Texture Mapping

CS 4620 Lecture 12

Texture mapping

- Objects have properties that vary across the surface

Texture Mapping

- So we make the shading parameters vary across the surface

[Foley et al. / Perlin]

Texture mapping

- Adds visual complexity; makes appealing images

[Pixar / *Toy Story*]

Texture mapping

- Color is not the same everywhere on a surface
  - one solution: multiple primitives
- Want a function that assigns a color to each point
  - the surface is a 2D domain, so that is essentially an image
  - can represent using any image representation
  - raster texture images are very popular

A definition

Texture mapping: a technique of defining surface properties (especially shading parameters) in such a way that they vary as a function of position on the surface.

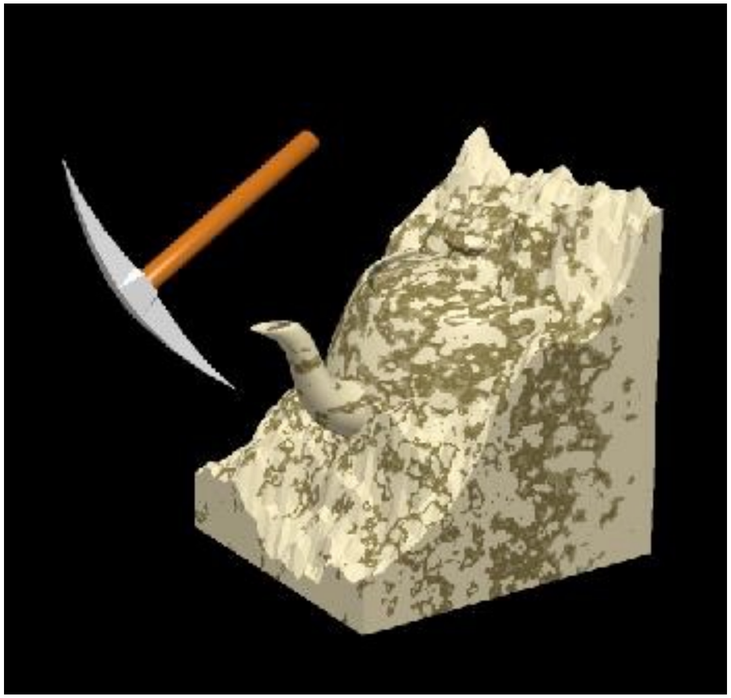
- This is very simple!
  - but it produces complex-looking effects

Examples

- Wood gym floor with smooth finish
  - diffuse color k_D varies with position
  - specular properties k_S, n are constant
- Glazed pot with finger prints
  - diffuse and specular colors k_D, k_S are constant
  - specular exponent n varies with position
- Adding dirt to painted surfaces
- Simulating stone, fabric, …
  - to approximate effects of small-scale geometry
    - they look flat but are a lot better than nothing

Mapping textures to surfaces

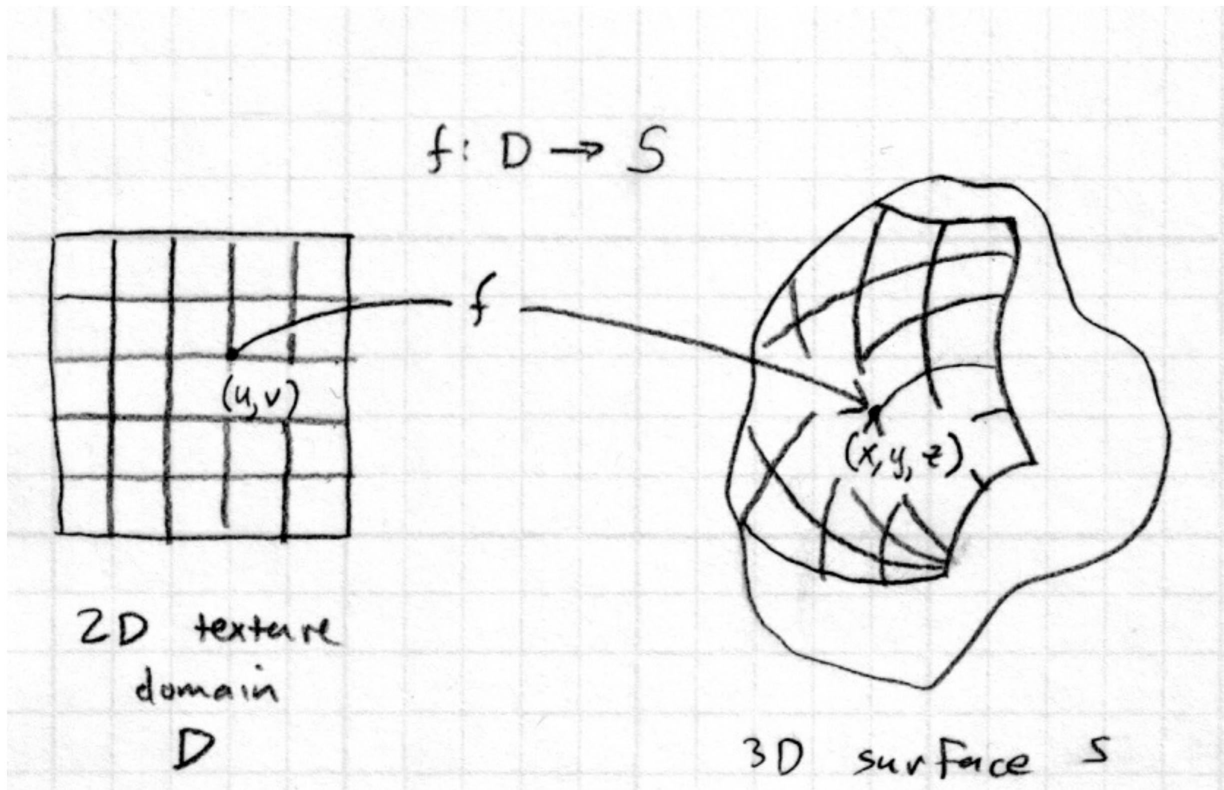
- Usually the texture is an image (function of *u*, v)
  - the big question of texture mapping: where on the surface does the image go?
  - obvious only for a flat rectangle the same shape as the image
  - otherwise more interesting
- Note that *3D textures* also exist
  - texture is a function of (*u*, *v*, *w*)
  - can just evaluate texture at 3D surface point
  - good for solid materials
  - often defined procedurally



[Wolfe / SG97 Slide set]

Mapping textures to surfaces

- "Putting the image on the surface"
  - this means we need a function *f* that tells where each point on the image goes
  - this looks a lot like a parametric surface function
  - for parametric surfaces you get *f* for free

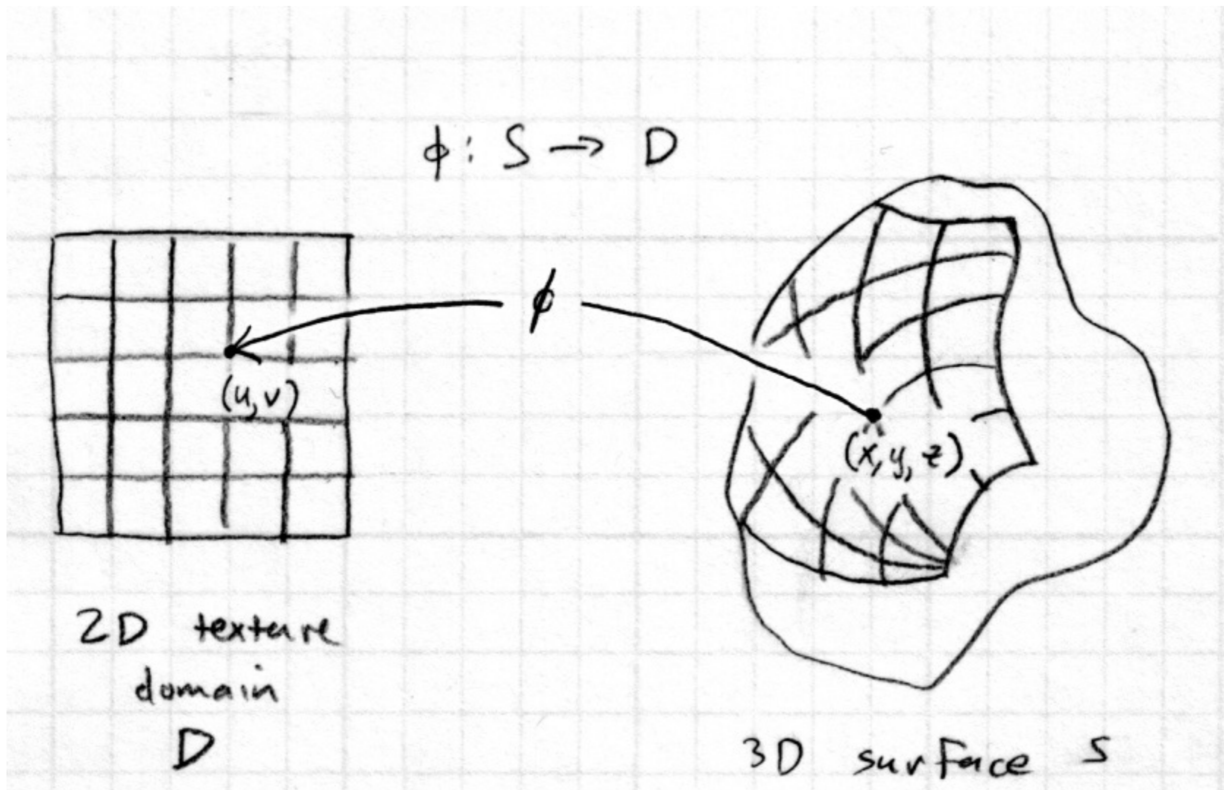


Texture coordinate functions

- Non-parametrically defined surfaces: more to do
  - can't assign texture coordinates as we generate the surface
  - need to have the *inverse* of the function *f*
- Texture coordinate fn.

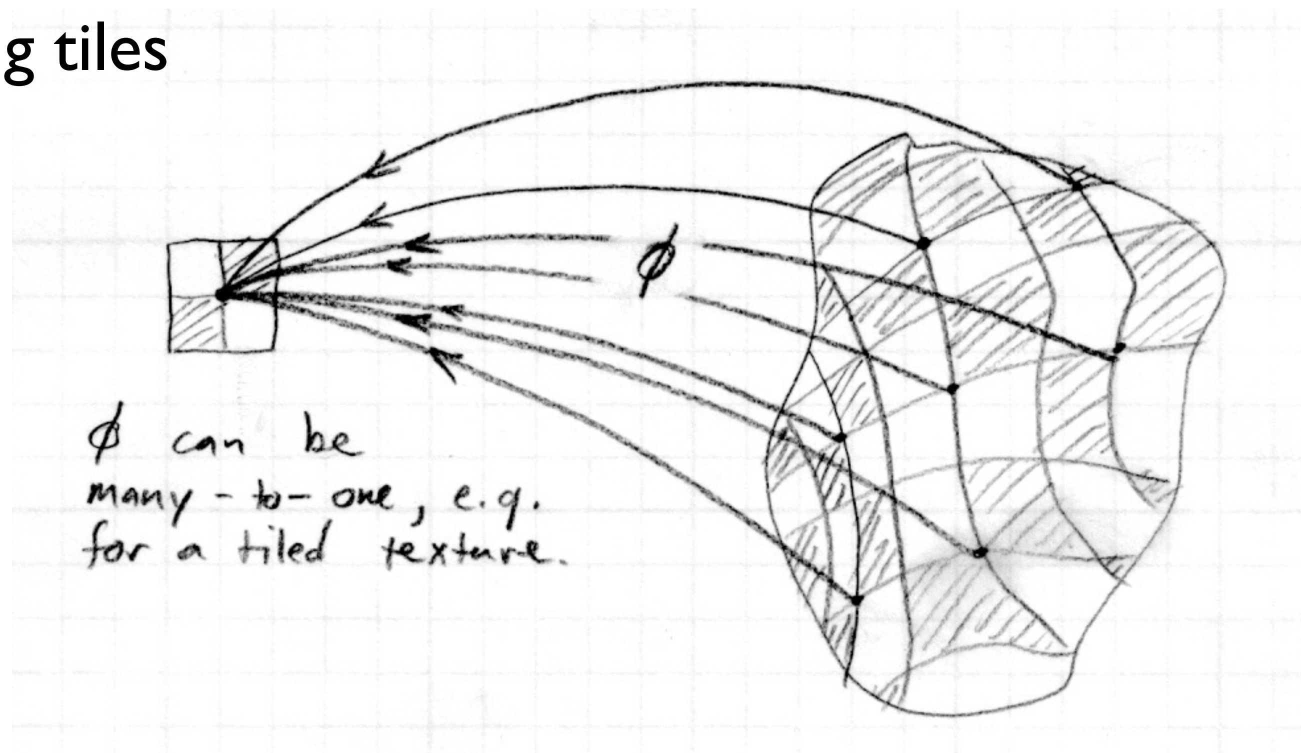
  $$\phi : S \to \mathbb{R}^2$$

  - for a vtx. at **p** get texture at ϕ(**p**)



Texture coordinate functions

- Mapping from *S* to *D* can be many-to-one
  - that is, every surface point gets only one color assigned
  - but it is OK (and in fact useful) for multiple surface points to be mapped to the same texture point
    - e.g. repeating tiles



Texture coordinate functions

- Define texture image as a function

$$T : D \to C$$

  - where *C* is the set of colors for the diffuse component

- Diffuse color (for example) at point **p** is then

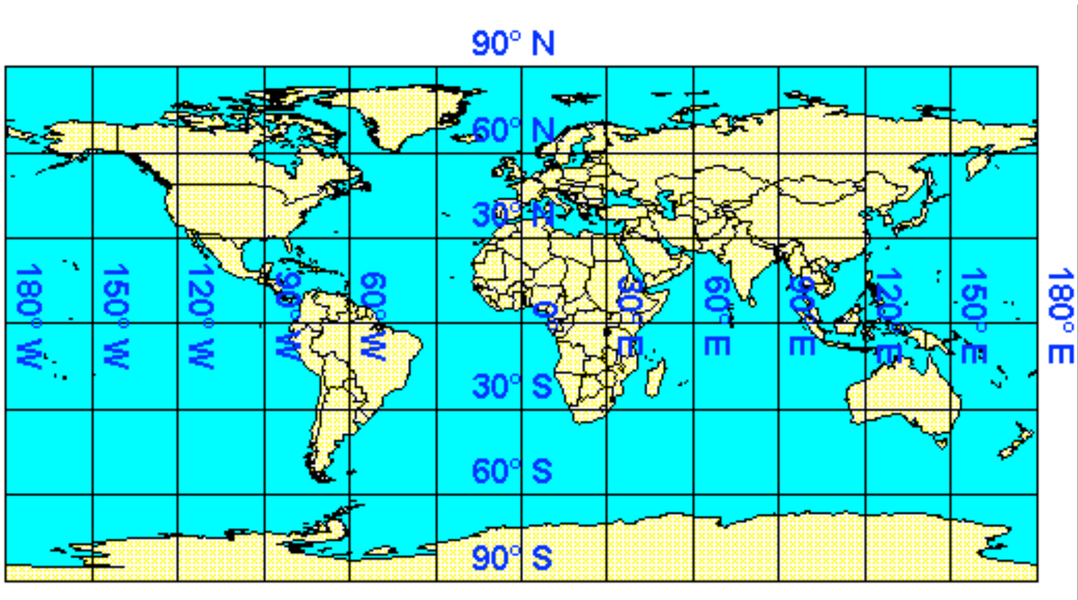
$$k_D(\mathbf{p}) = T(\phi(\mathbf{p}))$$

Examples of coordinate functions

- A rectangle
  - image can be mapped directly, unchanged

Examples of coordinate functions

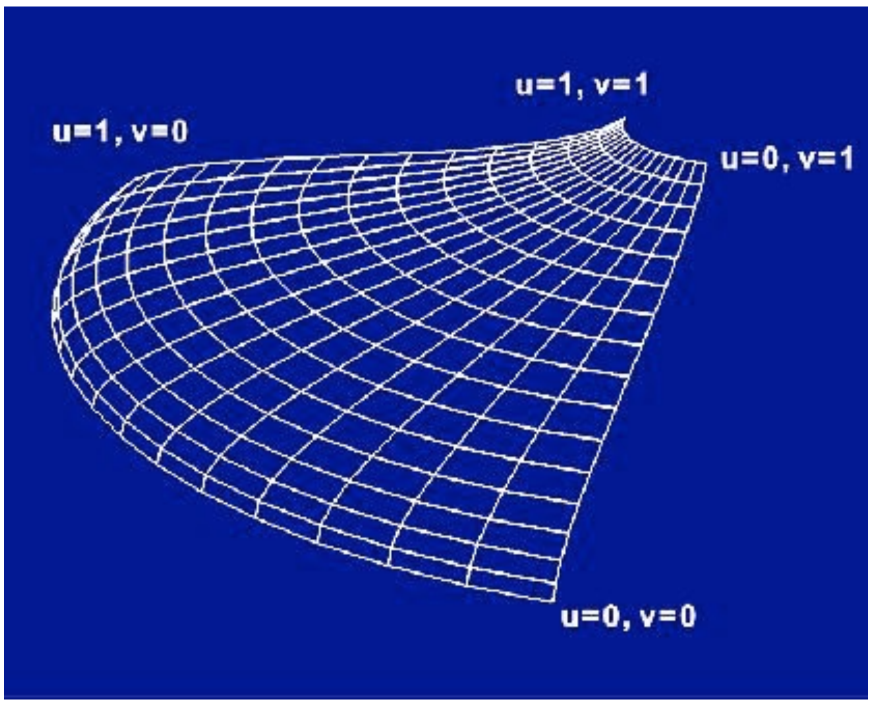
- For a sphere: latitude-longitude coordinates
  - ϕ maps point to its latitude and longitude

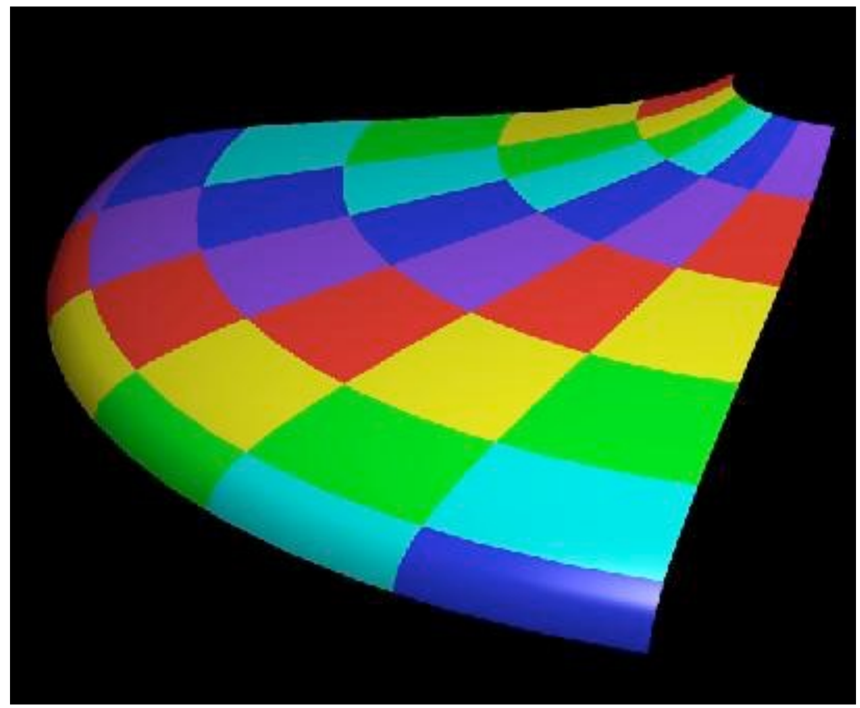


[map: Peter H. Dana]

Examples of coordinate functions

- A parametric surface (e.g. spline patch)
  - surface parameterization gives mapping function directly (well, the inverse of the parameterization)

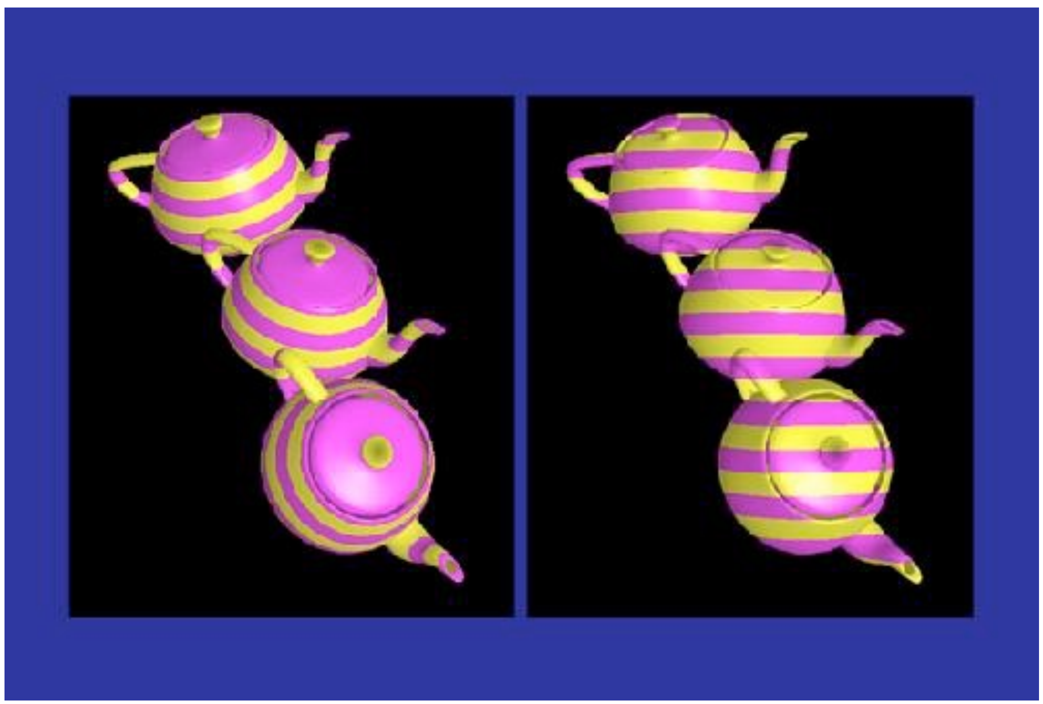




[Wolfe / SG97 Slide set]

Examples of coordinate functions

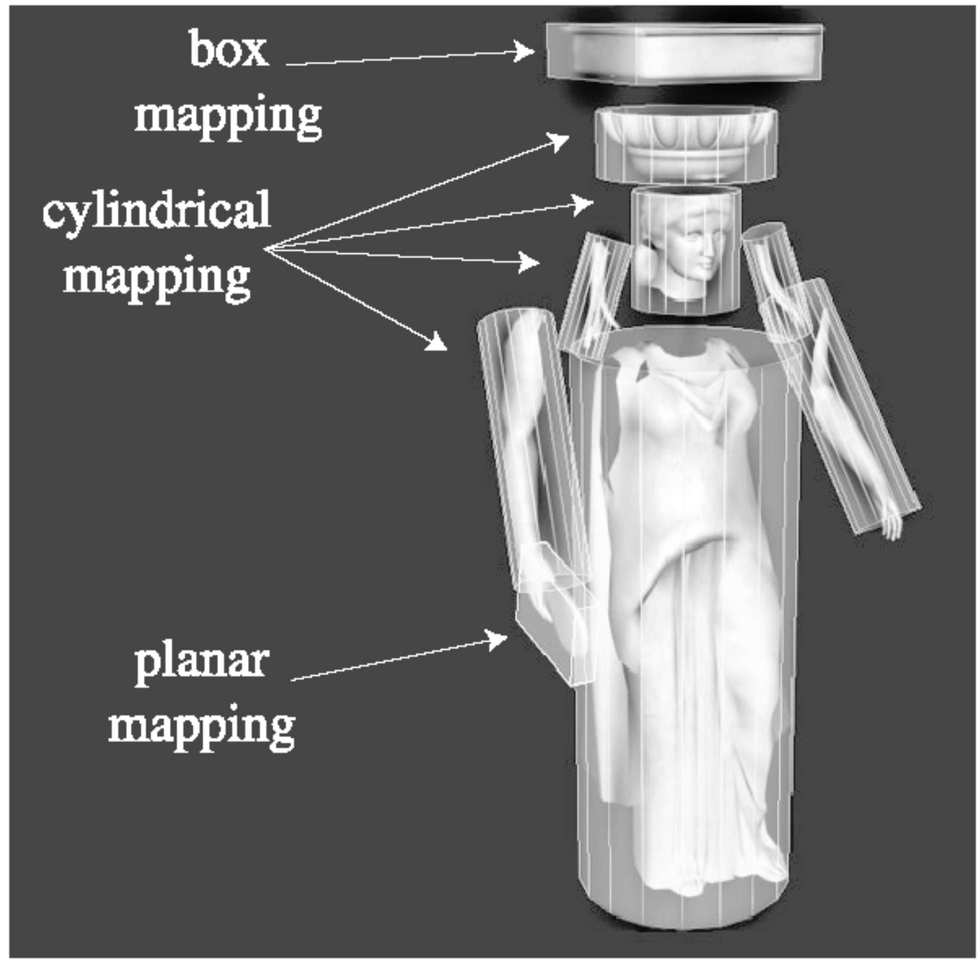
- For non-parametric surfaces it is trickier
  - directly use world coordinates
    - need to project one out



[Wolfe / SG97 Slide set]

Examples of coordinate functions

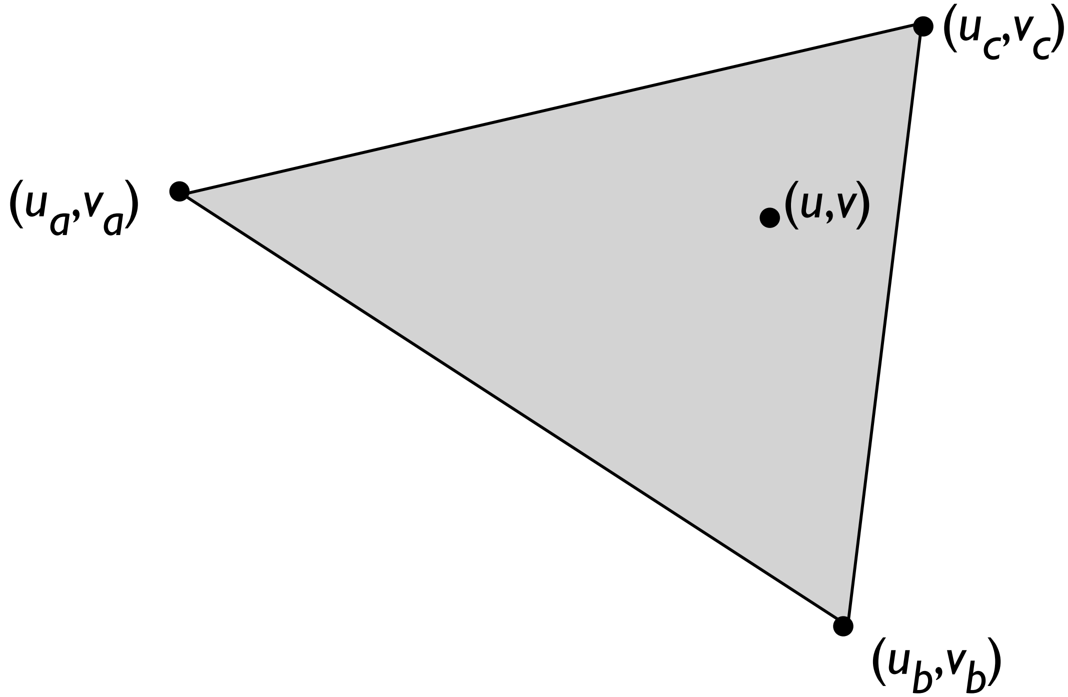
- Non-parametric surfaces: project to parametric surface



[Moller & Haines 2002]

Examples of coordinate functions

- Triangles
  - specify (u,v) for each vertex
  - define (u,v) for interior by linear interpolation

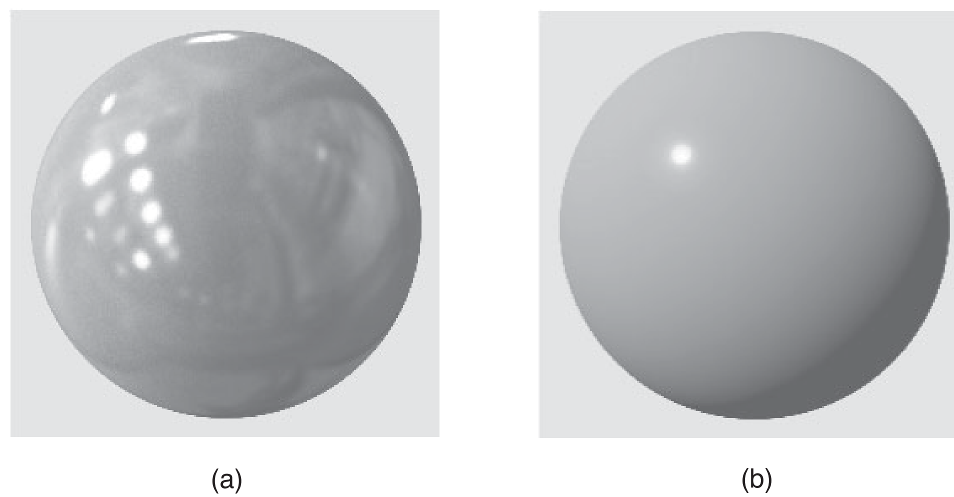


Texture coordinates on meshes

- Texture coordinates become per-vertex data like vertex positions
  - can think of them as a second position: each vertex has a position in 3D space and in 2D texure space
- How to come up with vertex (*u*,*v*)s?
  - use any or all of the methods just discussed
    - in practice this is how you implement those for curved surfaces approximated with triangles
  - use some kind of optimization
    - try to choose vertex (*u*,*v*)s to result in a smooth, low distortion map

Reflection mapping

- Early (earliest?) non-decal use of textures
- Appearance of shiny objects
  - Phong highlights produce blurry highlights for glossy surfaces.
  - A polished (shiny) object reflects a sharp image of its environment.
- The whole key to a shiny-looking material is providing something for it to reflect.

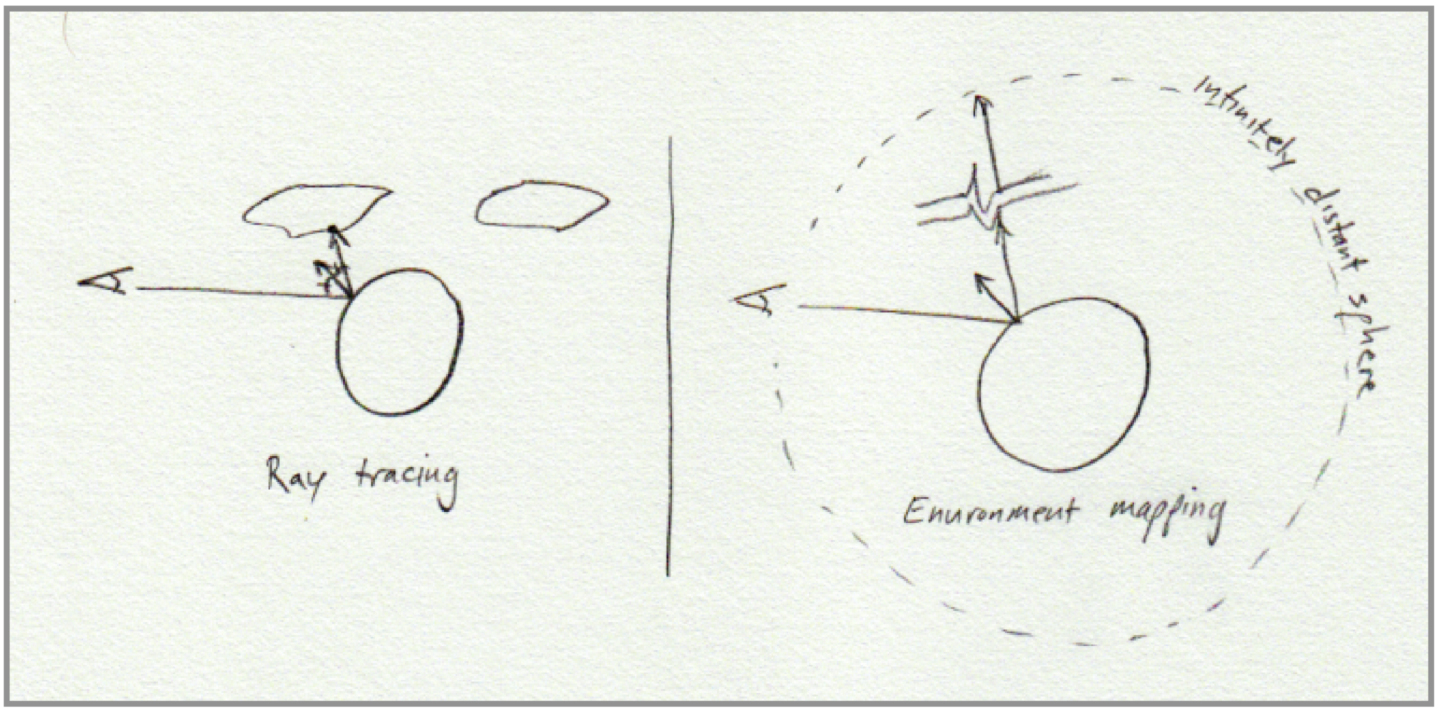


[Dror, Willsky, & Adelson 2004]

Figure 2. (a). A shiny sphere rendered under photographically acquired real-world illumination. (b). The same sphere rendered under illumination by a point light source.

Reflection mapping

- From ray tracing we know what we'd like to compute
  - trace a recursive ray into the scene—too expensive
- If scene is infinitely far away, depends only on direction
  - a two-dimensional function

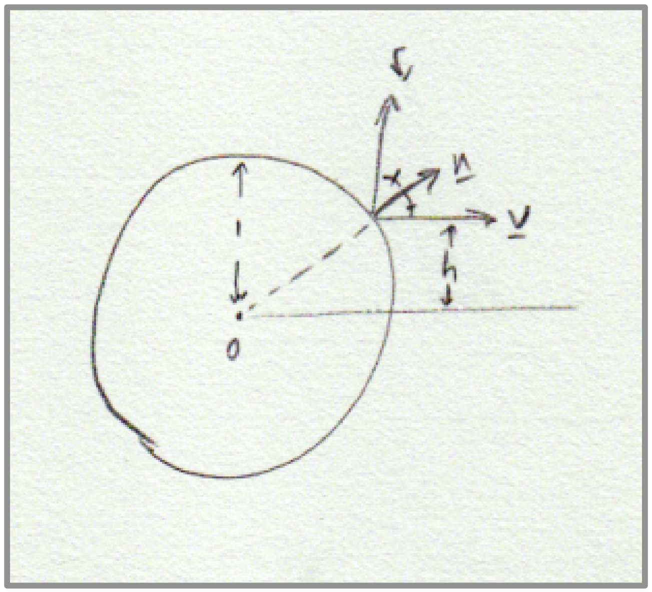


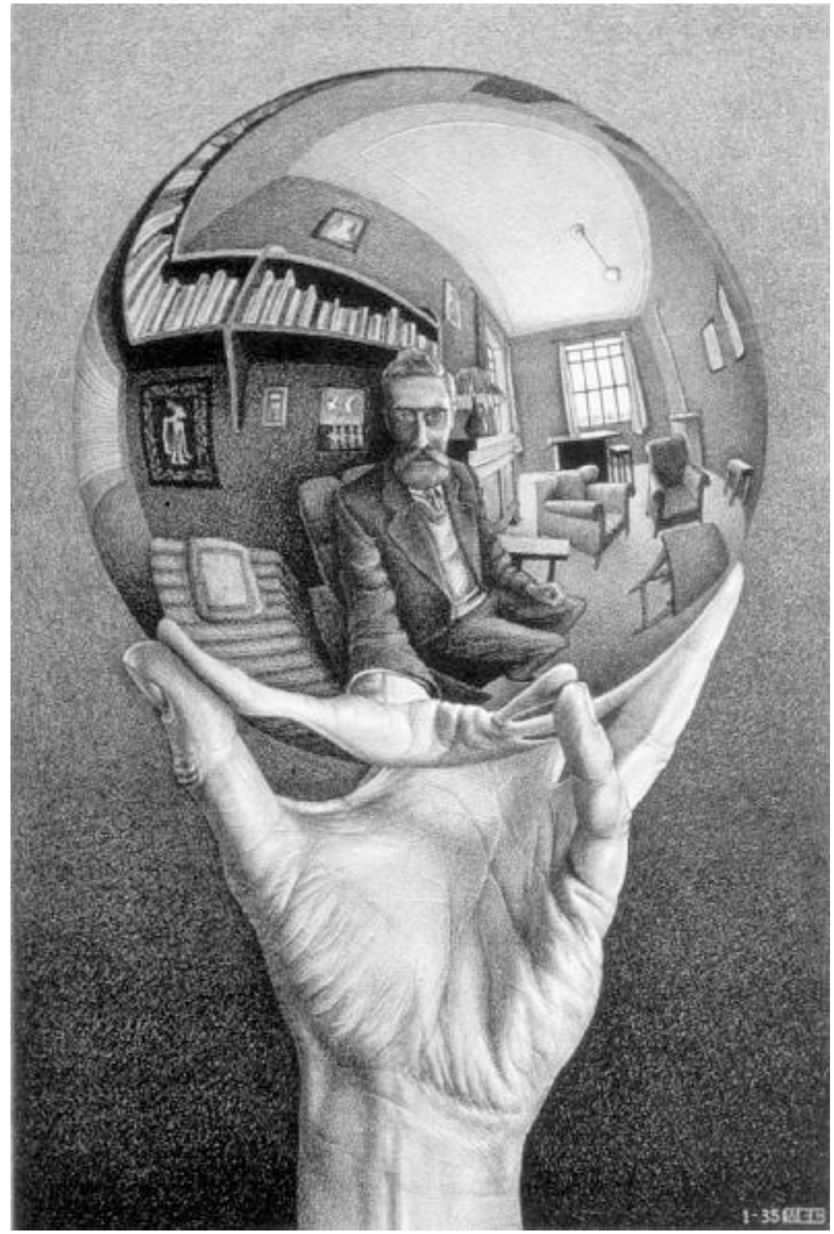
Environment map

- A function from the sphere to colors, stored as a texture.

[Blinn & Newell 1976]

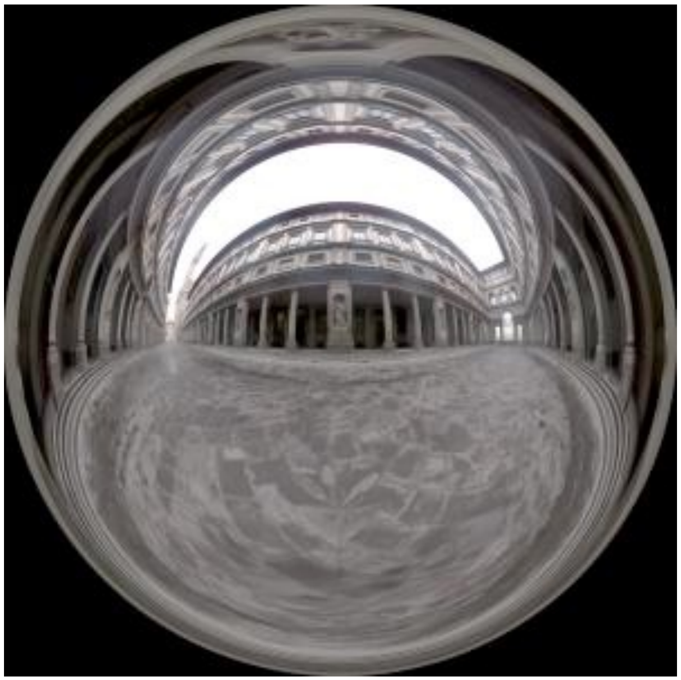
Spherical environment map

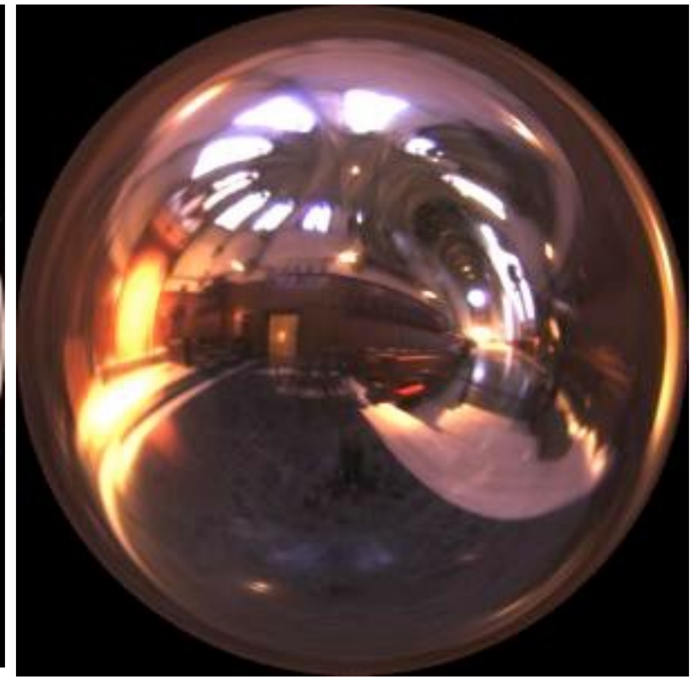




Hand with Reflecting Sphere. M. C. Escher, 1935. lithograph

Environment Maps

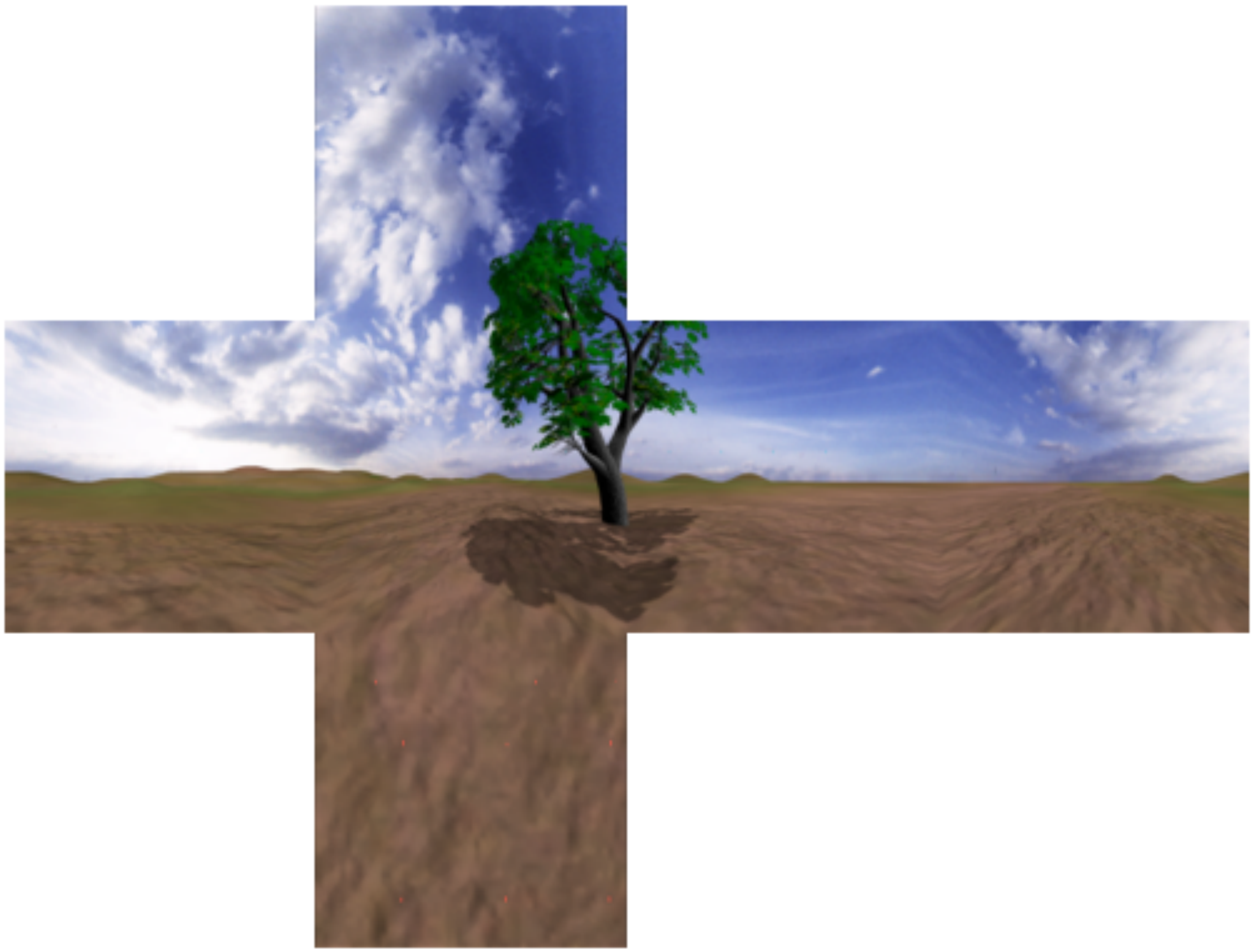




[Paul Debevec]

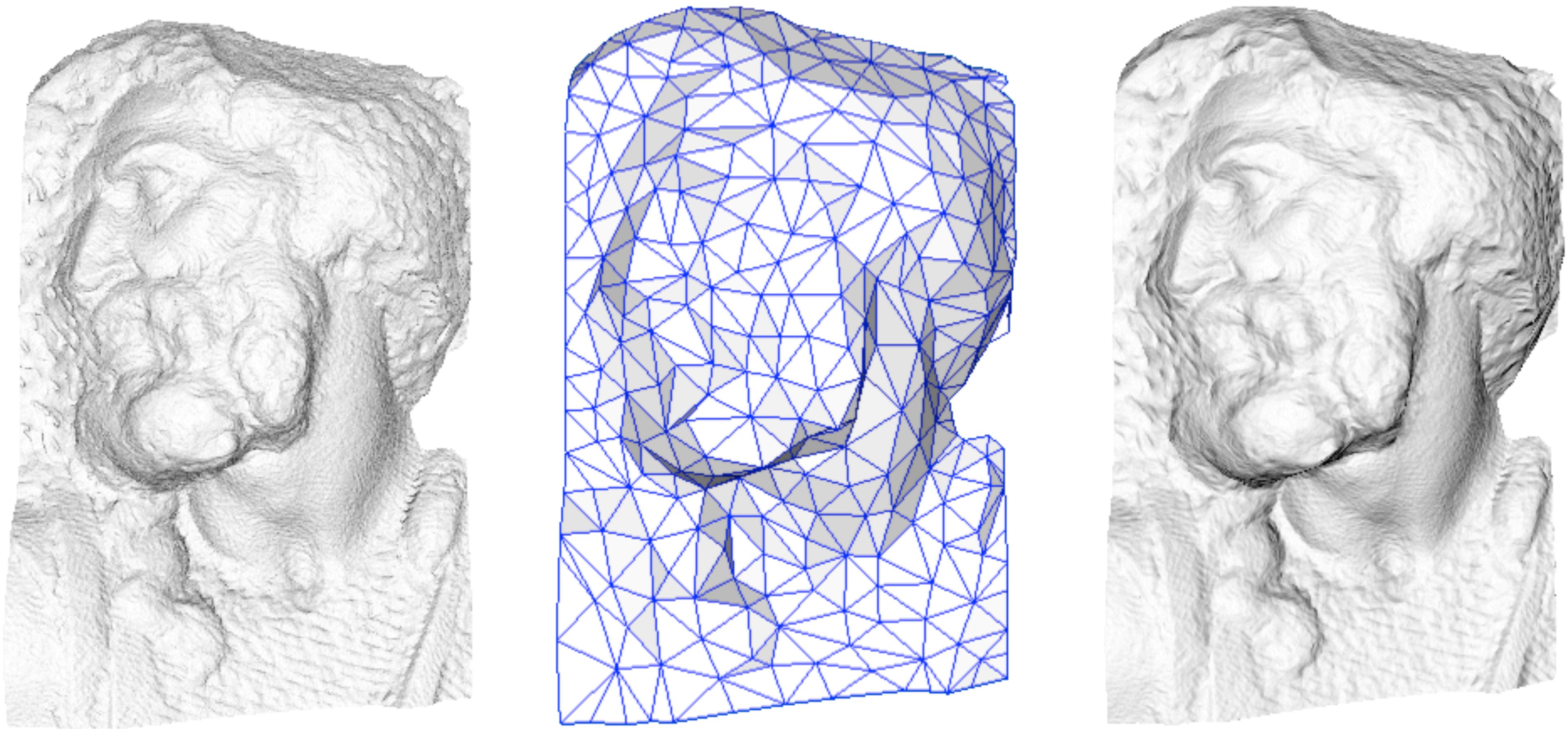
[CS467 slides]

Cube environment map



[Ned Greene]

Normal mapping

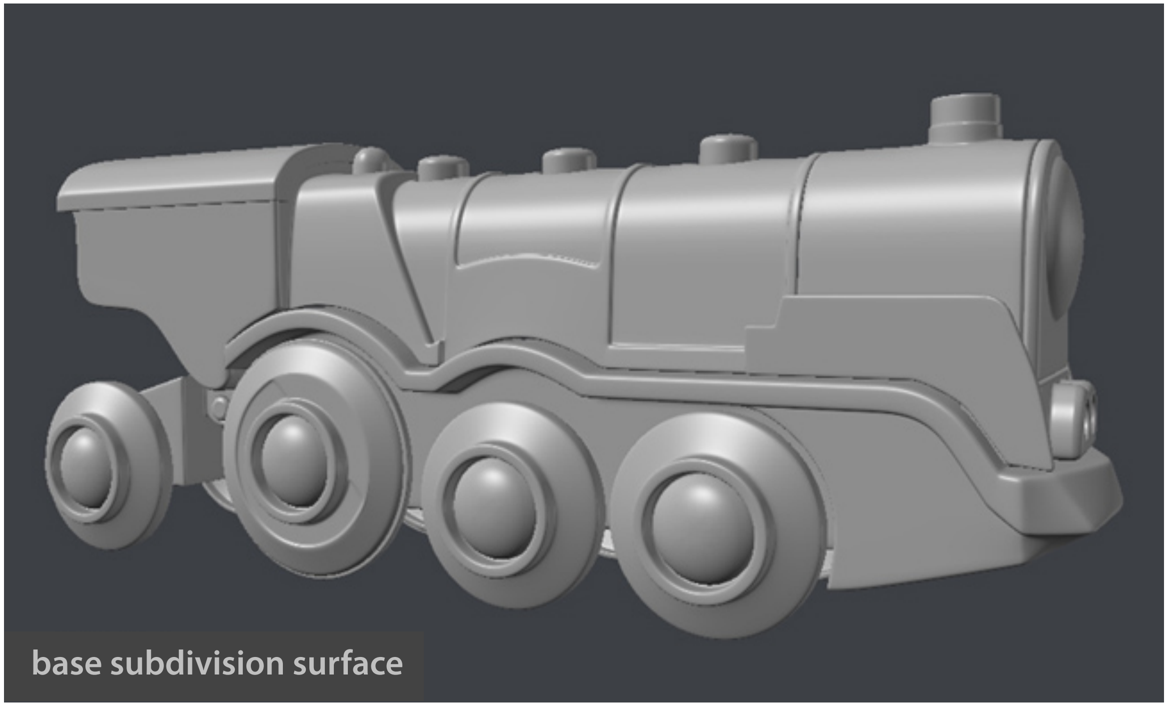


original mesh
4M triangles

simplified mesh
500 triangles

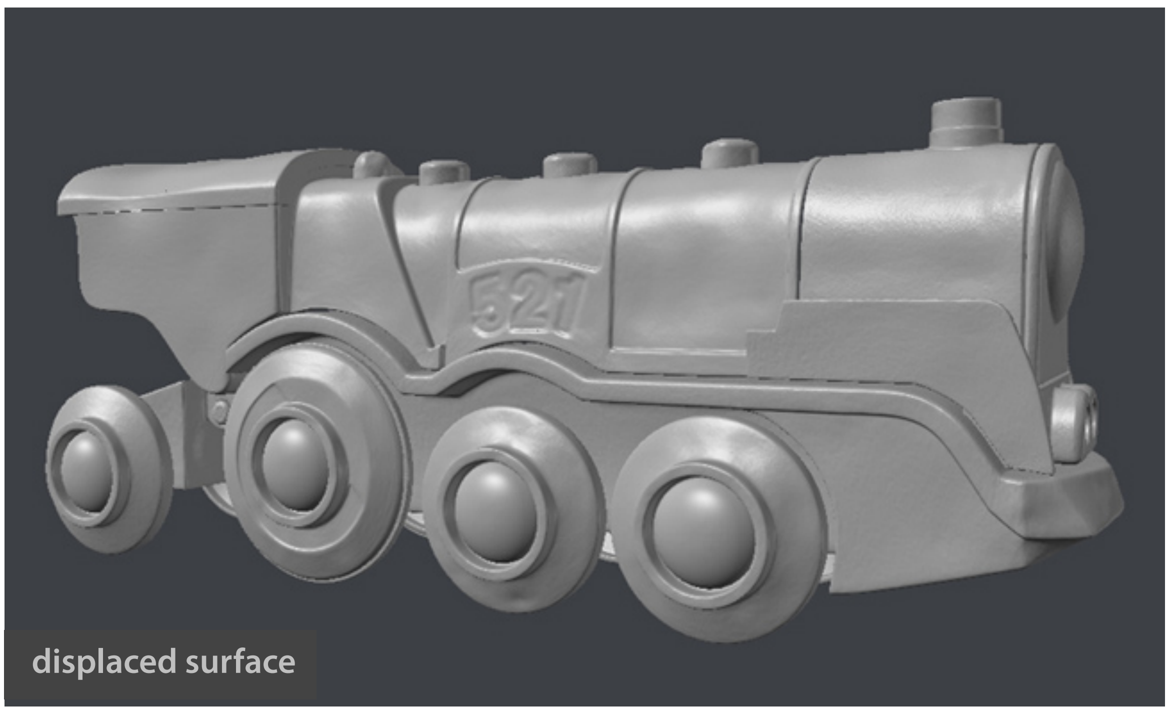
simplified mesh
and normal mapping
500 triangles

[Paolo Cignoni]



base subdivision surface

hand-painted displacement map (detail)



displaced surface

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521
fryrender
physically-based render engine
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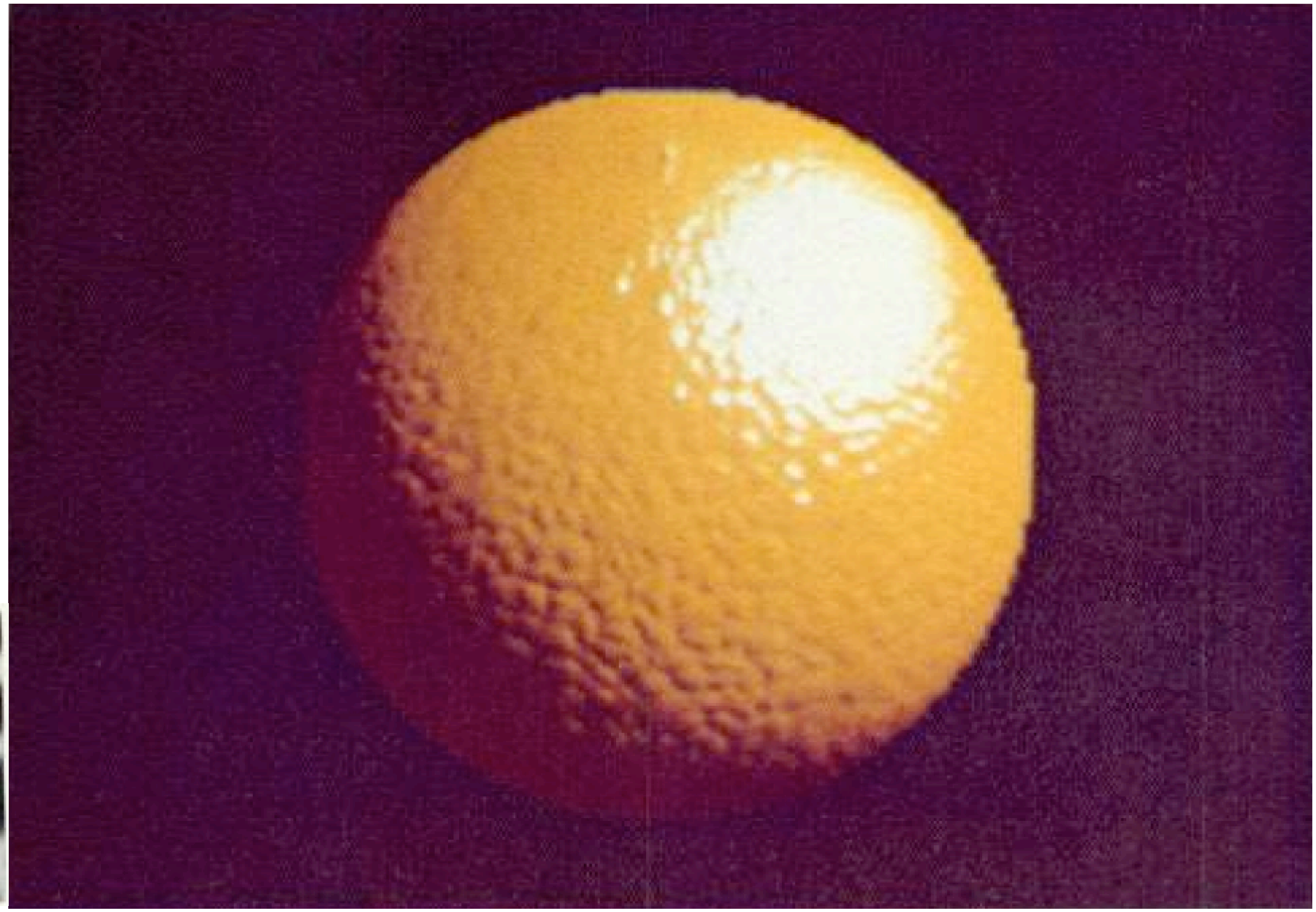
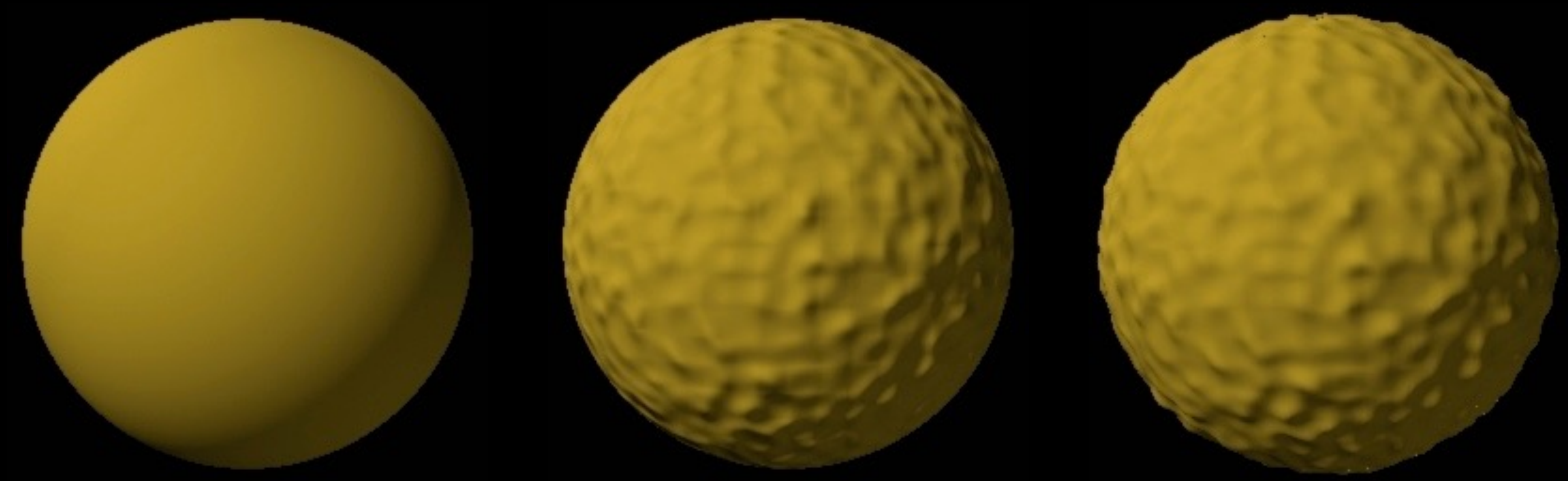
Bump mapping



[Blinn 1978]

Displacement mapping



Geometry

Bump mapping

Displacement mapping

[CS467 slides]

Another definition

Texture mapping: a general technique for storing and evaluating functions.

- They're not just for shading parameters any more!