Textures and normals in ray tracing

CS 4620 Lecture 6

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**

Texture mapping

- **Surface properties are not the same everywhere**
  - diffuse color (k_d) varies due to changing pigmentation
  - brightness (k_s) and sharpenss (p) of specular highlight varies due to changing roughness and surface contamination
- **Want functions that assign properties to points on the surface**
  - the surface is a 2D domain
  - given a surface parameterization, just need function on plane
  - images are a handy way to represent such functions
  - can represent using any image representation
  - raster texture images are very popular

A first definition

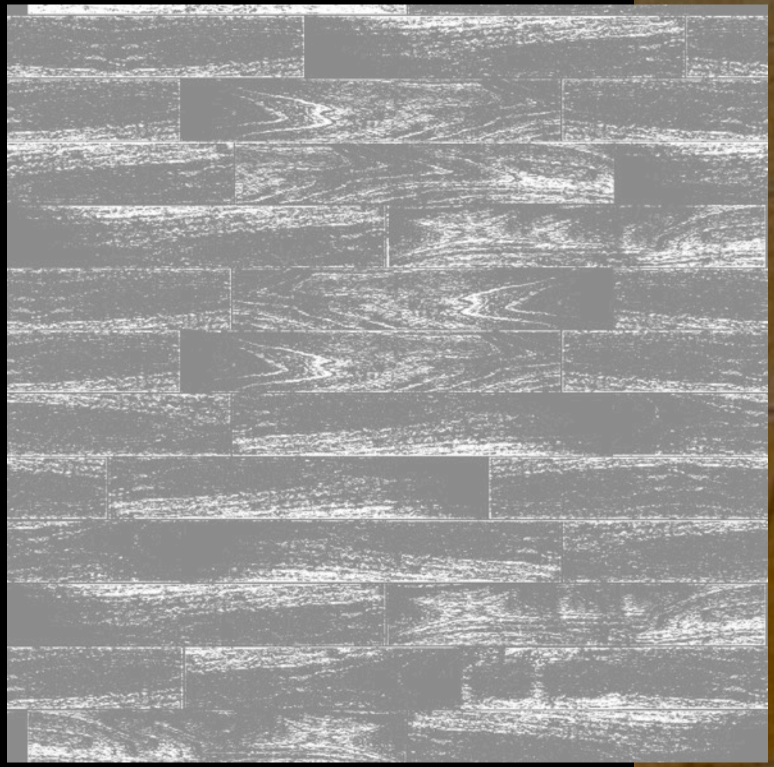
Texture mapping: a technique of defining surface properties (especially shading parameters) in such a way that they vary as a function of position on the surface.

- **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







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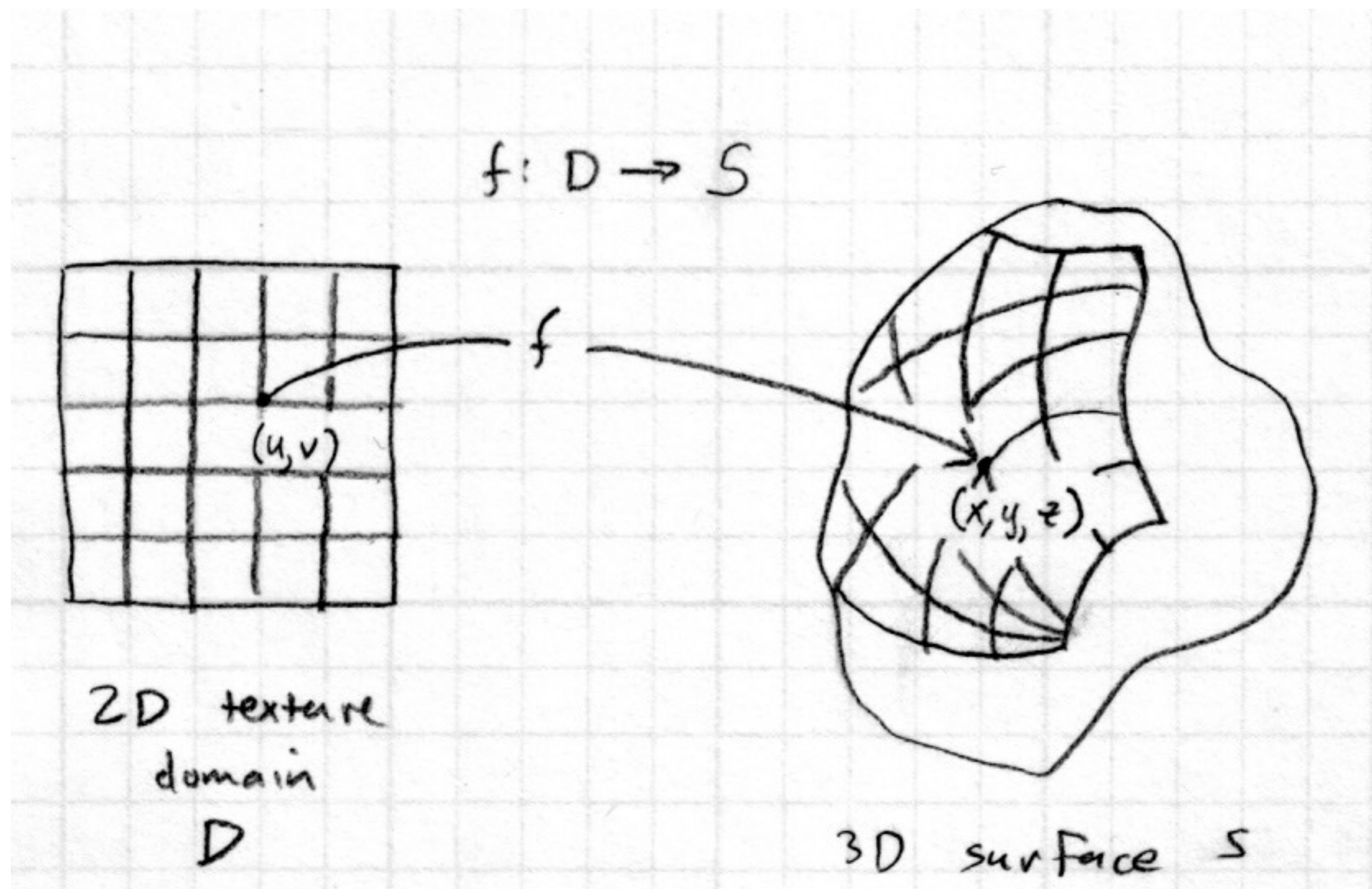
Mapping textures to surfaces

- **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

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 (e.g. sphere, cylinder) you get ***f*** for free

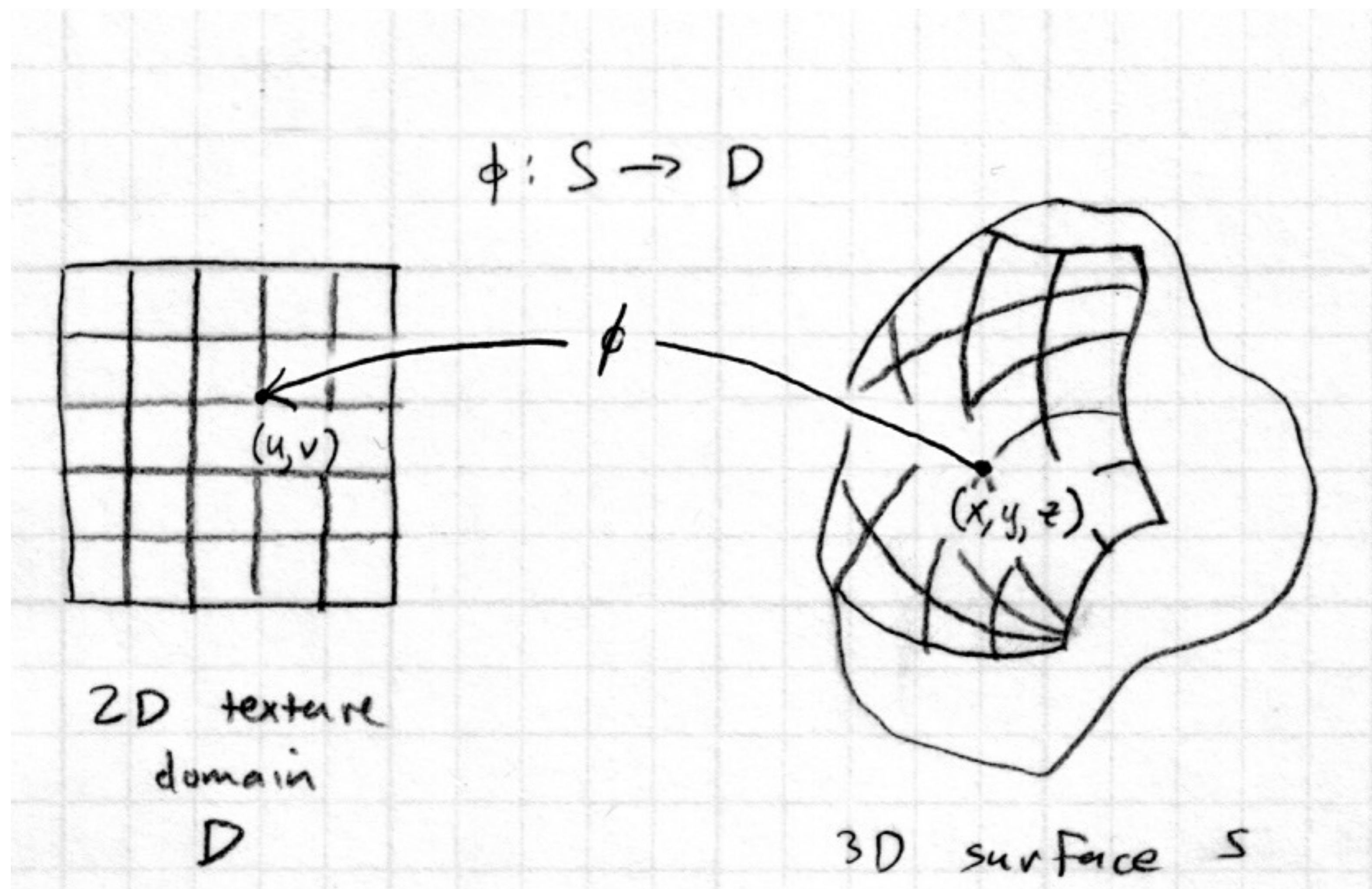


Texture coordinate functions

- **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.**

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

  - when shading **p** get texture at $\phi(\mathbf{p})$



Three spaces

- **Surface lives in 3D world space**
- **Every point also has a place where it goes in the image and in the texture.**

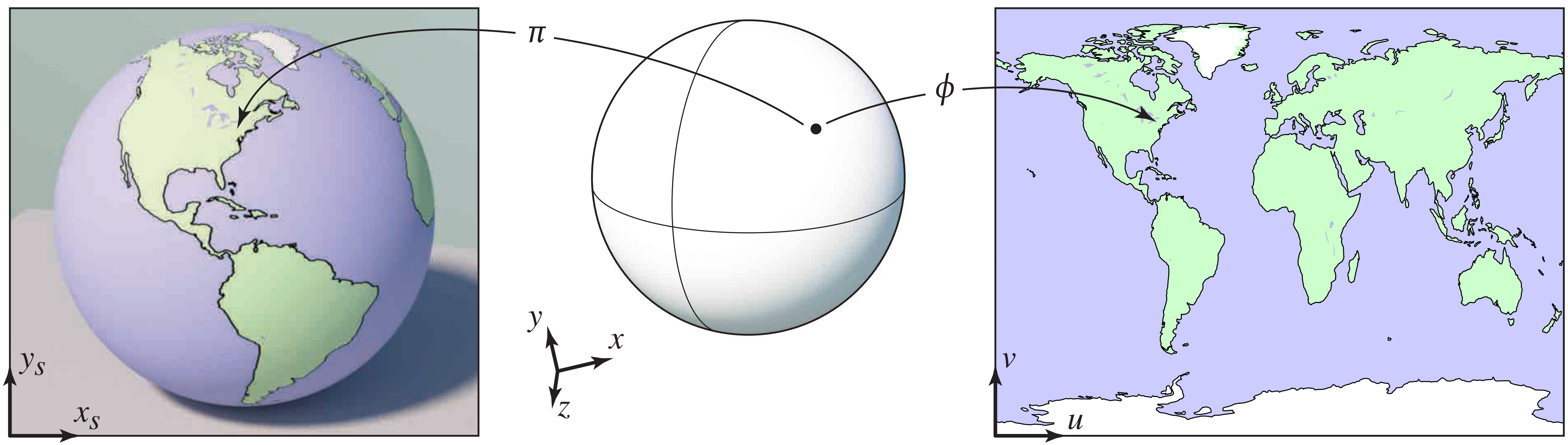


image space

world space

texture space

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**

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

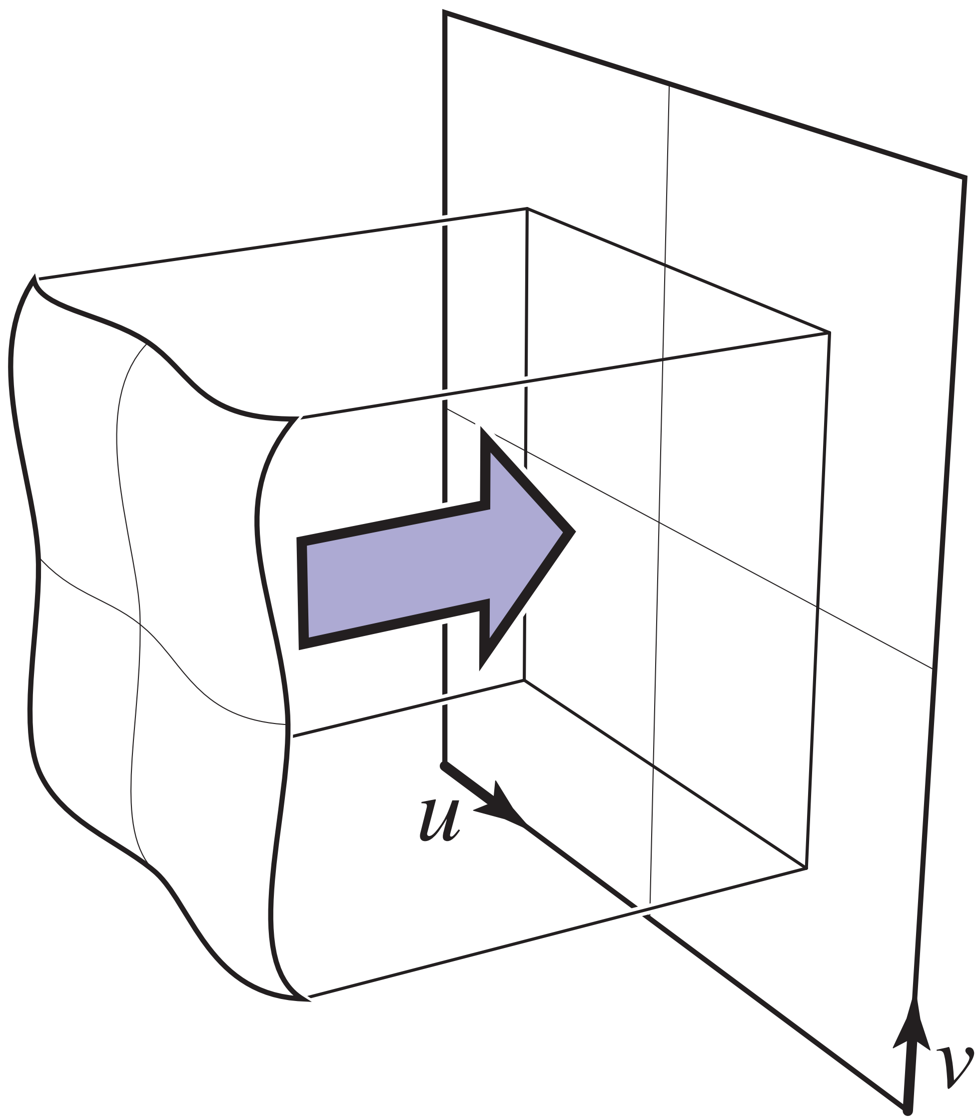
Coordinate functions: parametric

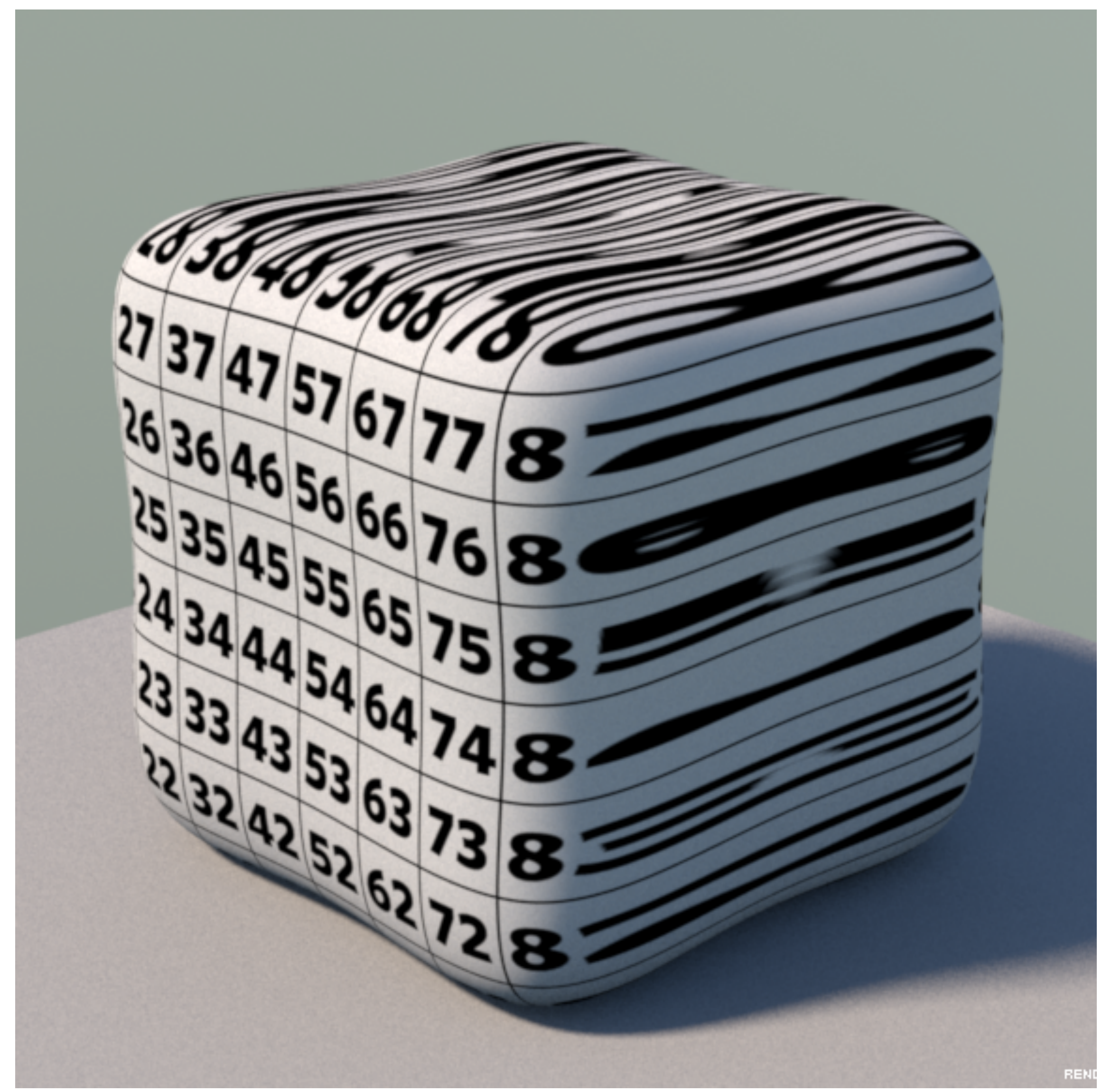
- **For parametric surfaces you already have coordinates**
- **Need to be able to invert the parameterization**
- **E.g. for a rectangle…**
- **E.g. for a sphere…**

Aside: parametric
vs. implicit
vs. piecewise
surface models

Examples of coordinate functions

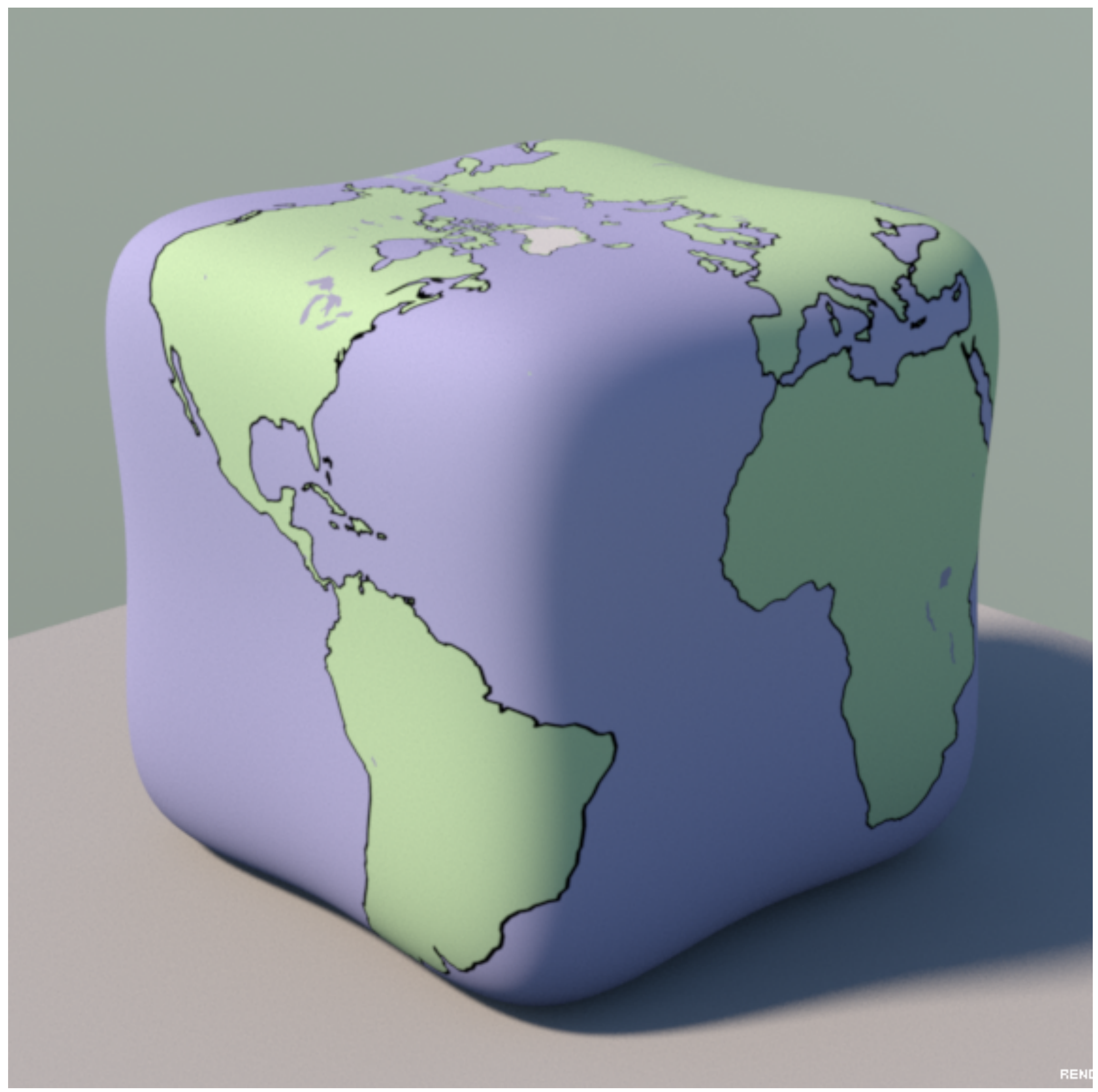
- **Planar projection**





Examples of coordinate functions

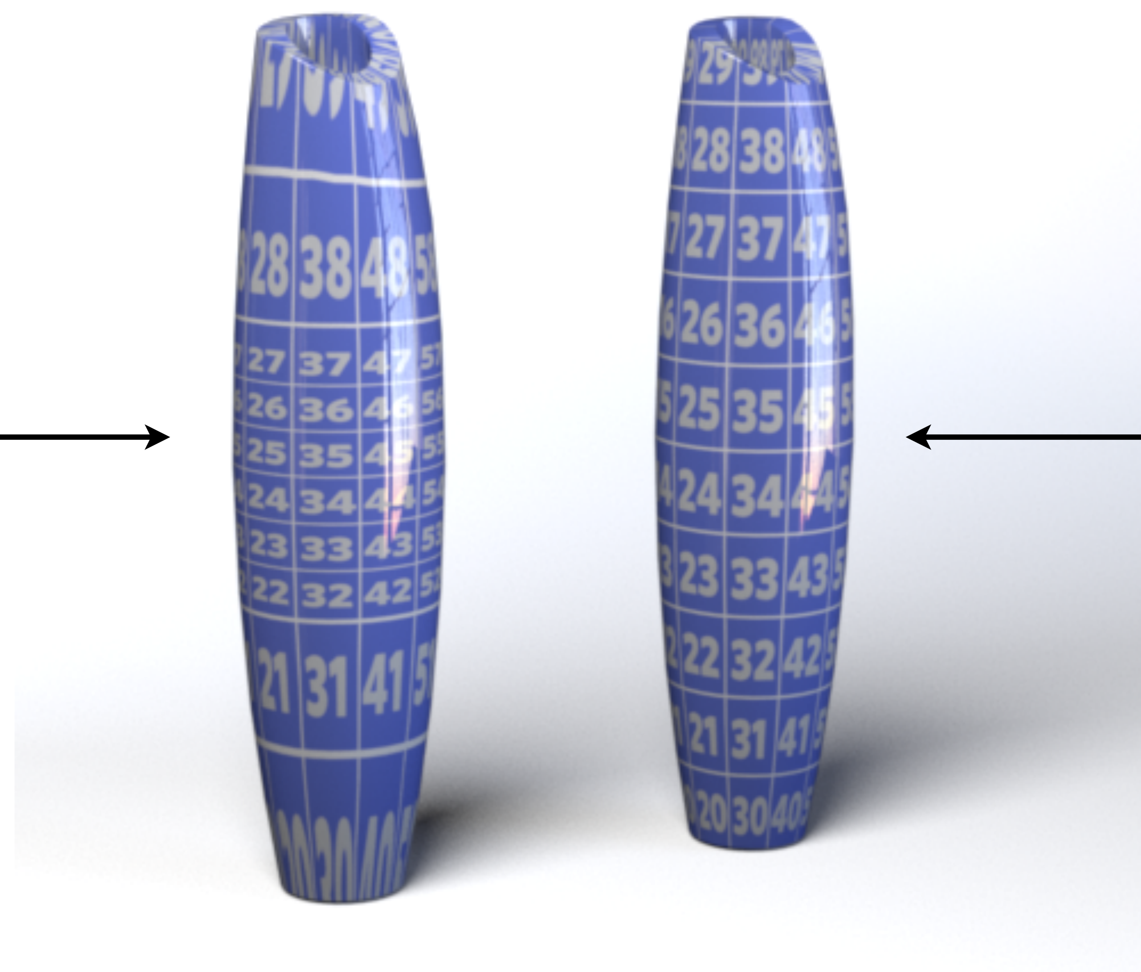
- **Spherical projection**



Examples of coordinate functions

- **Cylindrical projection**

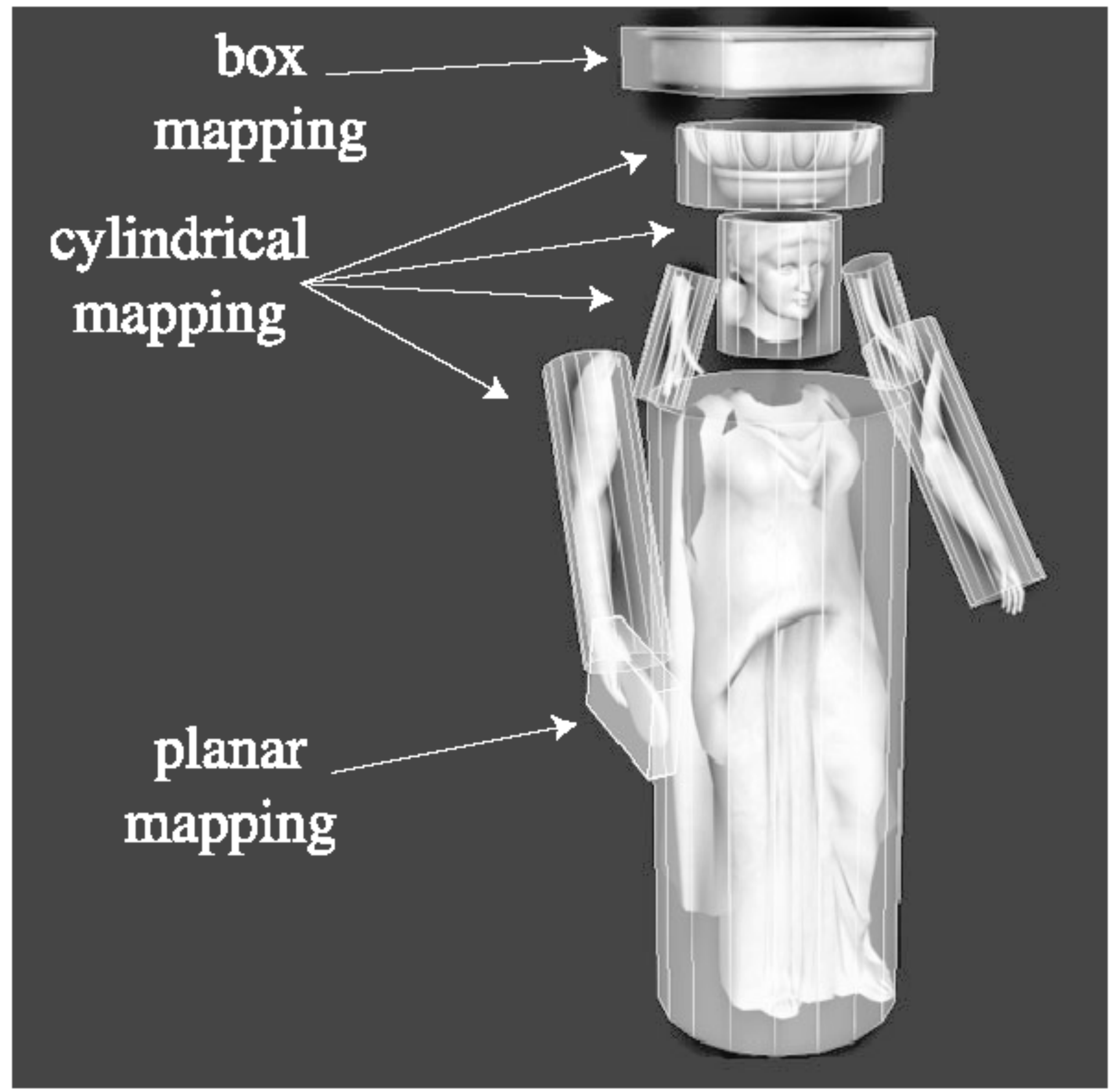
spherical →



← cylindrical

Examples of coordinate functions

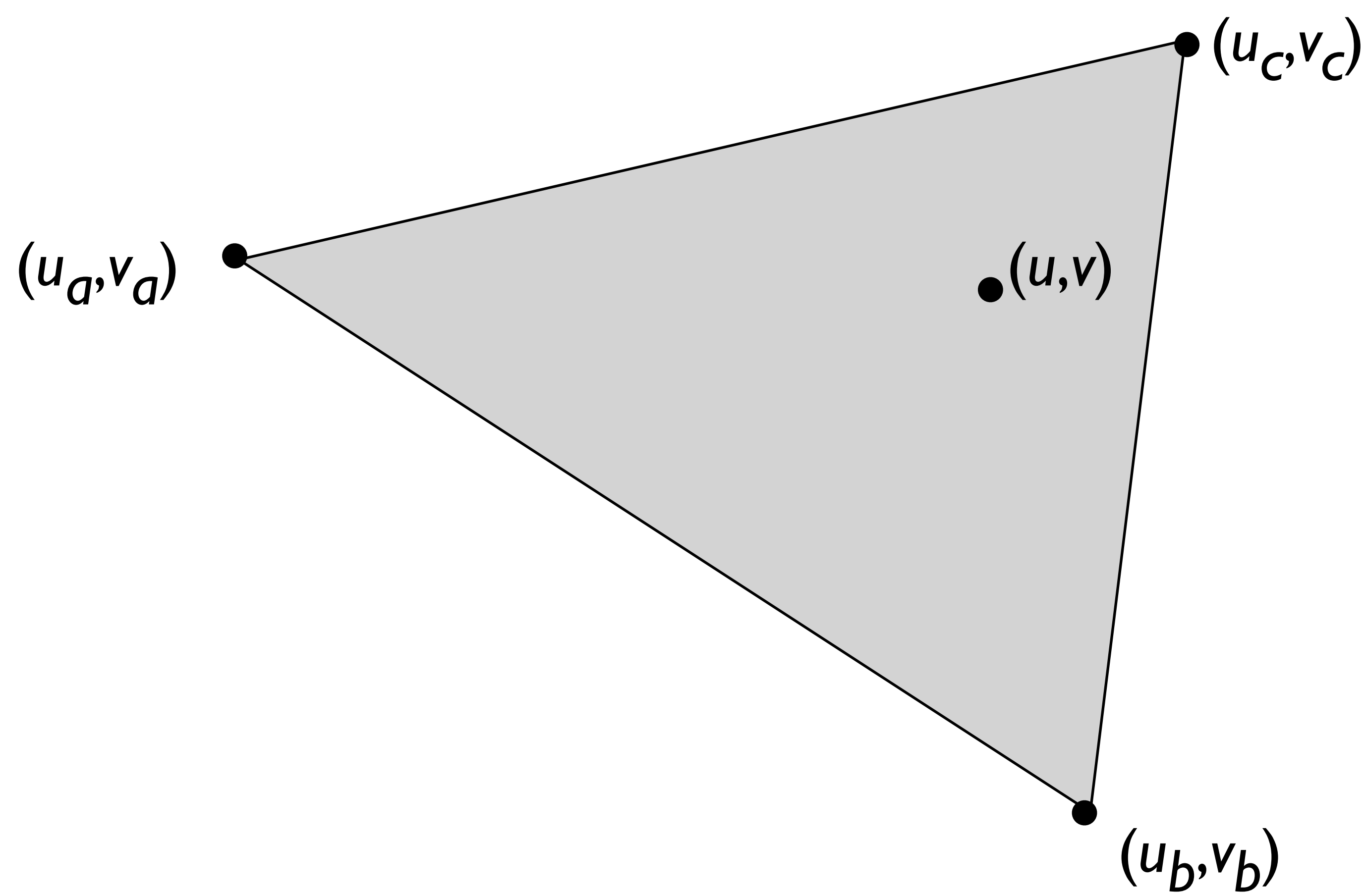
- **Complex surfaces: project parts to parametric surfaces**



[Tito Pagan]

Examples of coordinate functions

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

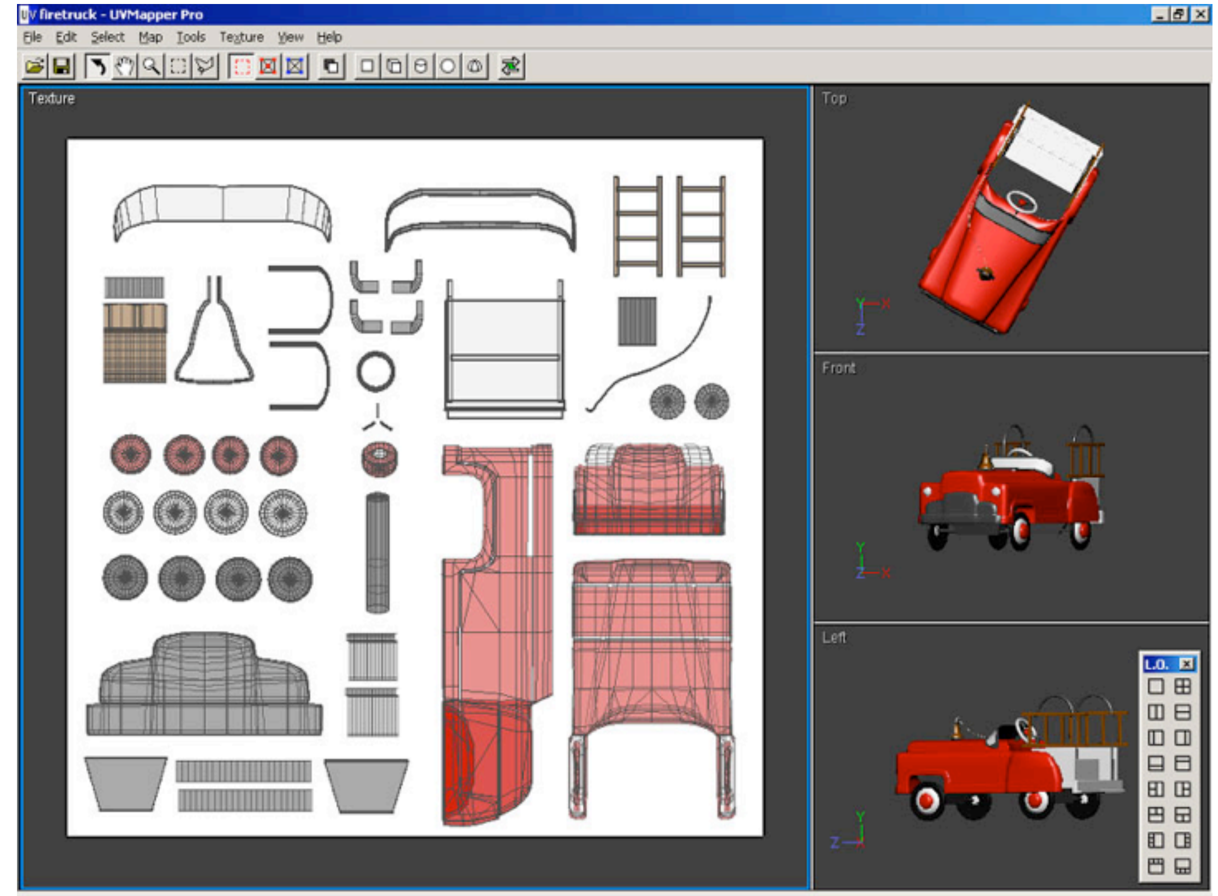


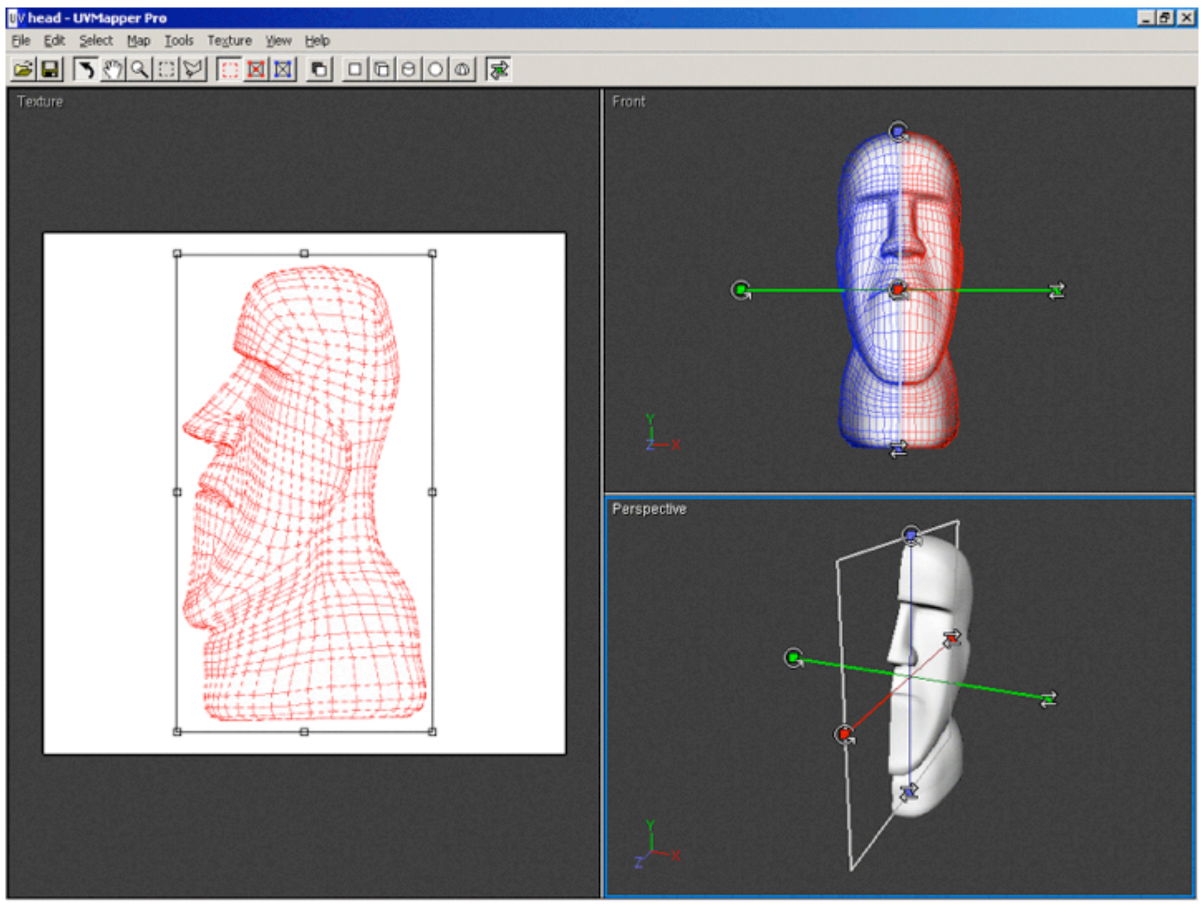
Texture coordinates on meshes

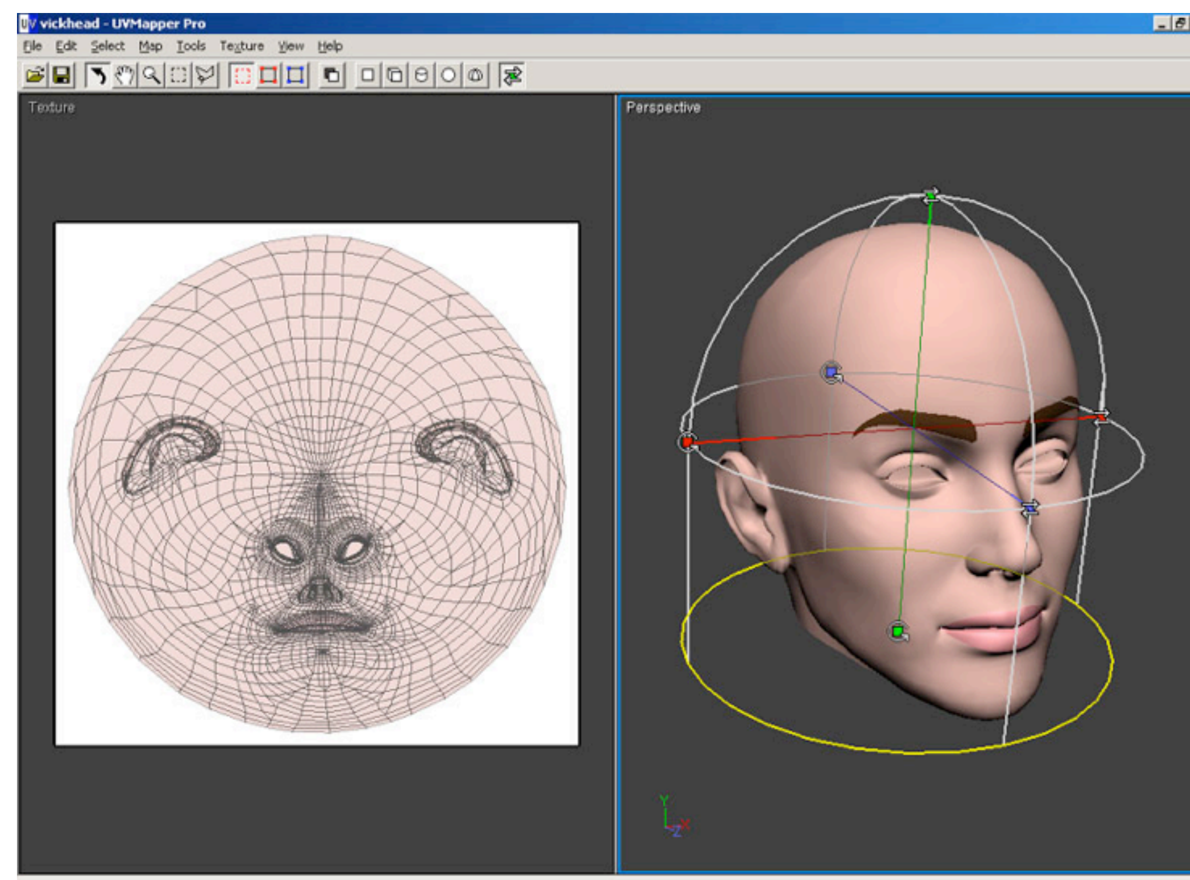
- **Texture coordinates become per-vertex data like vertex positions**
  – can think of them as a second position: each vertex has a position in 3D space and in 2D texure space
- **How to come up with vertex (*u*,*v*)s?**
  – use any or all of the methods just discussed
    – in practice this is how 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

Example: UVMapper

<u>http://www.uvmapper.com</u>

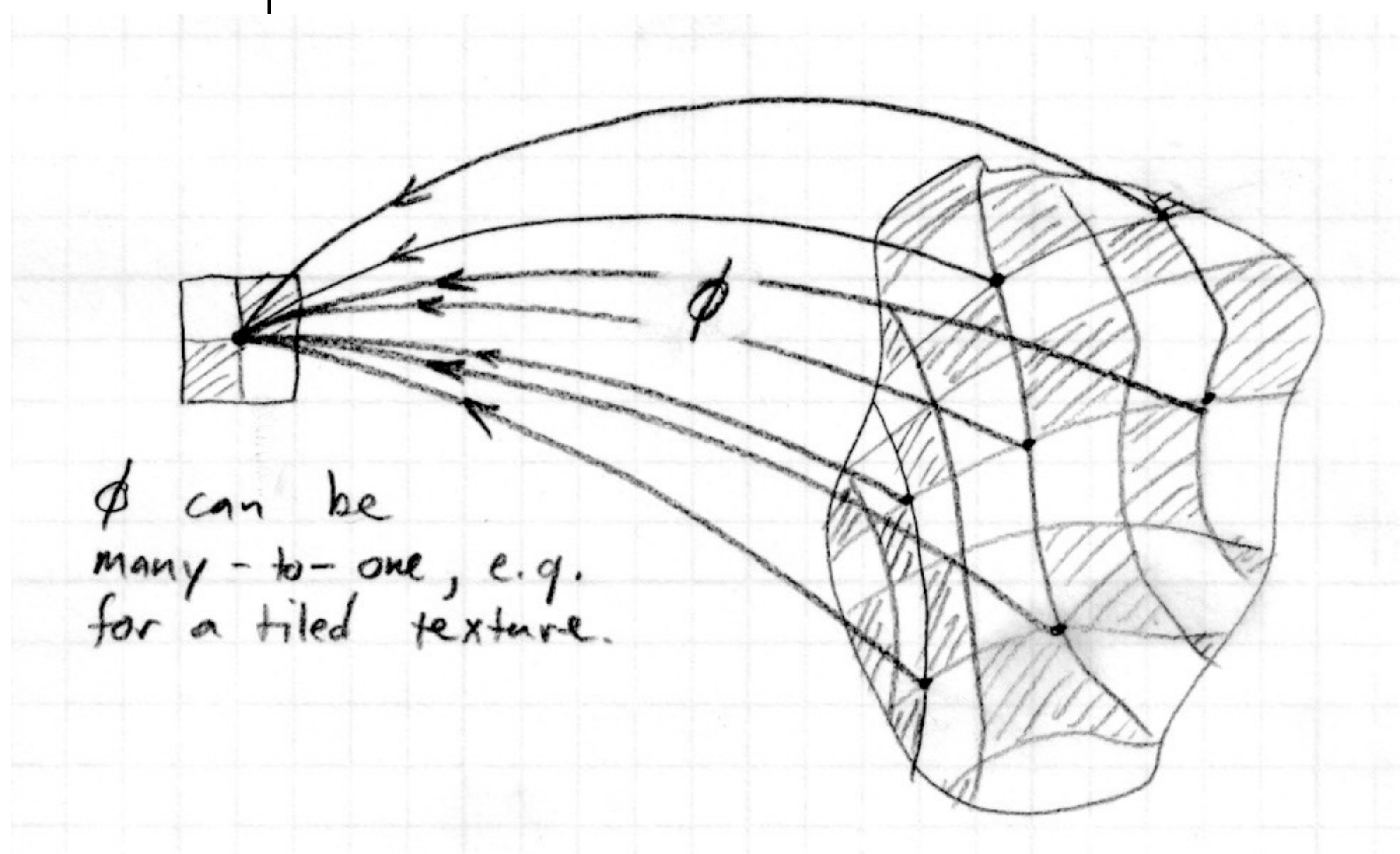






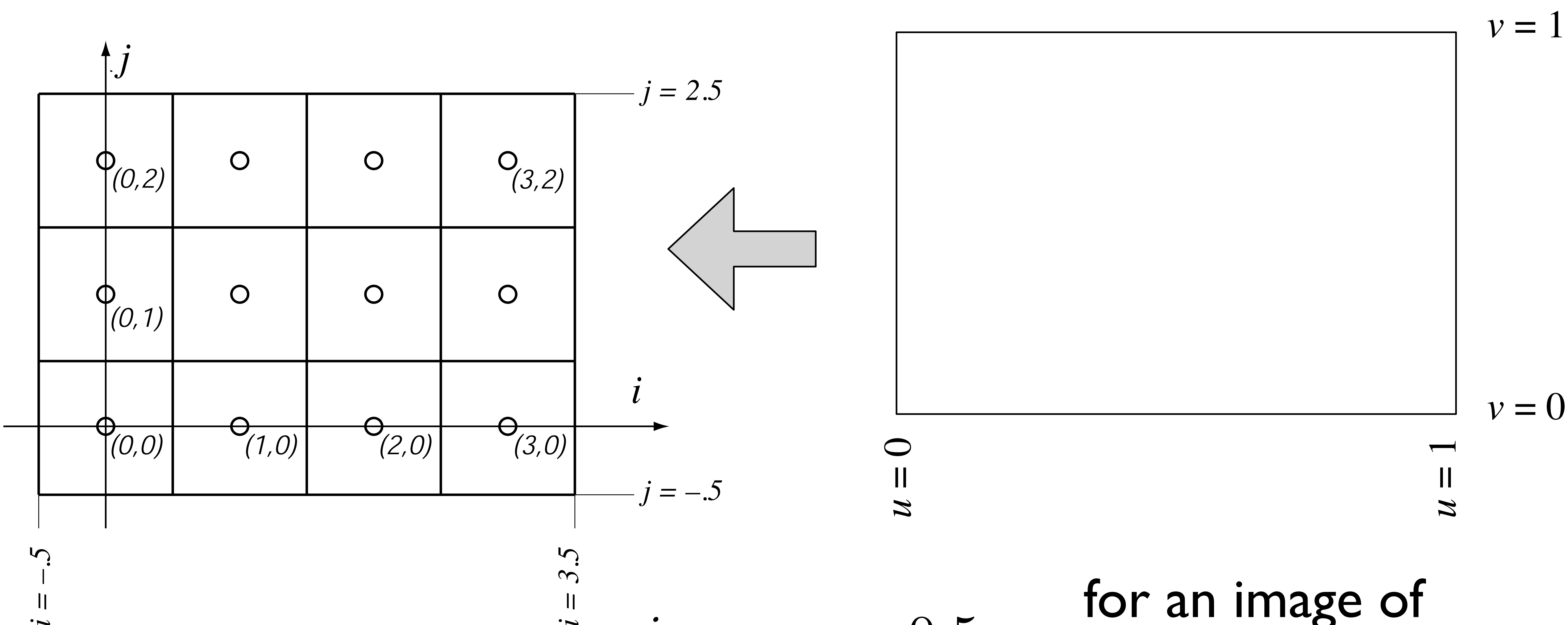
Texture coordinate functions

- **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



Pixels in texture images (texels)

- **Related to texture coordinates in the same way as normalized image coordinate to pixel coordinates**



$$i = u\, n_x - 0.5$$
$$j = v\, n_y - 0.5$$

for an image of n_x by n_y pixels

Texture lookups and wrapping

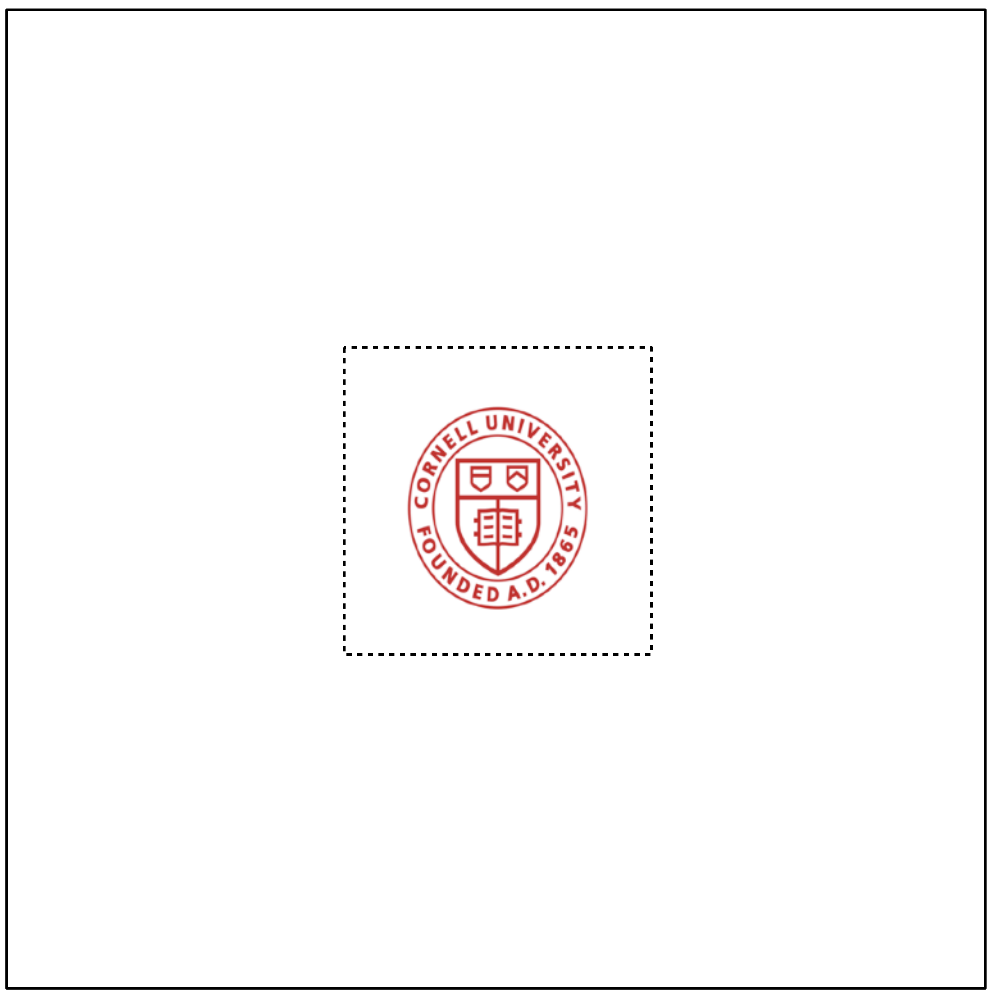
- **In shading calculation, when you need a texture value you perform a *texture lookup***
- **Convert (*u*, *v*) texture coordinates to (*i*, *j*) texel coordinates, and read a value from the image**
  - simplest: round to nearest (nearest neighbor lookup)
  - various ways to be smarter and get smoother results
- **What if *i* and *j* are out of range?**
  - option 1, clamp: take the nearest pixel that is in the image

$$i_{\text{pixel}} = \max(0, \min(n_x - 1, i_{\text{lookup}}))$$

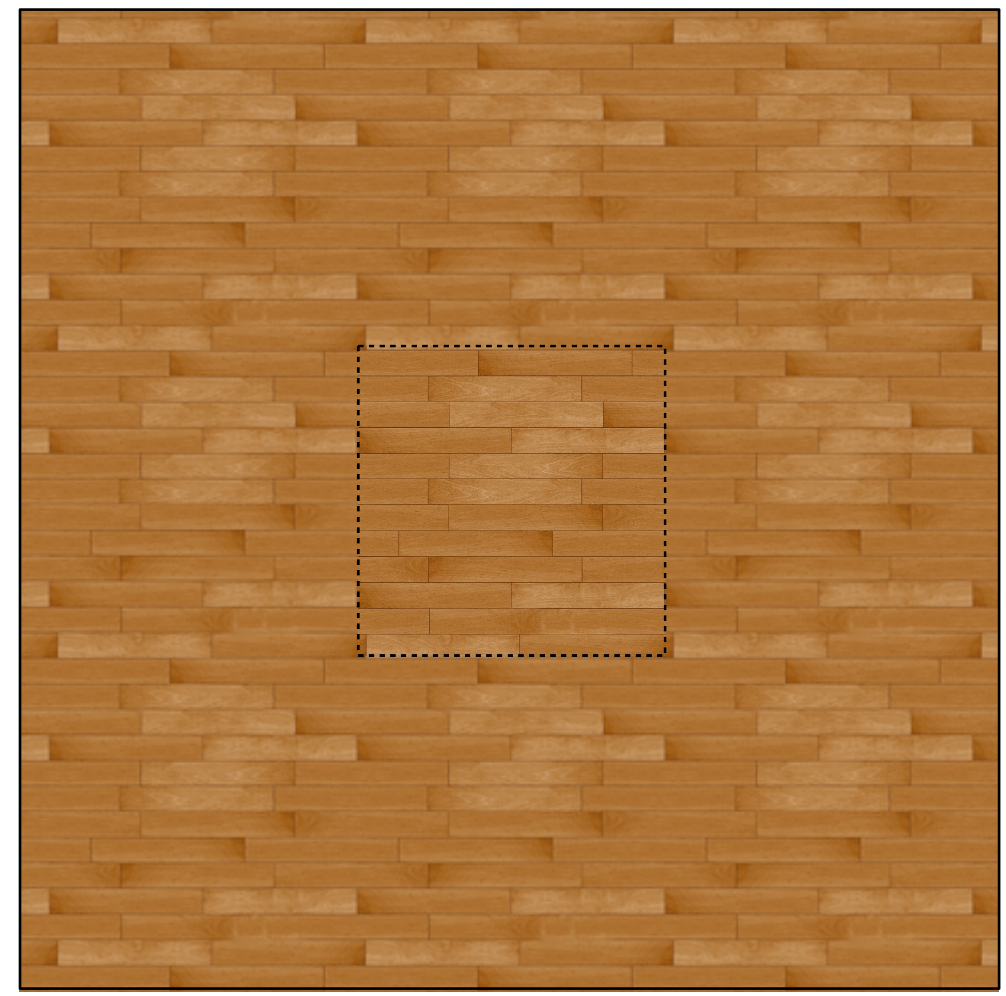
  - option 2, wrap: treat the texture as periodic, so that falling off the right side causes the look up to come in the left

$$i_{\text{pixel}} = \text{remainder}(i_{\text{lookup}}, n_x)$$

Wrapping modes



clamp



wrap

