CS559: Computer Graphics

Lecture 20: Project 2 Review and Texture mapping

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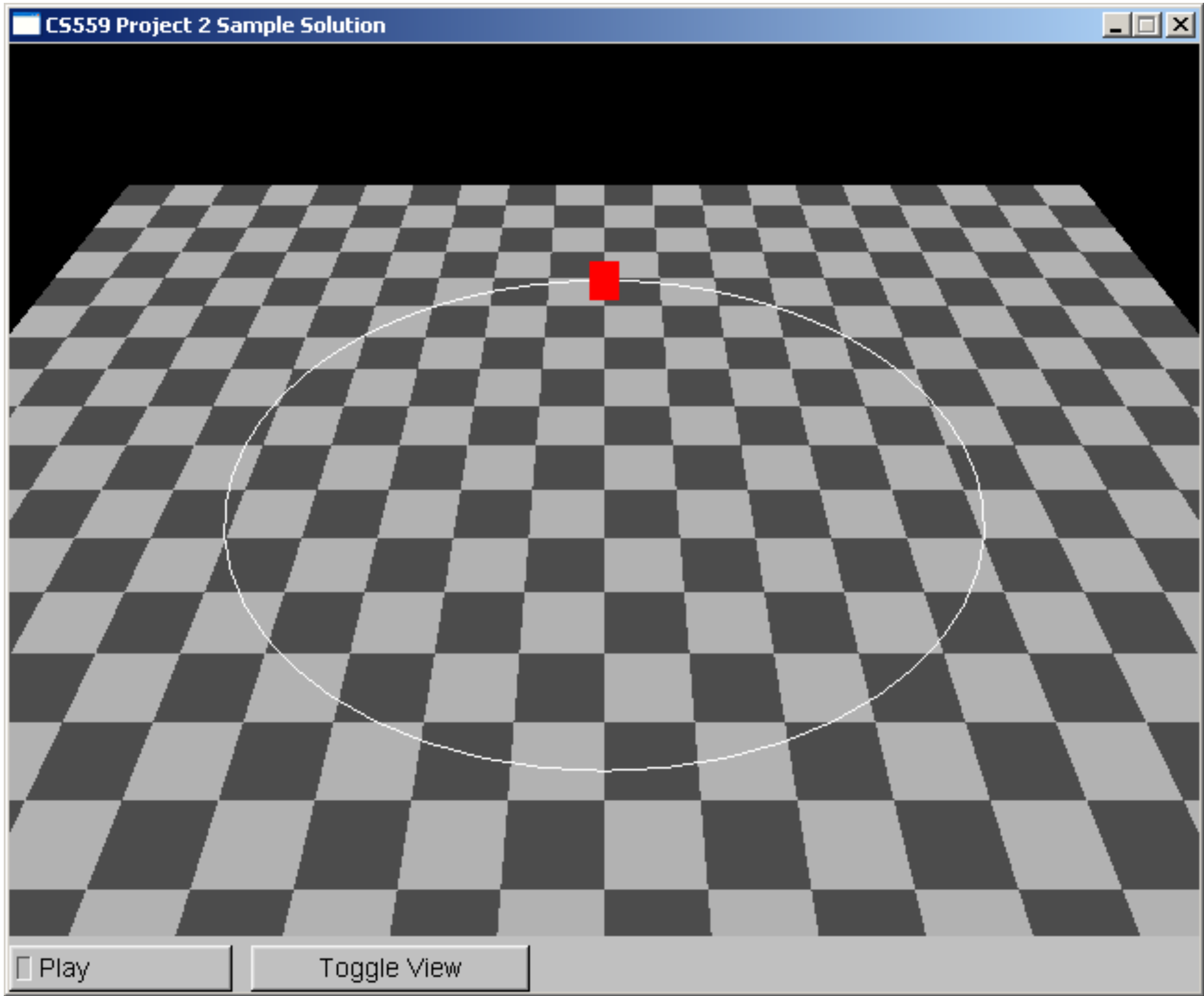
Many slides from Ravi Ramamoorthi, Columbia Univ, Greg Humphreys, UVA and Rosalee Wolfe, DePaul tutorial teaching texture mapping visually

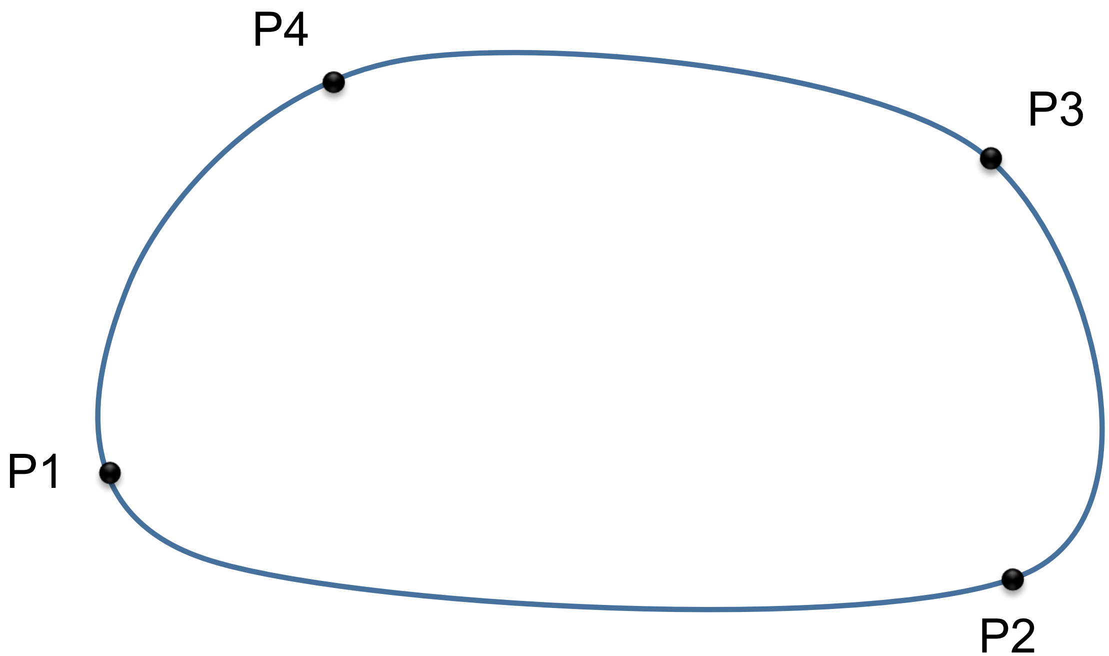
Sample Code by Chi Man Liu



Other basic features

- How to change speed?
  - Add a slider with a callback to change timePerFrame
- How to orient a car?
- How to draw trees?
  - A triangle + a rectangle
  - A cone + a cylinder
    - Using gluQuadrics

Piecewise Cubics



Piecewise Cubics

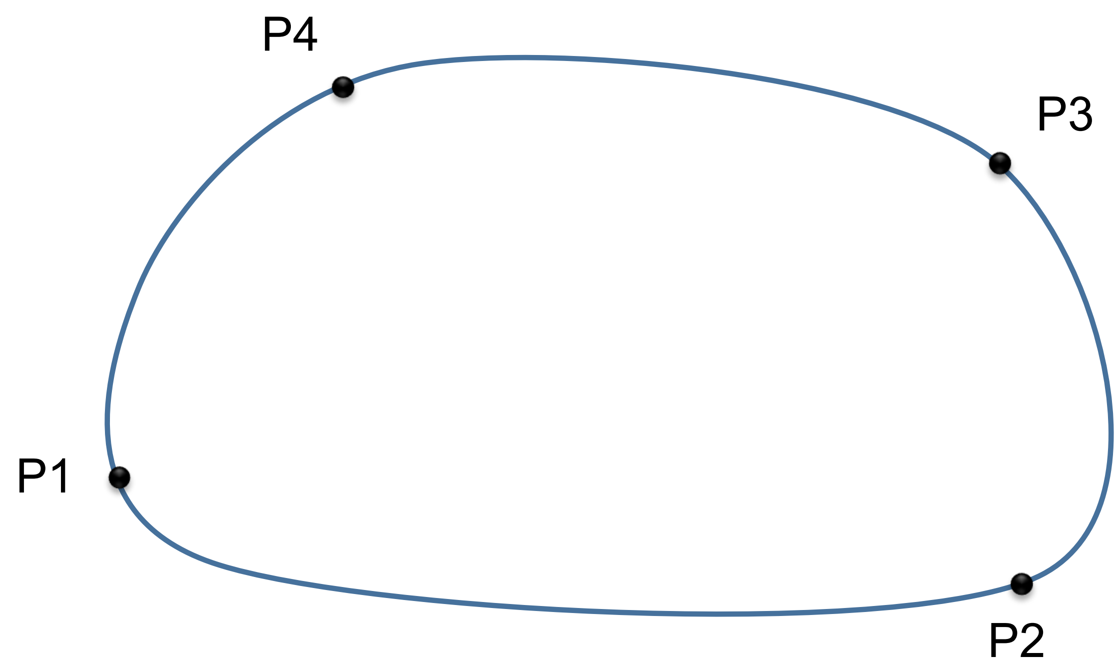
```
Task1: draw the whole curve
DrawCubic(P4,P1,P2,P3);
DrawCubic(P1,P2,P3,P4);
DrawCubic(P2,P3,P4,P1);
DrawCubic(P3,P4,P1,P2);

DrawCubic(Q1,Q2,Q3,Q4)
For (t=0; t < 0.1; t+=0.01)
{
A=computePoint(Q1,Q2,Q3,Q4,t);
B=computePoint(Q1,Q2,Q3,Q4,t+0.01);
drawLine(A,B);
}
```

Fine with Hermite, Catmull-Ron, Cardinal
How about Bezier?

```
Task 2: find where the train is at time t:
If (0<=t<1) return computePoint(P4,P1,P2,P3,t)
If (1<=t<2) return computePoint(P1,P2,P3,P4,t-1);
If (2<=t<3) return computePoint(P2,P3,P4,P1,t-2);
If (3<=t<4) return computePoint(P3,P4,P1,P2,t-3);
```

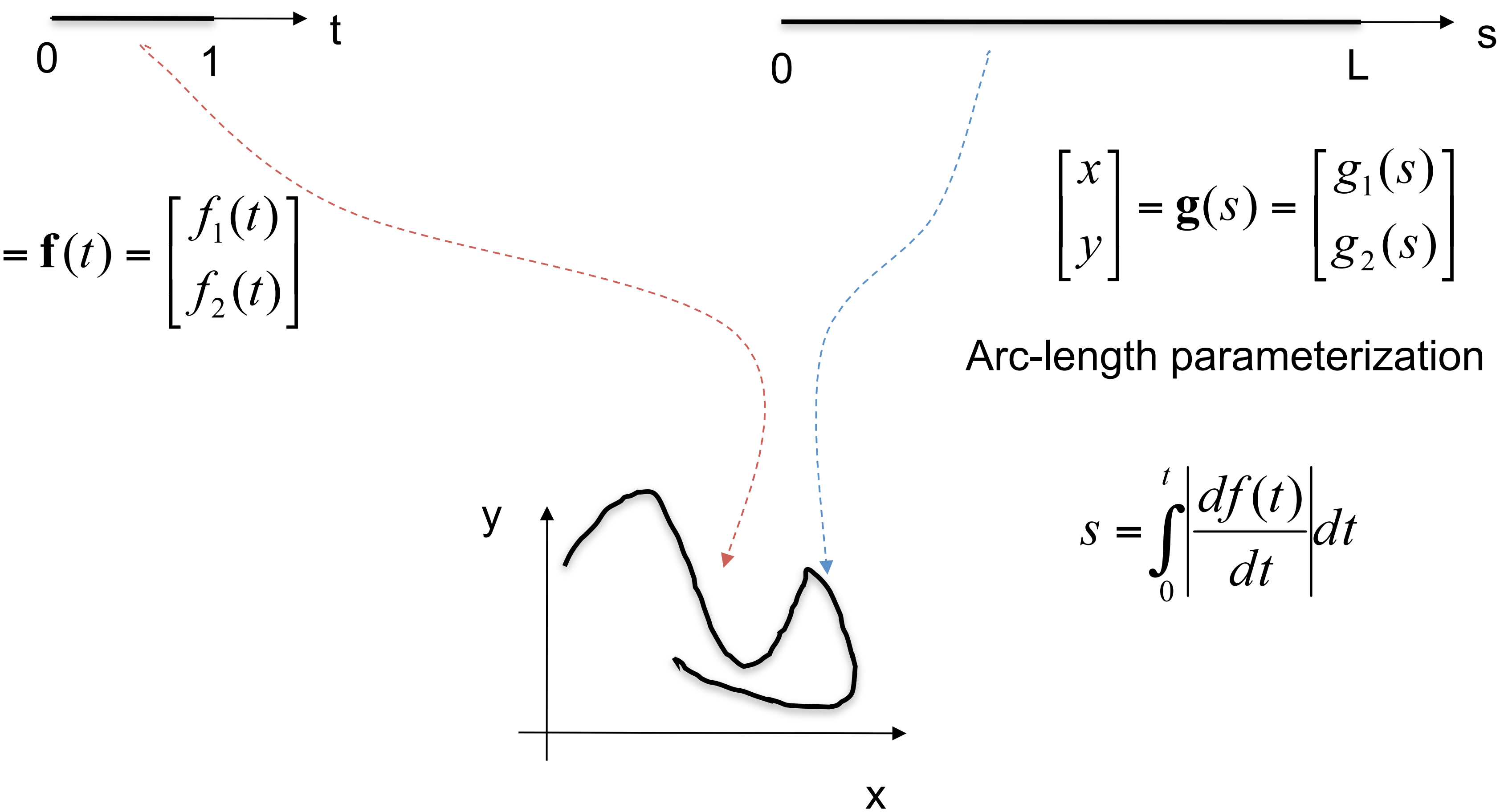
Arc-Length Parameterization

- Arbitrary curves?



$$s = \int_0^t \left| \frac{d\mathbf{f}(u)}{du} \right| du$$

Arc-length parameterization



$$\begin{bmatrix} x \\ y \end{bmatrix} = \mathbf{f}(t) = \begin{bmatrix} f_1(t) \\ f_2(t) \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \end{bmatrix} = \mathbf{g}(s) = \begin{bmatrix} g_1(s) \\ g_2(s) \end{bmatrix}$$

Arc-length parameterization

$$s = \int_0^t \left| \frac{df(t)}{dt} \right| dt$$

Freeform

Correct Orientation in 3D

- Define and interpolate up vector

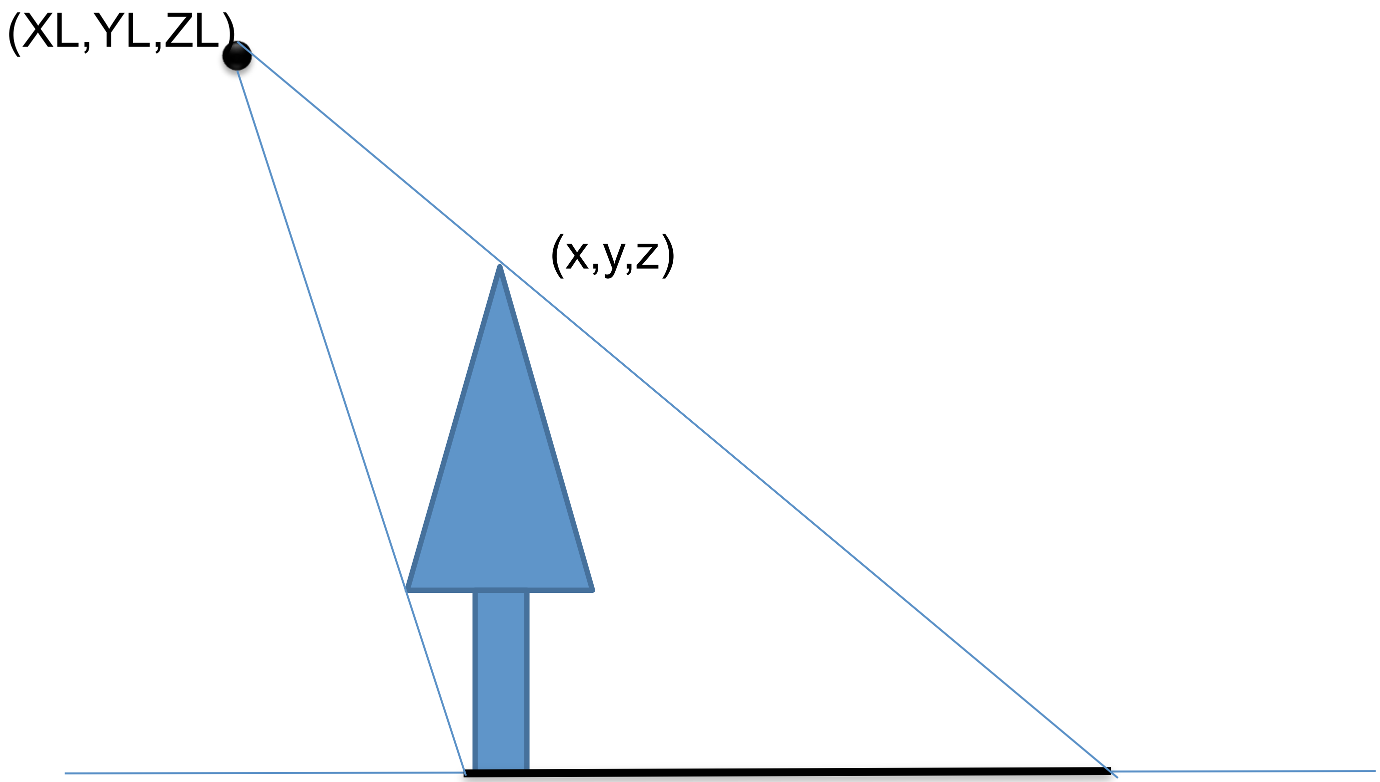
Implement simple physics

- Energy conservation

Multiple Cars

- Each has its own parameter t, assuming arc-length parameterization

Hack Shadow



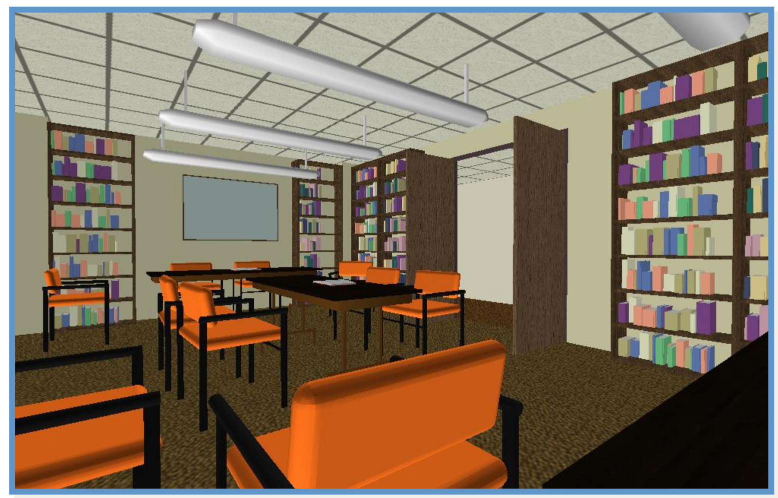
Train smoke?

- Balls moving upward and dissipating

Texture Mapping

- Important topic: nearly all objects textured
  - Wood grain, faces, bricks and so on
  - Adds visual detail to scenes

Polygonal model

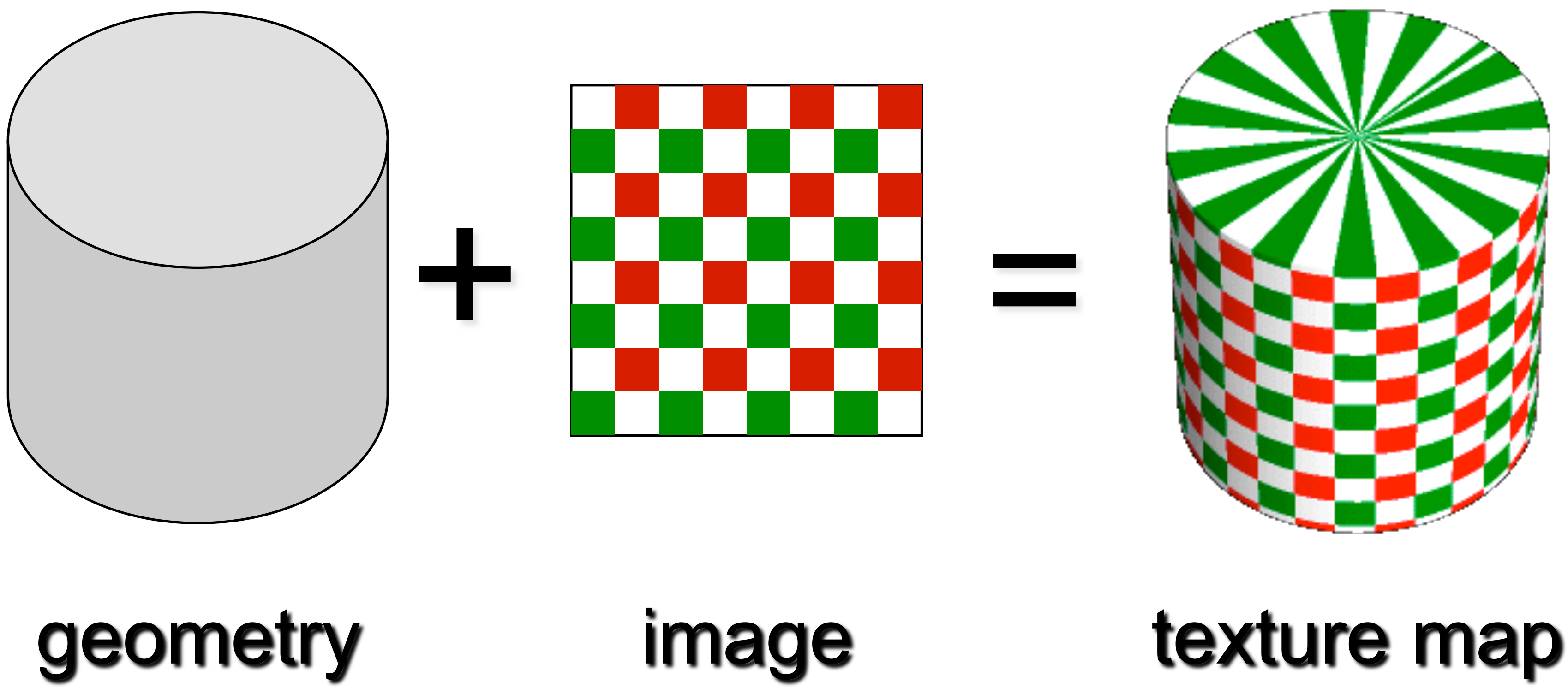


With surface texture

Adding Visual Detail

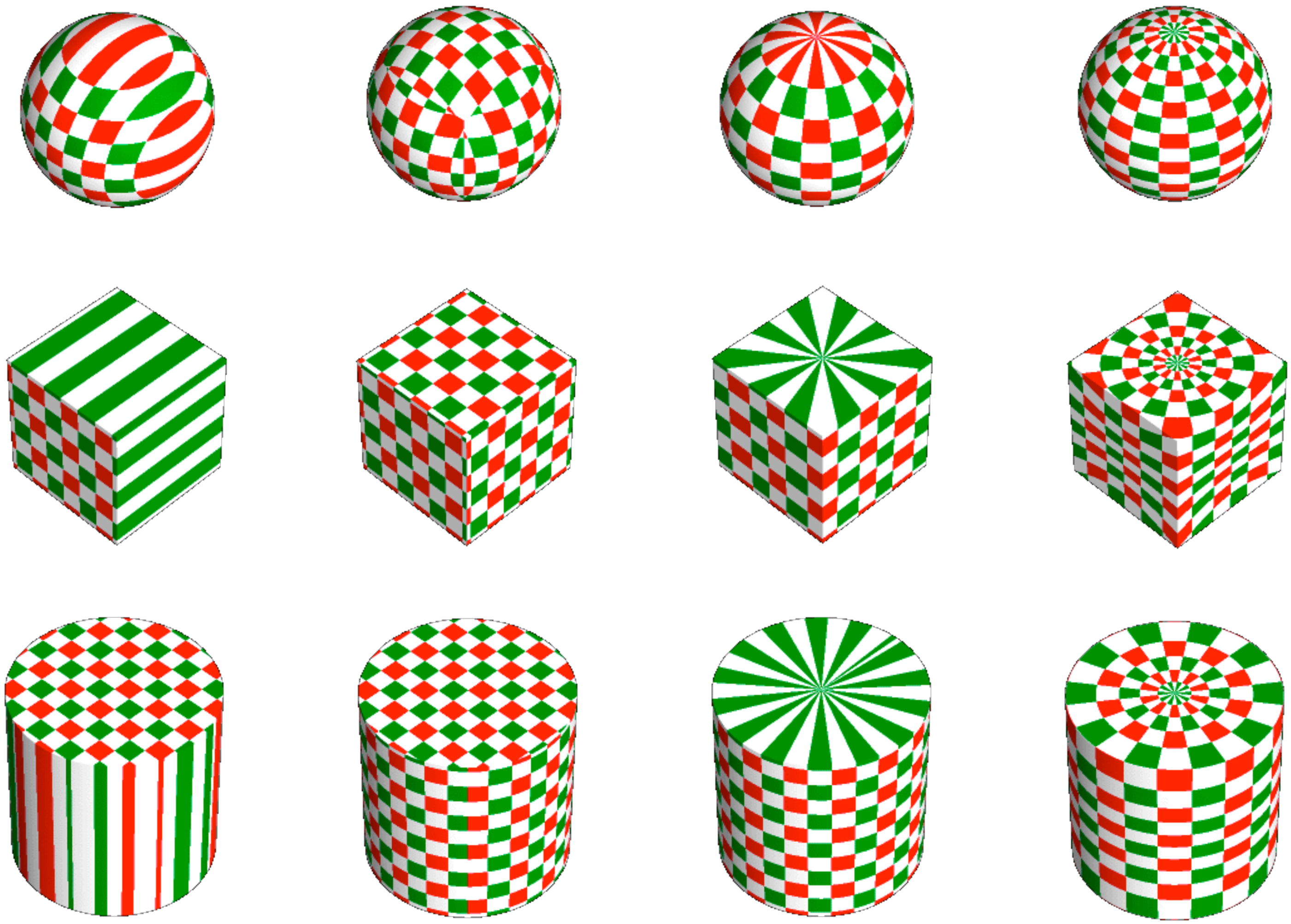
- Basic idea: use images instead of more polygons to represent fine scale color variation

Parameterization



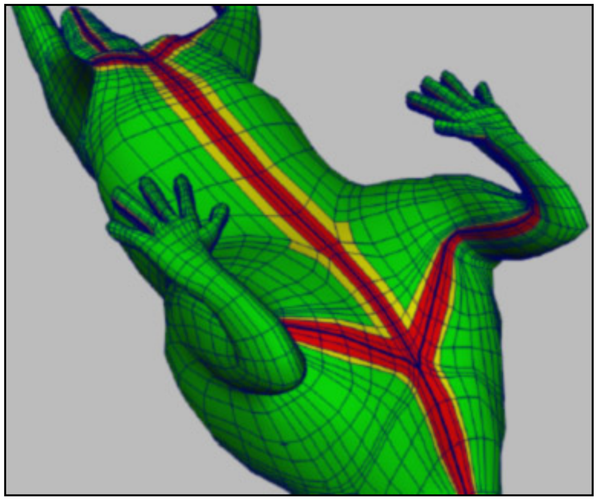
- Q: How do we decide *where* on the geometry each color from the image should go?

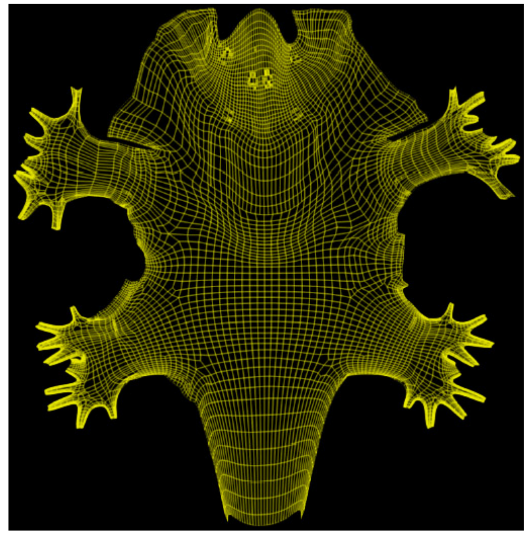
Option: Varieties of mappings



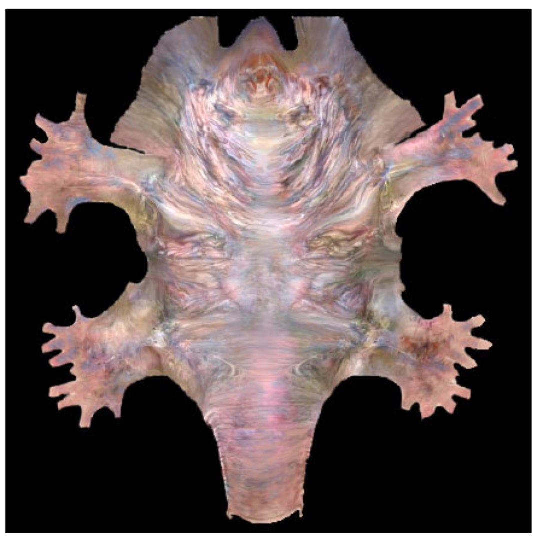
[Paul Bourke]

Option: unfold the surface



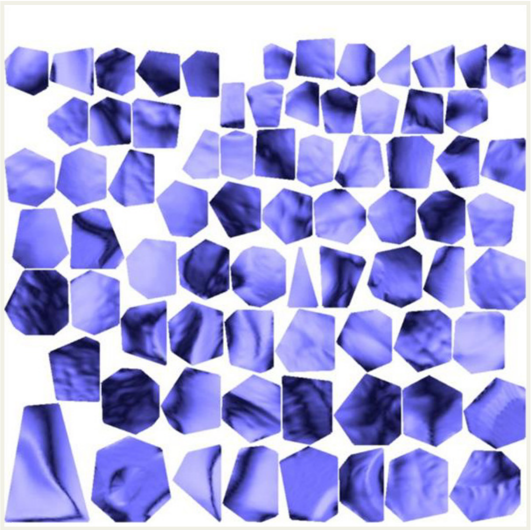


[Piponi2000]

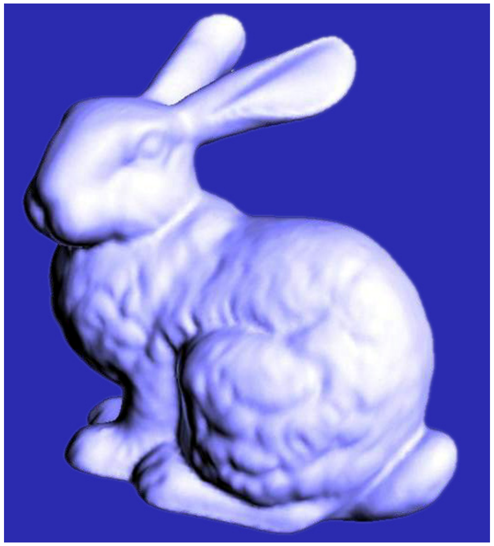


Option: make an atlas

charts



atlas



surface

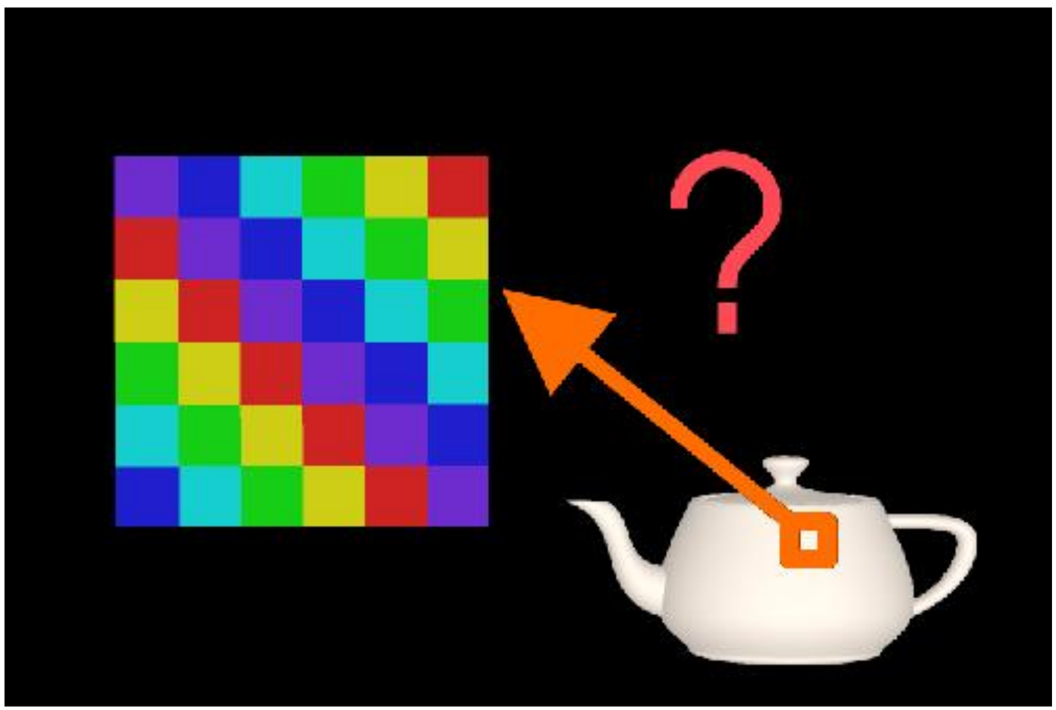
[Sander2001]

Outline

- *Types of mappings*
- Interpolating texture coordinates
- Broader use of textures

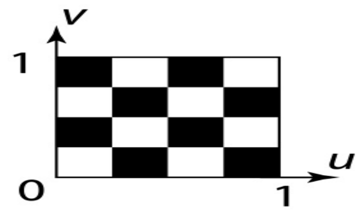
How to map object to texture?

- To each vertex (x,y,z in object coordinates), must associate 2D texture coordinates (s,t)
- So texture fits "nicely" over object

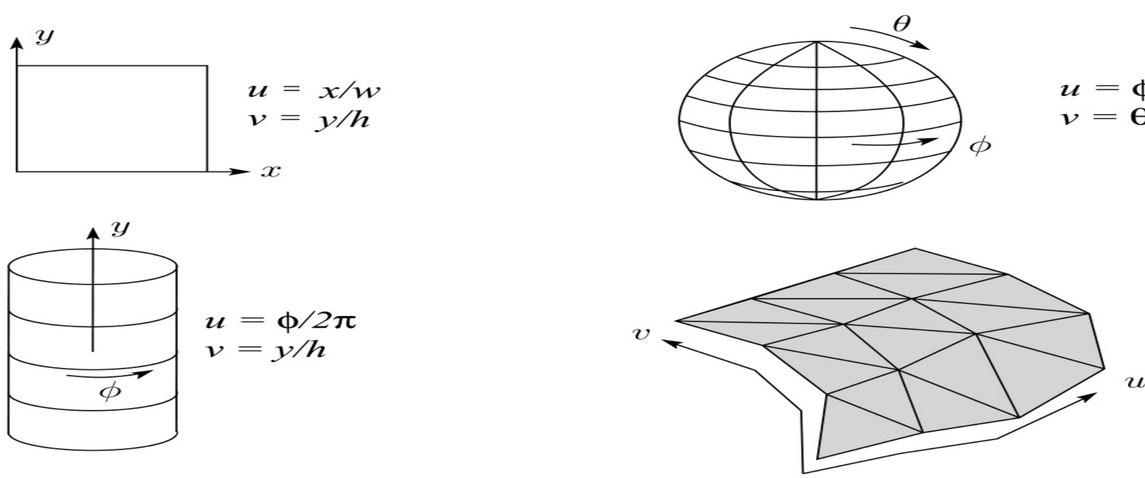


Implementing texture mapping

- A texture lives in it own abstract image coordinates paramaterized by (*u,v*) in the range ([0..1], [0..1]):



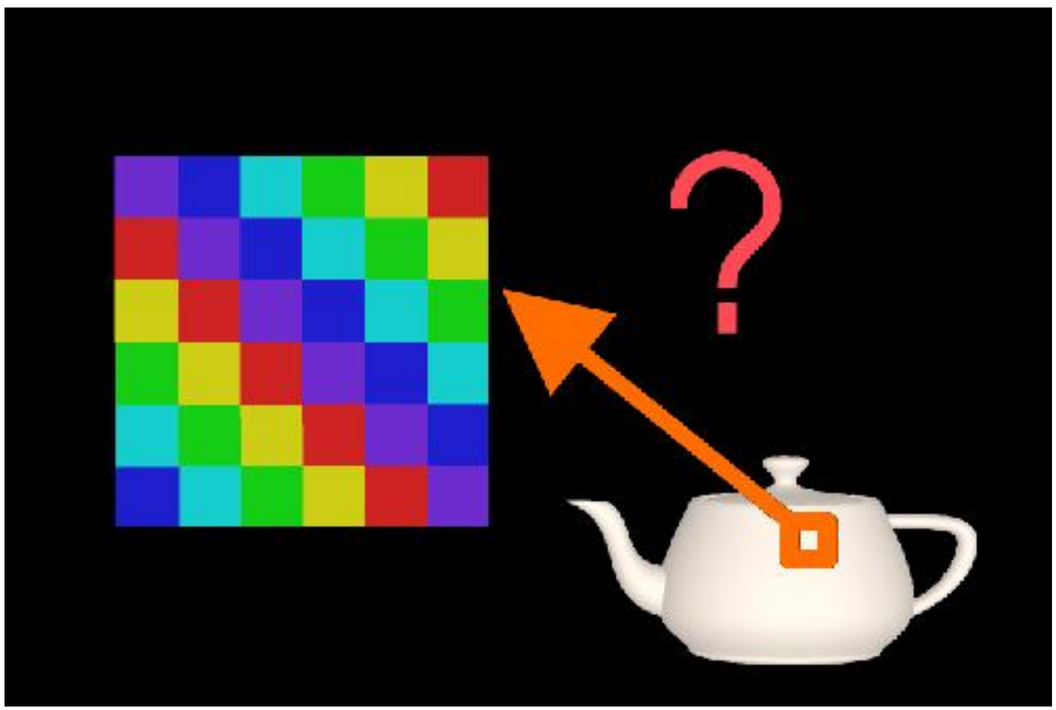
- It can be wrapped around many different surfaces:



- Note: if the surface moves/deforms, the texture goes with it.

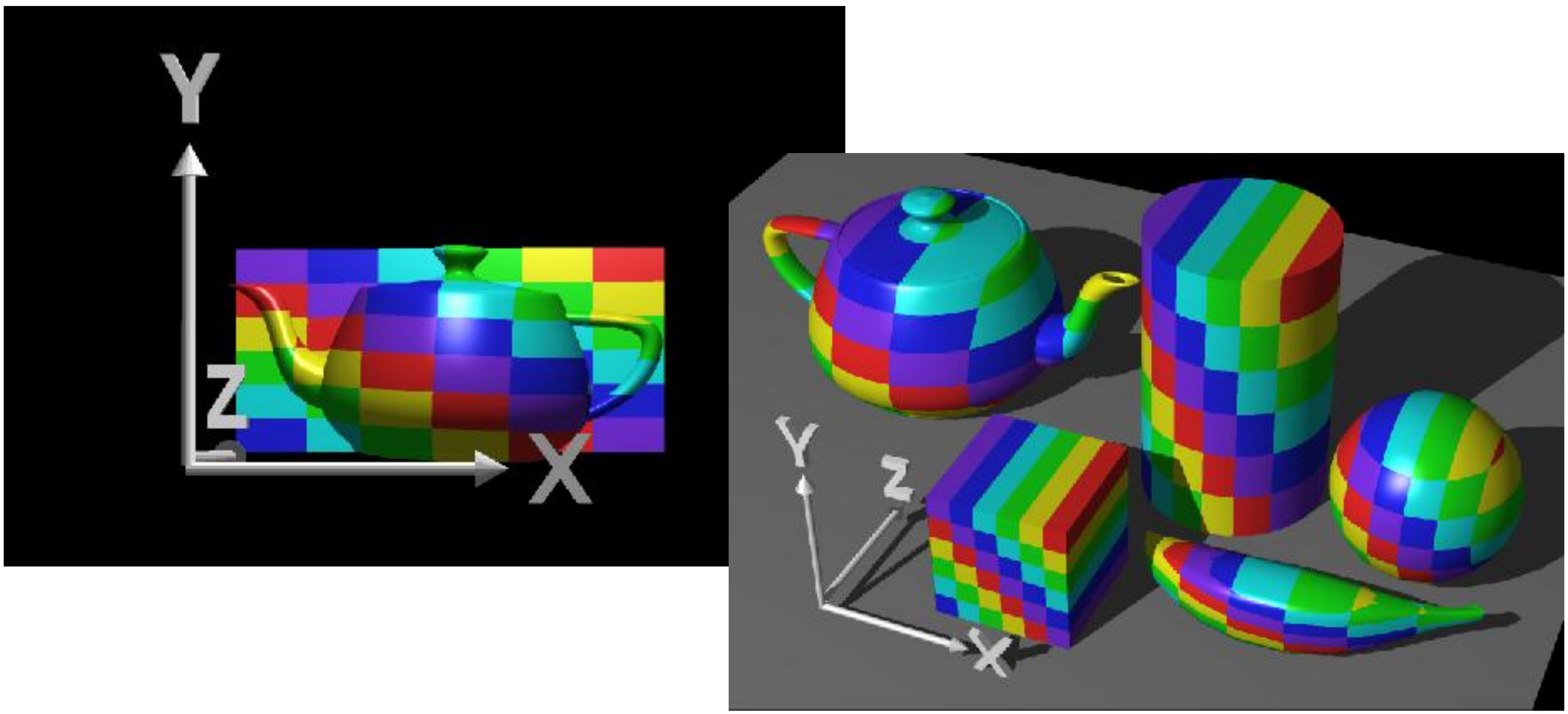
How to map object to texture?

- To each vertex (x,y,z in object coordinates), must associate 2D texture coordinates (s,t)
- So texture fits "nicely" over object



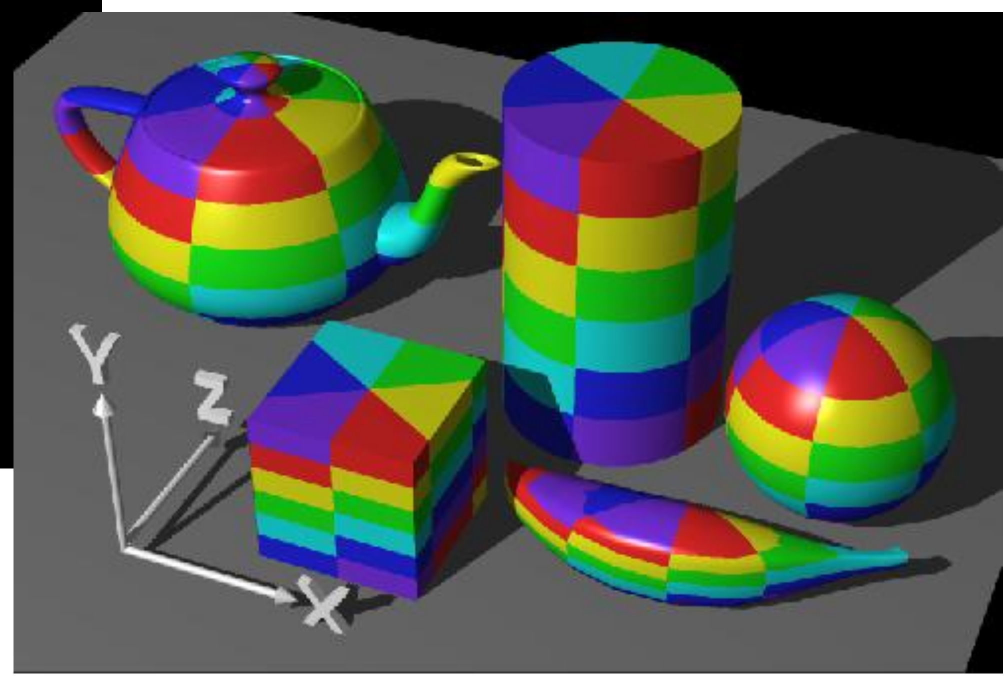
Planar mapping

- Like projections, drop z coord (u,v) = (x/W,y/H)
- Problems: what happens near silhouettes?



Cylindrical Mapping

- Cylinder: r, θ, z with (u,v) = (θ/(2π),z)
  - Note seams when wrapping around (θ = 0 or 2π)

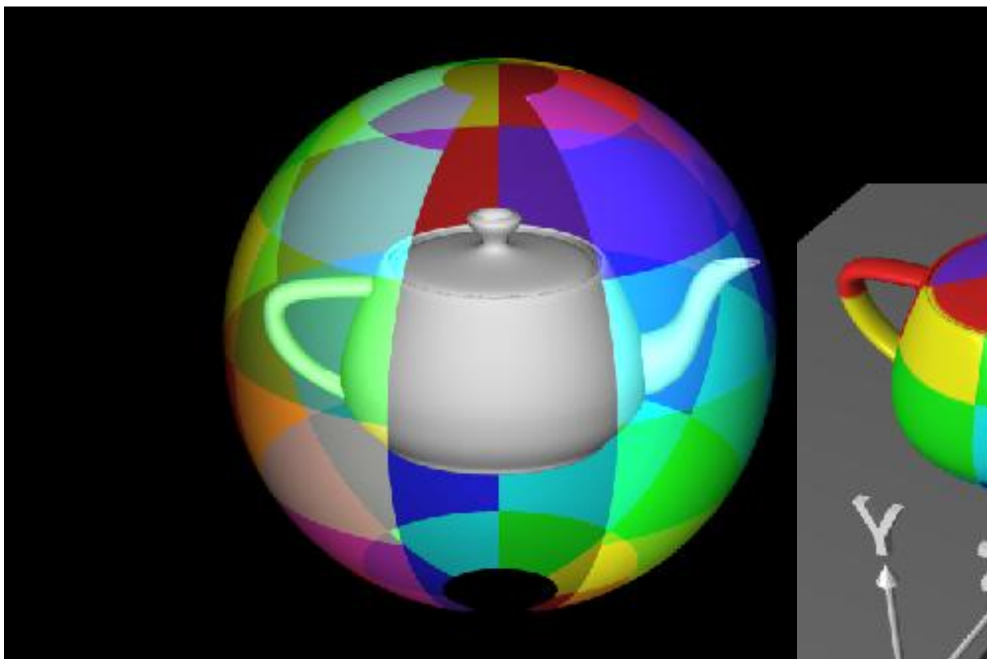


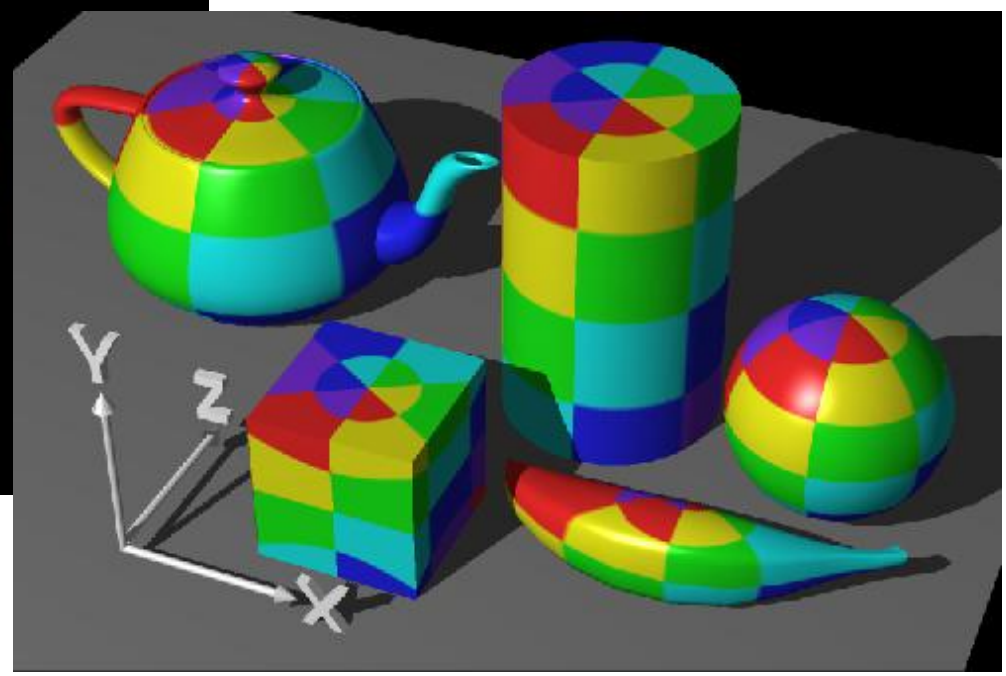
Basic procedure

- First, map (square) texture to basic map shape
- Then, map basic map shape to object
  - Or vice versa: Object to map shape, map shape to square
- Usually, this is straightforward
  - Maps from square to cylinder, plane, …
  - Maps from object to these are simply coordinate transform

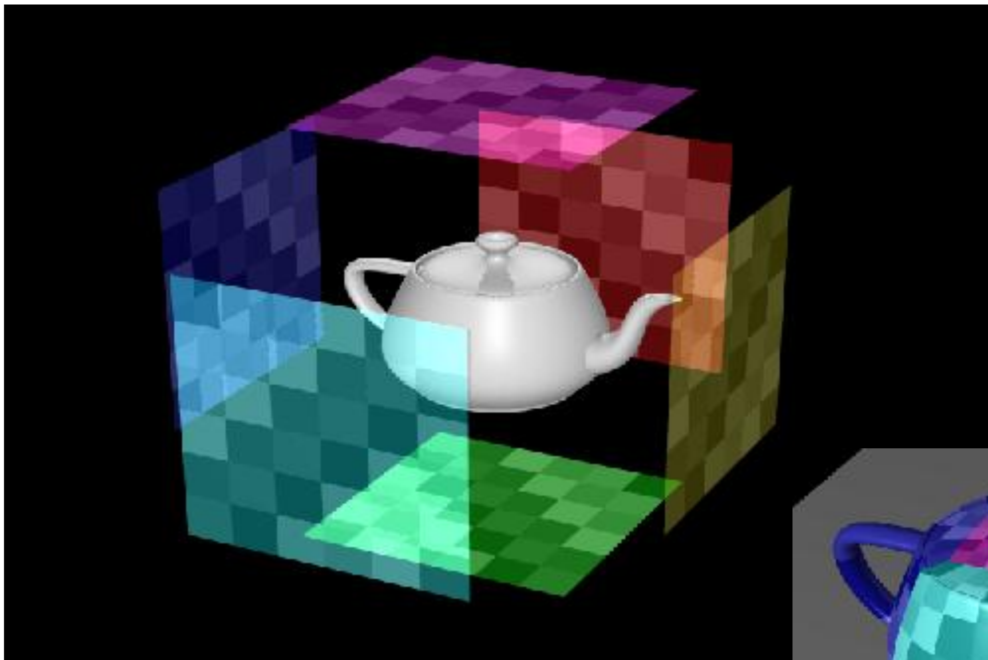
Spherical Mapping

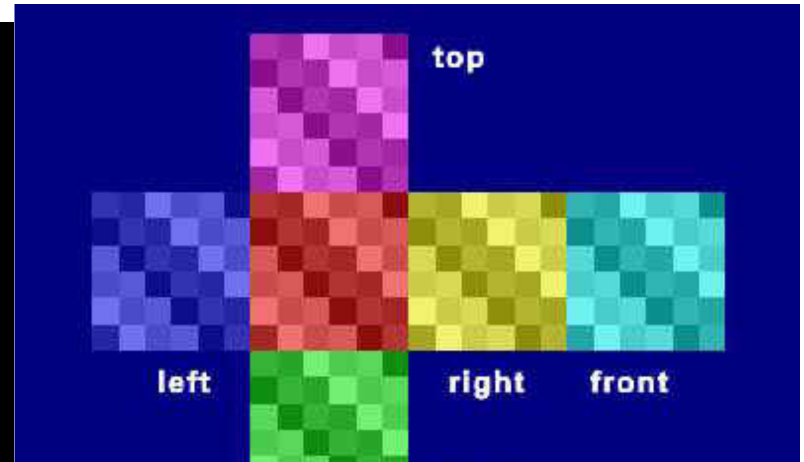
- Convert to spherical coordinates: use latitude/ long.
  - Singularities at north and south poles

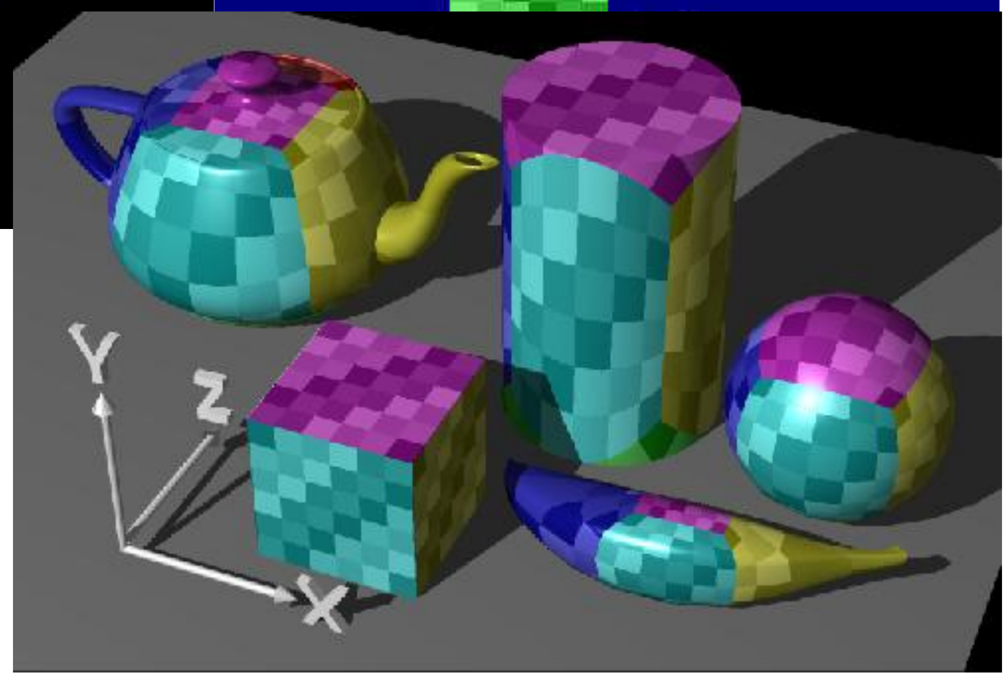




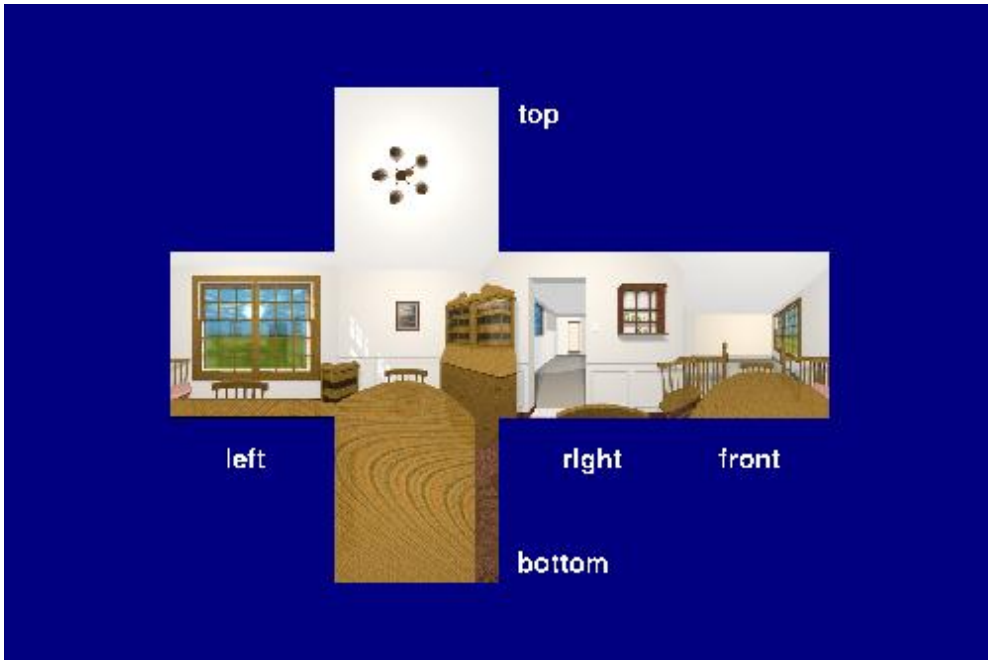
Cube Mapping



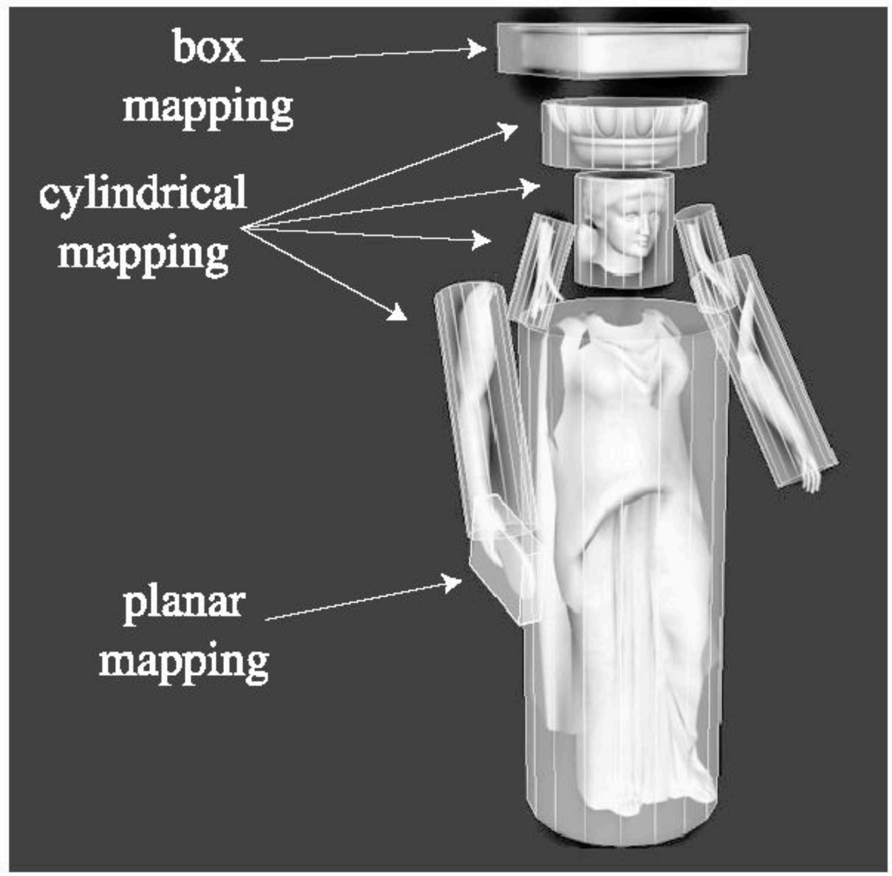




Cube Mapping



Piecewise Mapping

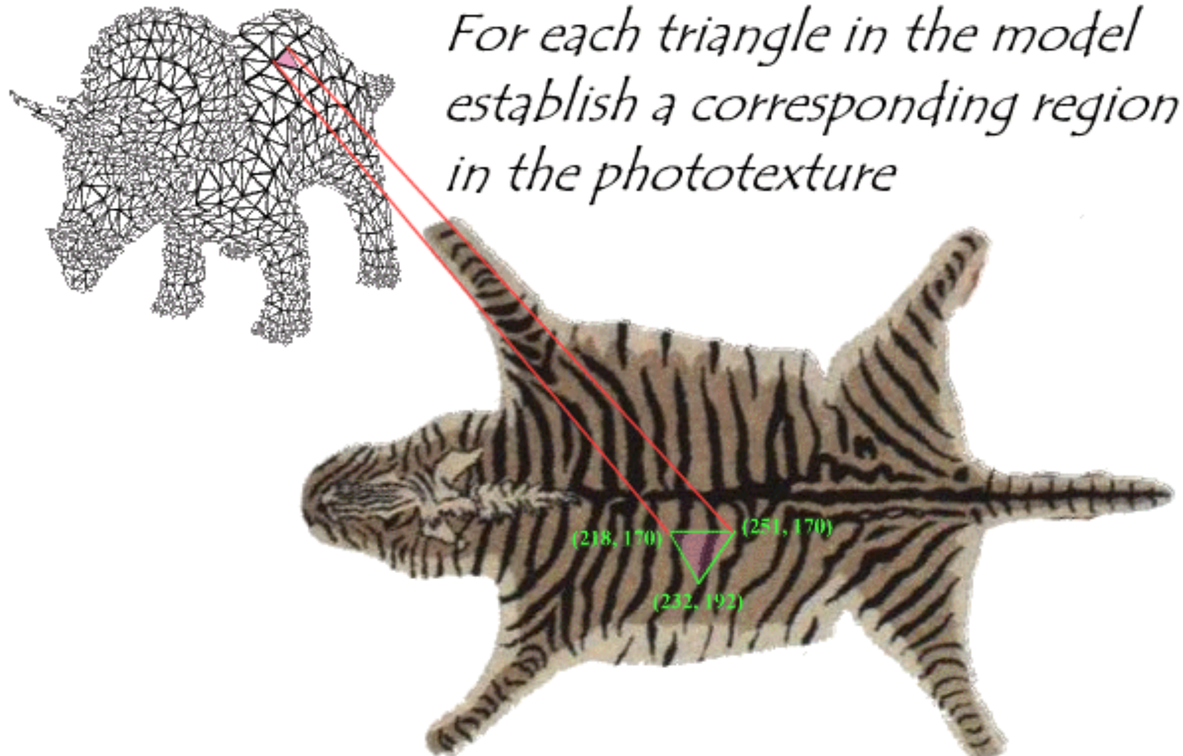


From Steve Marschner

Photo-textures

The concept is very simple!

For each triangle in the model establish a corresponding region in the phototexture



During rasterization interpolate the coordinate indices into the texture map

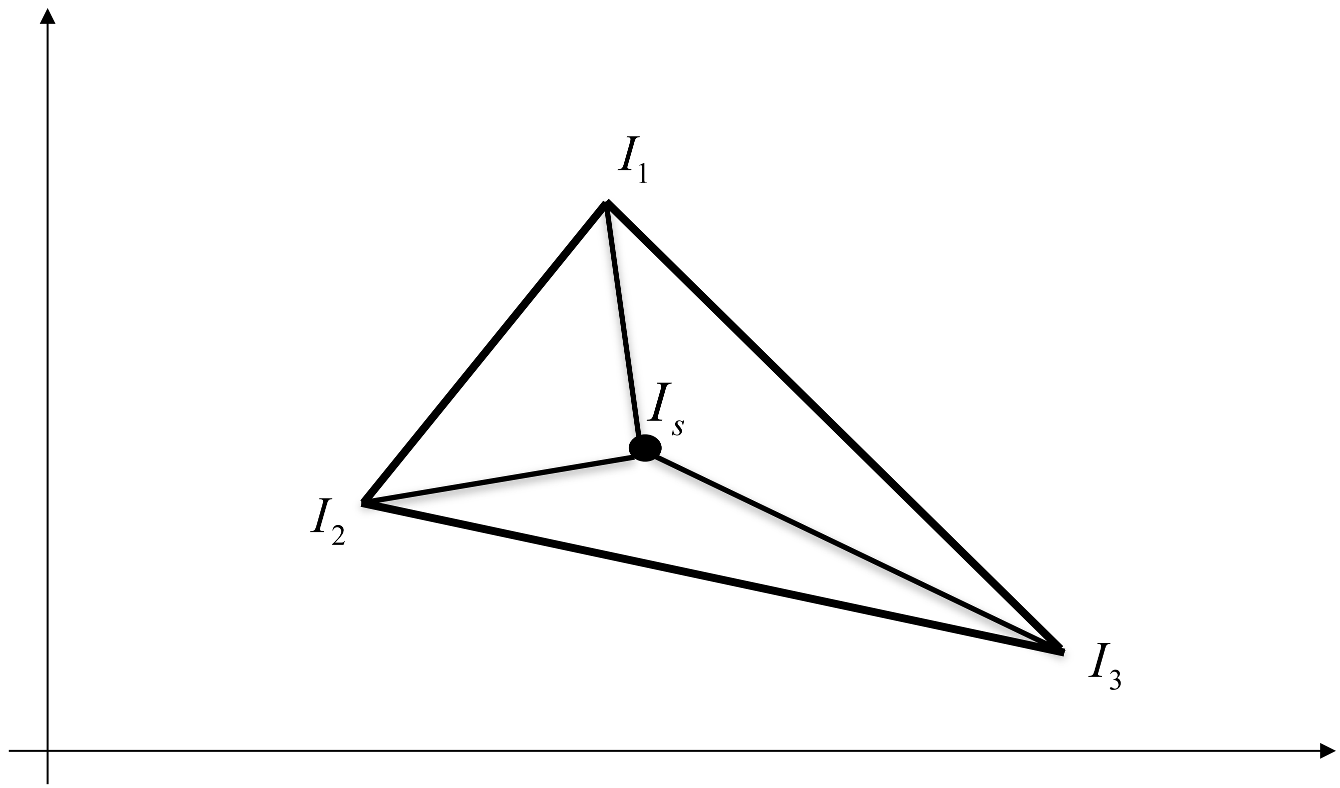
Slides from Leonard Mcmillan

Outline

- Types of projections
- *Interpolating texture coordinates*
- Broader use of textures

1st idea: Gouraud interp. of texcoords

Using barycentric Coordinates

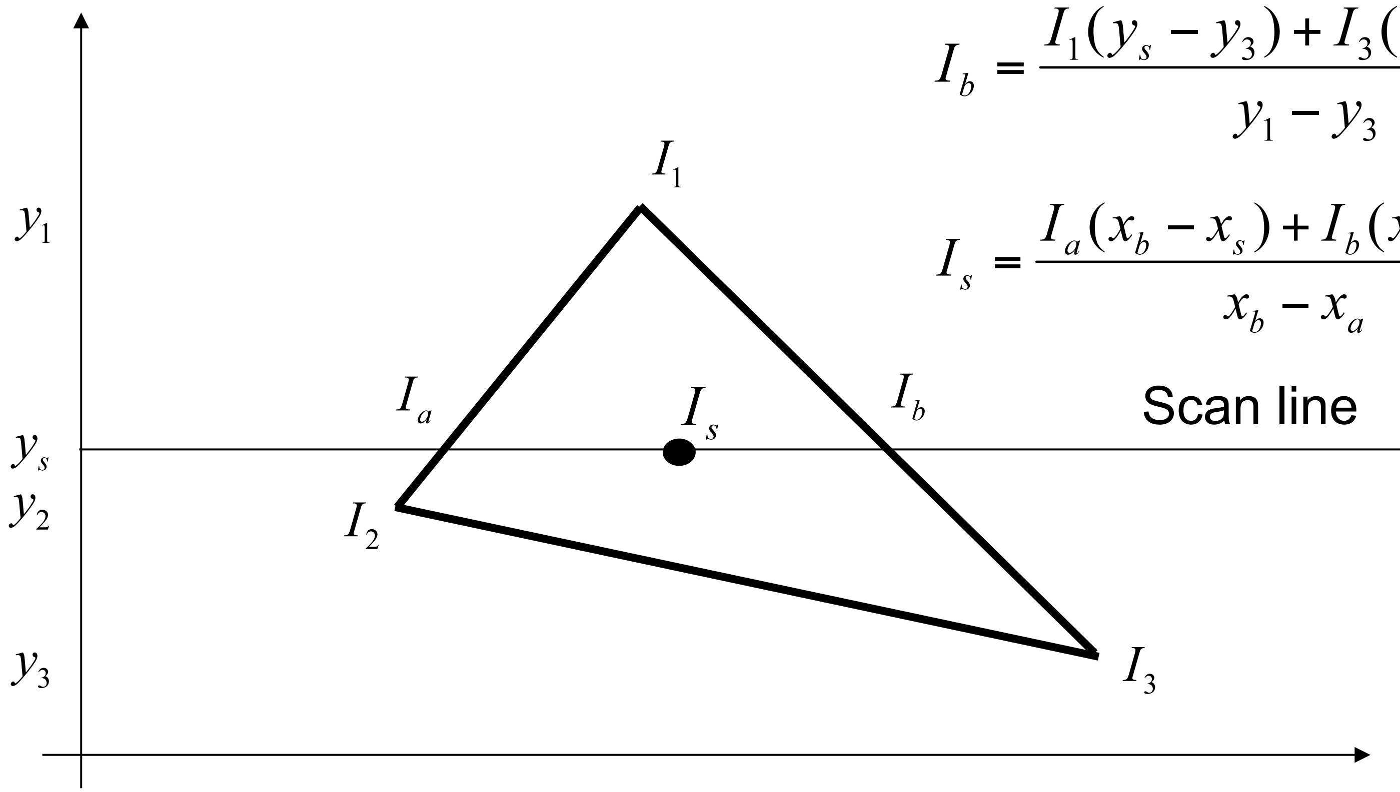


1^{st} idea: Gouraud interp. of texcoords

$$I_a = \frac{I_1(y_s - y_2) + I_2(y_1 - y_s)}{y_1 - y_2}$$

$$I_b = \frac{I_1(y_s - y_3) + I_3(y_1 - y_s)}{y_1 - y_3}$$

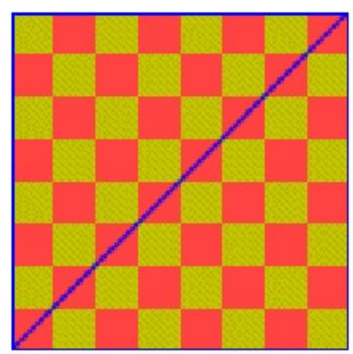
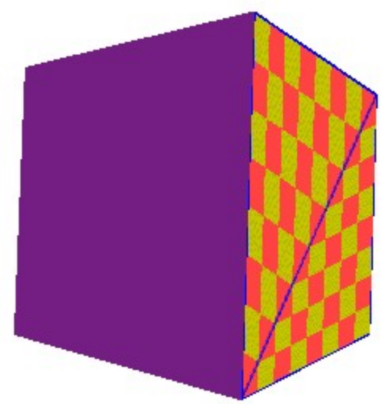
$$I_s = \frac{I_a(x_b - x_s) + I_b(x_s - x_a)}{x_b - x_a}$$



Artifacts

- McMillan's demo of this is at
  http://graphics.lcs.mit.edu/classes/6.837/F98/Lecture21/Slide05.html
- Another example
  http://graphics.lcs.mit.edu/classes/6.837/F98/Lecture21/Slide06.html
- What artifacts do you see?
- Why?
- Hint: problem is in interpolating parameters



Interpolating Parameters

- The problem turns out to be fundamental to interpolating parameters in screen-space
  - *Uniform steps in screen space ≠ uniform steps in world space*