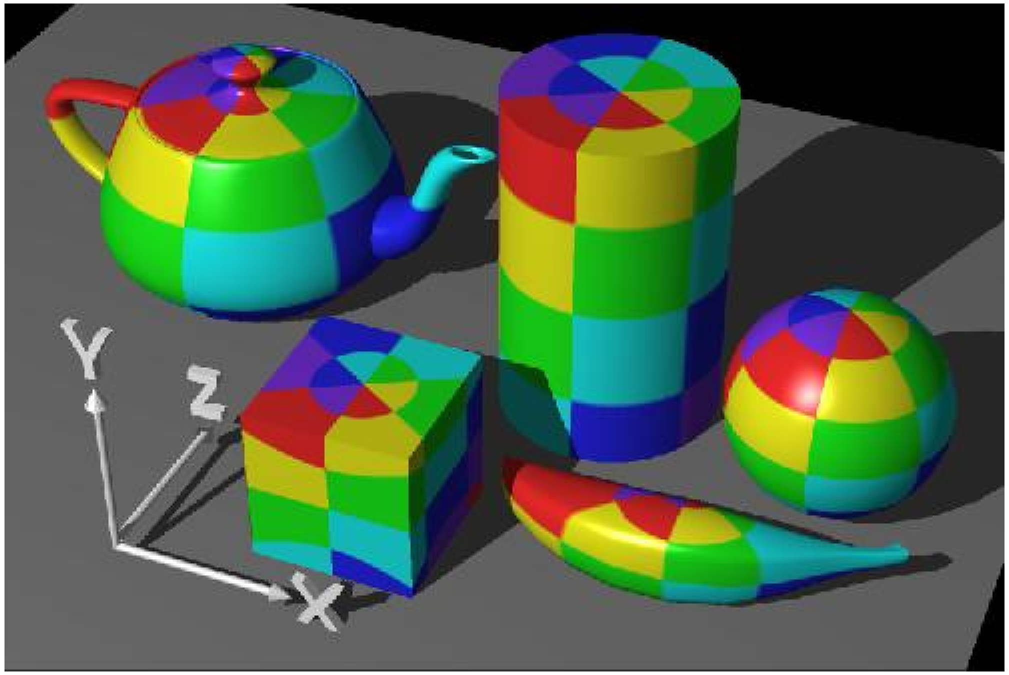
Examples of two-part texture mapping. The intermediate surfaces are (left) a plane; (middle) a cylinder; and (right) a sphere.

Plane Projection

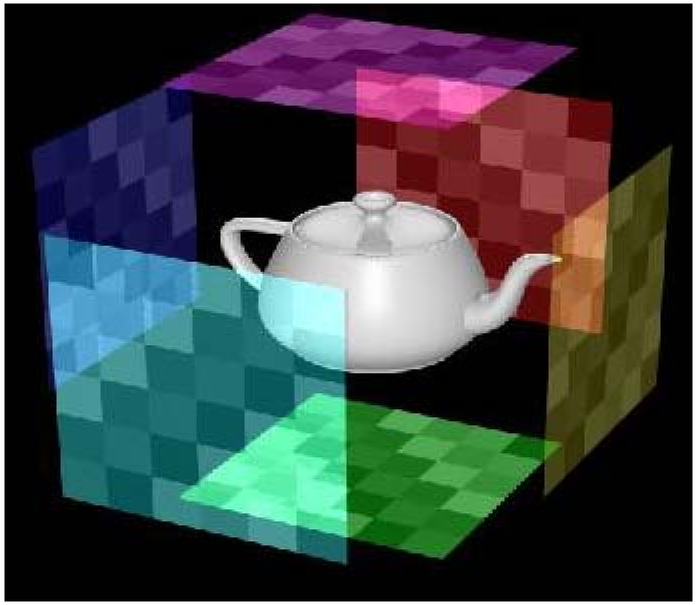


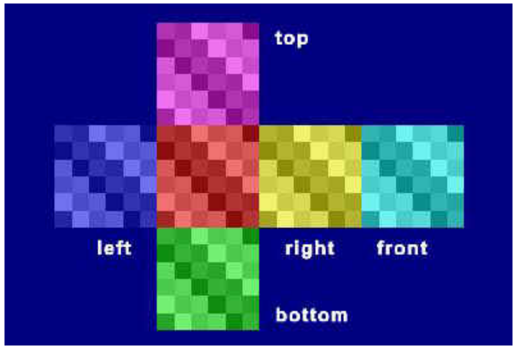


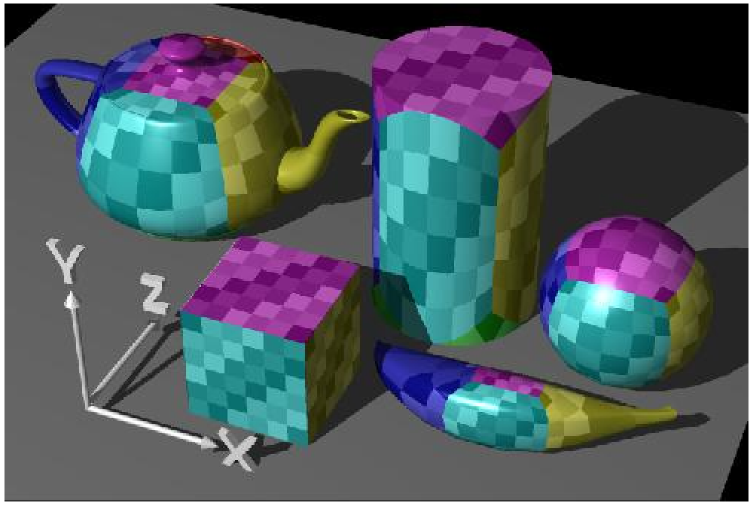
Cylinder Projection



Cube Projection







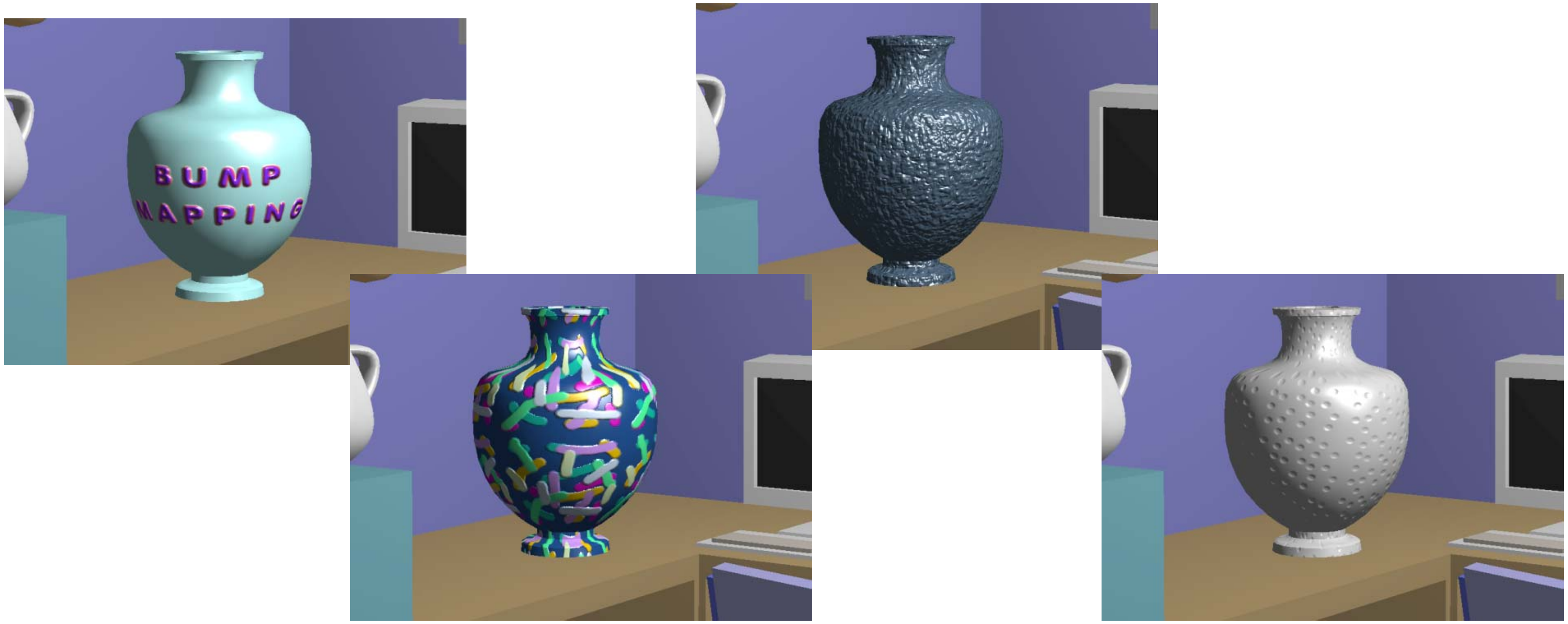
When will the projection method fail?

→ Solution: Intrinsic Parameterization Methods (later)

Bump Mapping and Normal Mapping

- Bump Mapping : to enable a (low resolution) surface to
  - Appear as if it were wrinkled or dimpled
  - Without the need to model these depressions geometrically

  →modify normal according to info in 2D bump map
  - Problem: geometry doesn't change, silhouette follows original geometry
- Normal mapping : use "normal" to enrich details



The Nature of Light and Perception

- Perception: what you can see isn't based on the objects that you are viewing but on the rays of light cast from a light source and reflected from those objects.
  - your eyes don't directly see objects as there is no physical correlation between your eyes and those objects.
- the light rays originate from an energy source (e.g. sun, lamp) →
  - you visually perceive an object = it is the rays of light reflected or scattered off that object that your eyes absorb.

Four types of lights in OpenGL

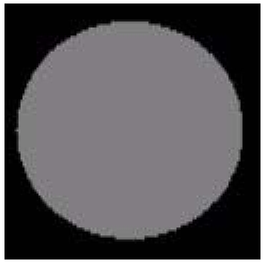
- Lights from the light source:
  1) AMBIENT LIGHT

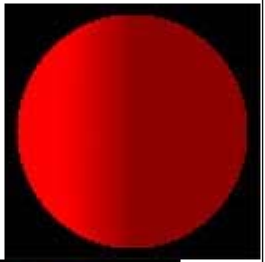
     light scattered, averagely brightens up the whole room
  2) DIFFUSE LIGHT

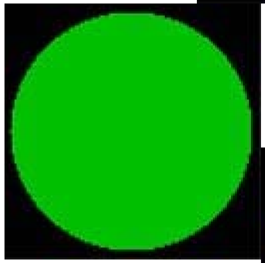
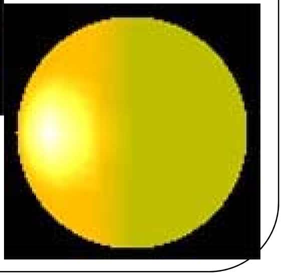
     directional light cast by a light source
  3) SPECULAR LIGHT

     reflects off the surface in a sharp and uniform way
- Lights from the object:
  4) EMISSIVE LIGHT :

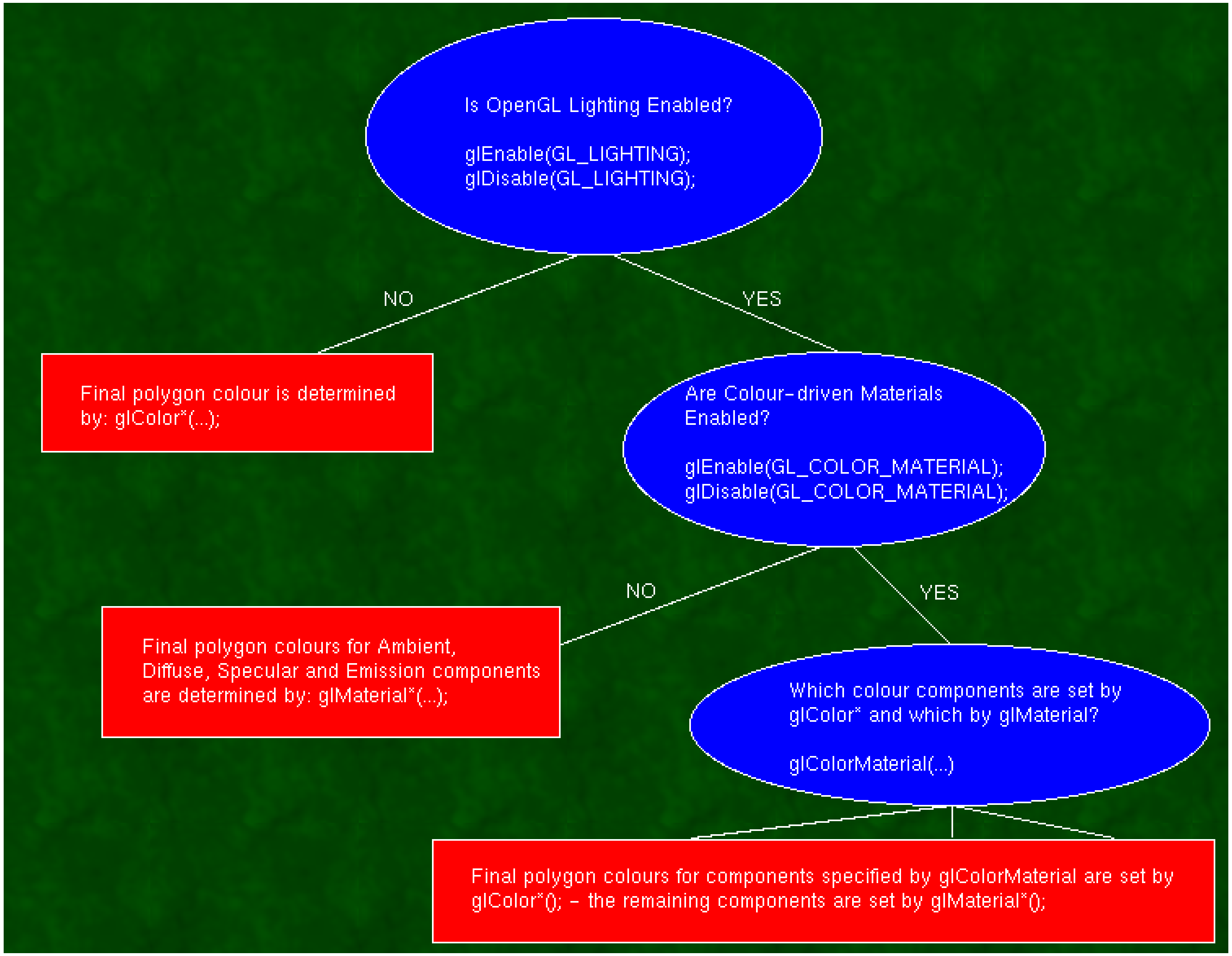
     being emitted by an object





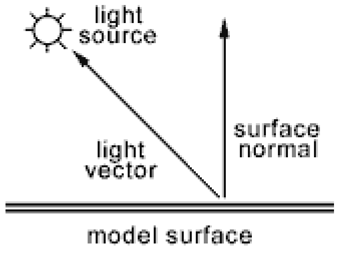
A Good Tutorial: http://www.falloutsoftware.com/tutorials/gl/gl8.htm


Is OpenGL Lighting Enabled?
glEnable(GL_LIGHTING);
glDisable(GL_LIGHTING);
NO
YES
Final polygon colour is determined by: glColor*(...);
Are Colour-driven Materials Enabled?
glEnable(GL_COLOR_MATERIAL);
glDisable(GL_COLOR_MATERIAL);
NO
YES
Final polygon colours for Ambient, Diffuse, Specular and Emission components are determined by: glMaterial*(...);
Which colour components are set by glColor* and which by glMaterial?
glColorMaterial(...)
Final polygon colours for components specified by glColorMaterial are set by glColor*(); - the remaining components are set by glMaterial*();

How does the normal work?

- About the lighting:
  - B = N • L

    (brightness ← normal dot product light vector)



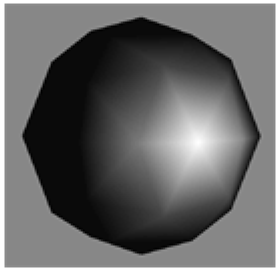
❑Gouraud shading: (in most real-time video game models, and openGL)

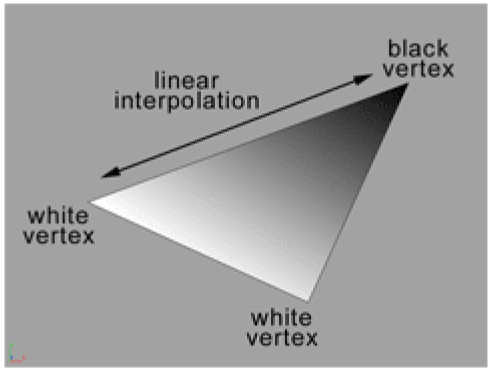
➢only compute the normal and lighting on vertices

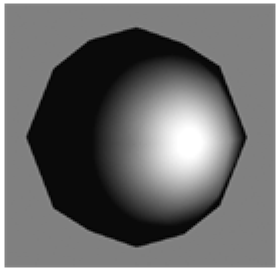
➢linear interpolate the lighting on interior pixels

❑With normal texture:

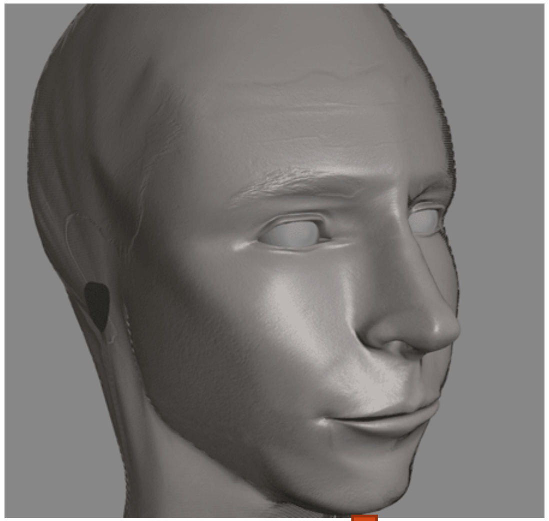
➢per-pixel lighting (on each pixel, we have normal now)

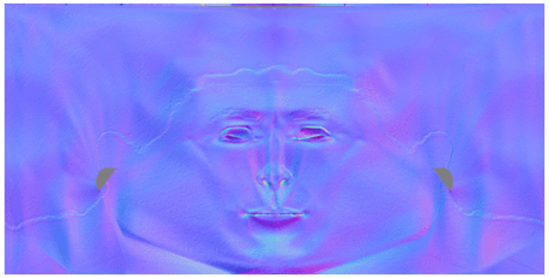


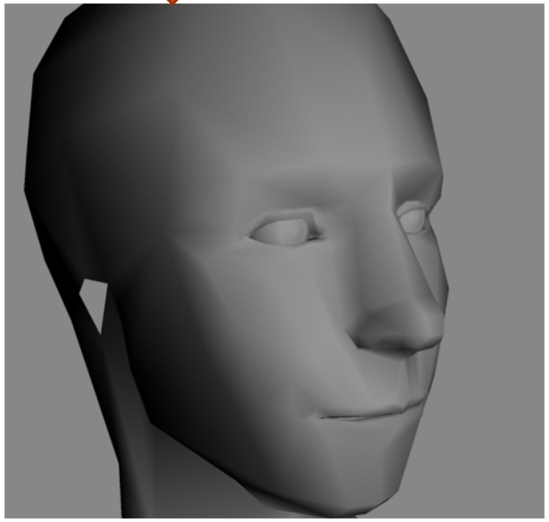


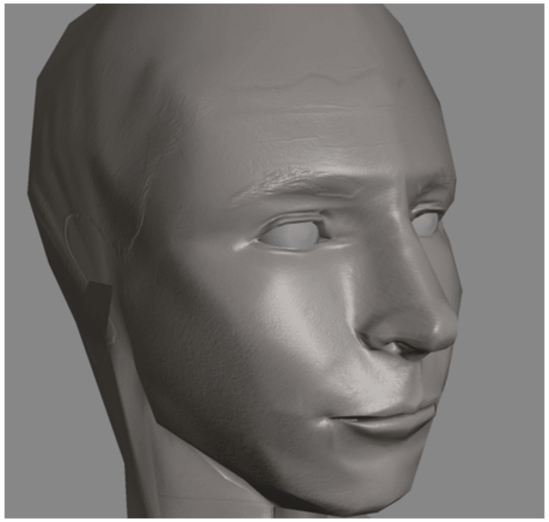


How does the normal work?


original mesh

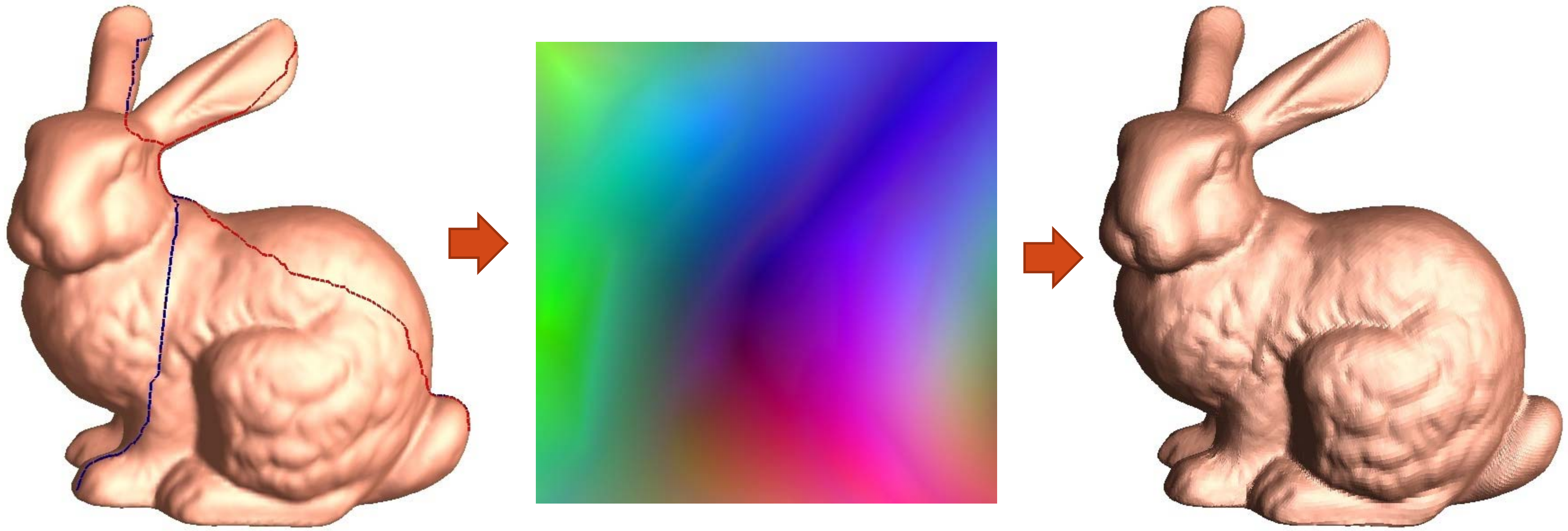

normal as the texture


simplified mesh


texture mapped simplified mesh

Geometry as texture

- Geometry Image [Gu, Gortler, and Hoppe, SIGGraph02]
  - Store the geometry (x,y,z) of each vertex → (r,g,b) in the texture space
  - Work for general surfaces, but need a cutting preprocess
    - Good cutting → less distortion
    - An intuitive topological method to generate the cut

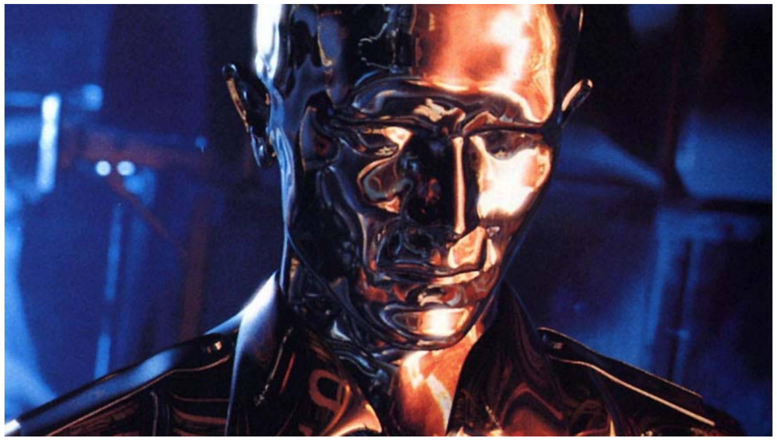


Environment Mapping

--Some surfaces texture should reflect the surrounding (example: Movie "Terminator")

- also called "reflection mapping"

  → a shortcut to rendering shiny objects that reflect its surrounding environment
  - Ray tracing process → map construction (offline) + indexing (online)
  - Nearly every 3D computer game today uses this form of texture mapping

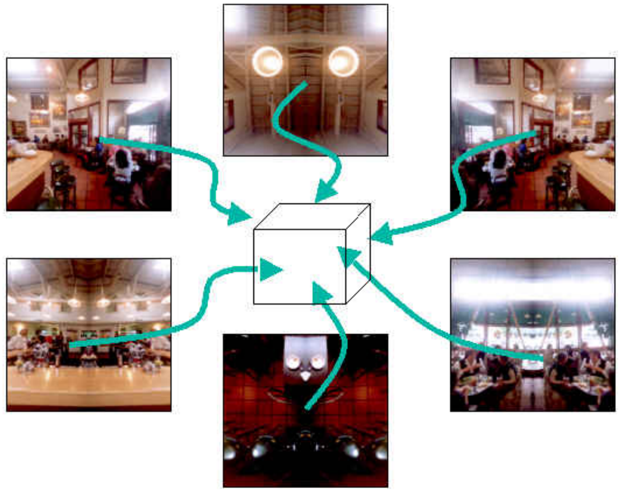


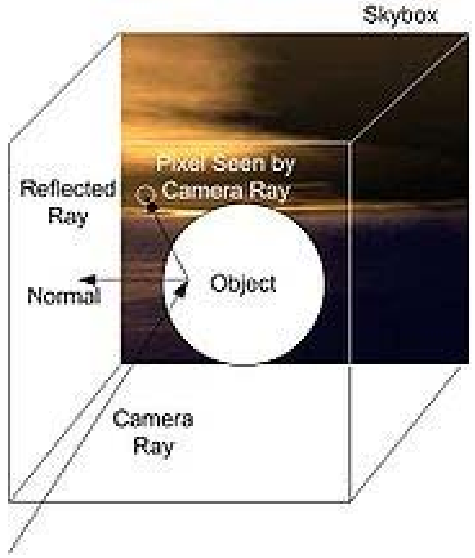
- Not a single image wrapped onto the surface:
  - when the viewer position changes, or the object moves → the reflection changes
  - should map surface points to an appropriate reflected direction in the 360 degree environment surrounding the object

Codes Demo

Environment Mapping (cont.)

- Common Mapping Techniques for Environment Mapping:
  - Sphere Mapping
  - Cubic Mapping
- Environment texture
  - Pre-computed and stored by projections
  - indexed by a 3D direction vector
- Problems:
  - Geometrically correct when objects is small w.r.t. the environment (o/w lighting might change)
  - Only reflect the environment – not itself → wrong for concave objects (why?)
  - Separate maps are required for different objects in one scene (why?)





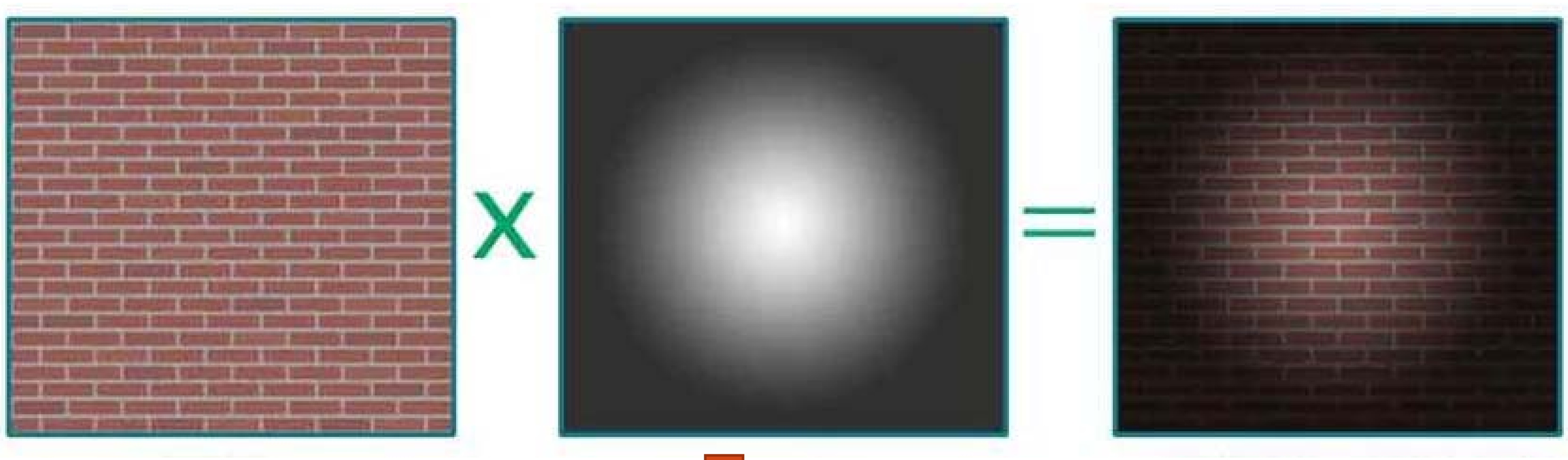
Light Mapping

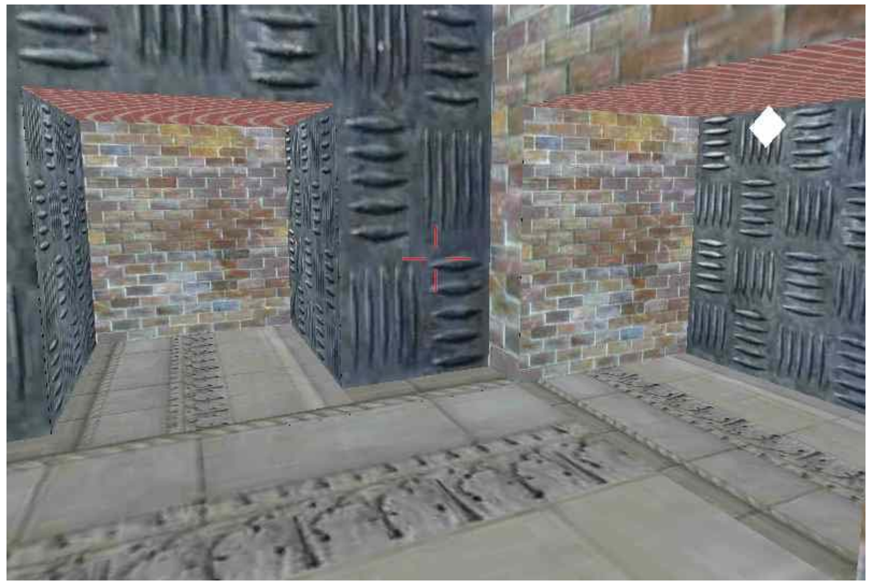
- To enable lighting to be pre-calculated and stored as a two-dimensional texture map
  - Pre-compute:
    - Vertex brightness using distance from each vertex to a light
    - Pixel brightness using multitexture when texture map is also used
  - Shading → Indexing
  - Can stored separately from other texture maps with lower resolution

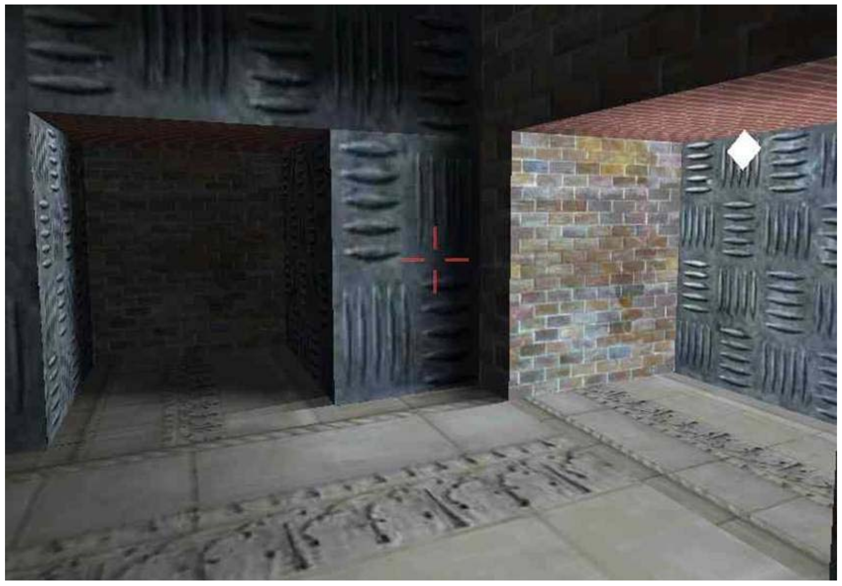
<u>Example: Quake</u>
(a first-person shooter video game)

- ❑ Moving objects? → multiple maps + interpolation

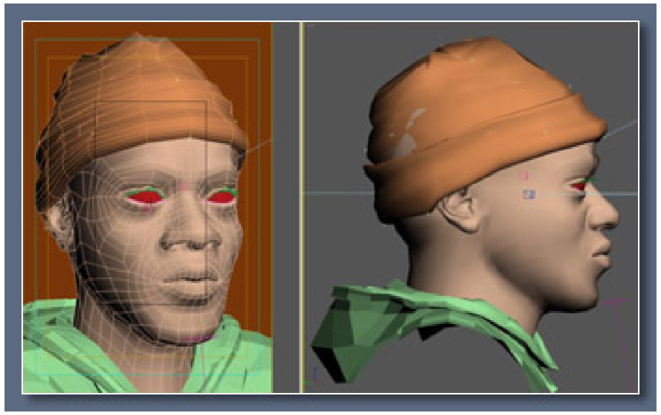
Light Mapping (cont.)

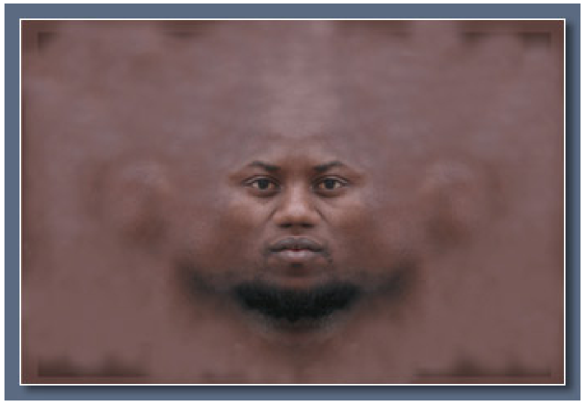


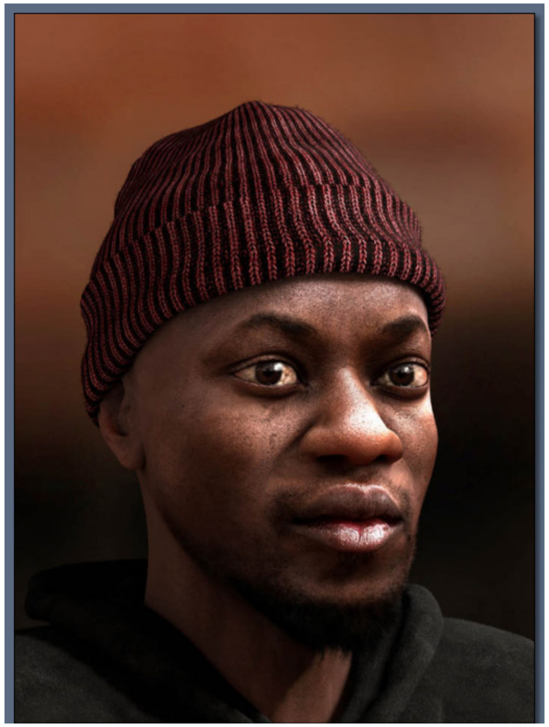




Difficulty in 2D Texture Mapping



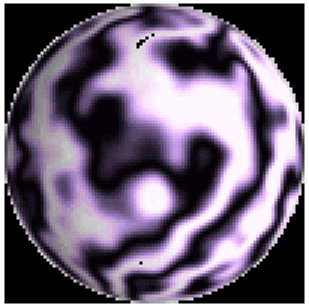




Need low-distorted mapping, sometimes not easy to compute!

3D Texture

- Challenges for wrapping texture images onto surfaces (for 2D texture mapping):
  - Distortion control could be non-trivial
  - Topological discontinuity could be awkward
- Procedural texture
  - Define a continuous texture function over the whole R^3 space
  - Spatial Efficiency : functions instead of 3D texture images



…

Check the paper: [Perlin Noise 1985] , google "Perlin Noise"
– using noise function to simulate turbulence

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- Texture synthesis
  - Not a mapping problem any more
  - Less texture patterns (less resources)

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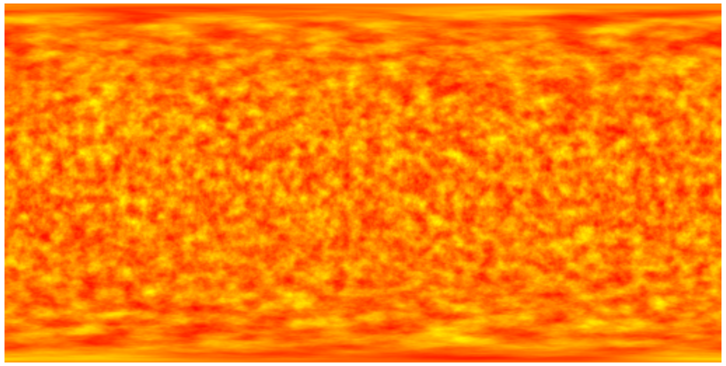
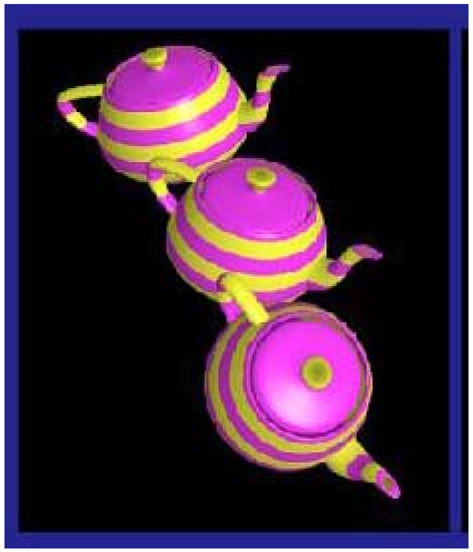
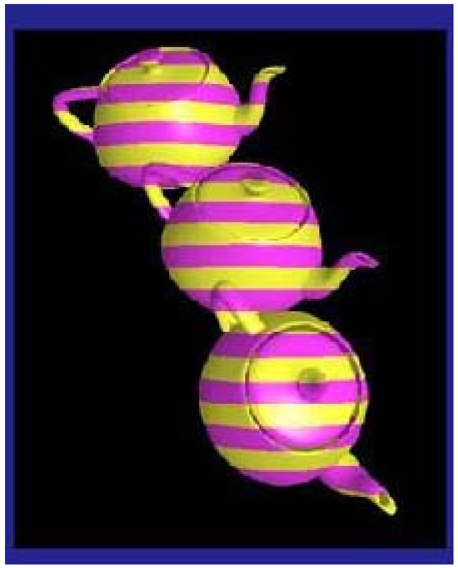


3D Texture (cont.)

Big visual difference:

-- Texture moving with the object





Next:

The surface mapping (parameterization) problem:

How to control the distortion? (What distortion?)
How about other issues – boundary continuity, poles?