Computer Graphics

CSE 167 [Win 24], Lecture 18: Texture Mapping

Ravi Ramamoorthi

http://viscomp.ucsd.edu/classes/cse167/wi24

Many slides from Greg Humphreys, formerly UVA and Rosalee Wolfe, DePaul tutorial teaching texture mapping visually
Chapter 11 in text book covers some portions

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To Do

- Submit HW4 milestone by tomorrow
- Prepare for final push on HW 4
- Written assignment due Mar 13, 11:59pm
  - Individually, no collaboration, piazza posts
  - Open notes, online. But understand what you turn in, and try to use your own words
  - No final

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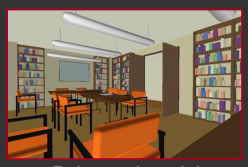
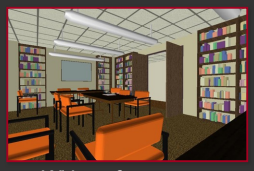
Texture Mapping

- Important topic: nearly all objects textured
  - Wood grain, faces, bricks and so on
  - Adds visual detail to scenes
- Meant as a fun and practically useful lecture



Polygonal model



With surface texture

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Adding Visual Detail

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

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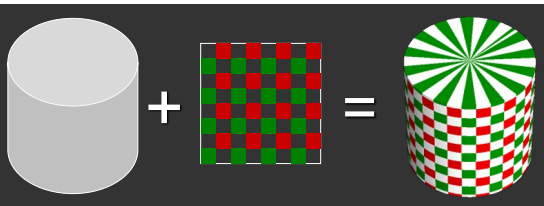
Parameterization



geometry image texture map

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

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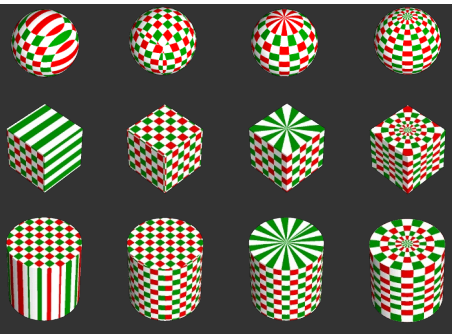
Option: Varieties of projections



[Paul Bourke]

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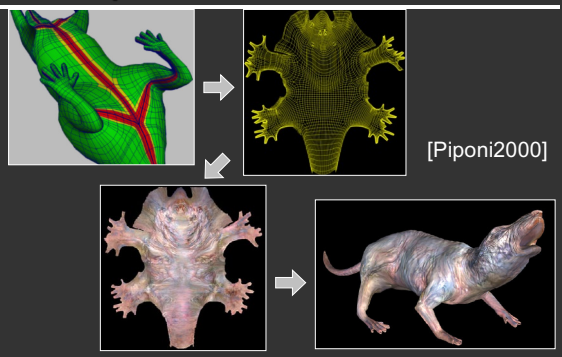
Option: unfold the surface



[Piponi2000]

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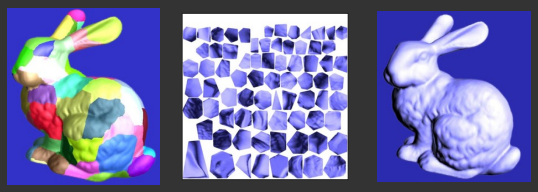
Option: make an atlas



charts atlas surface

[Sander2001]

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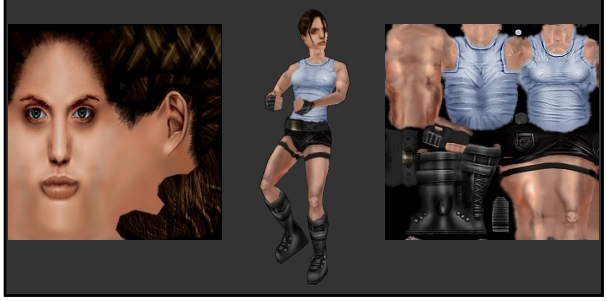
Option: it's the artist's problem



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Course Evaluations

- Fill out now, can be done on phone
- Enthusiasm important to future offerings
- Comments useful to future years
- Some key innovations: modern OpenGL, GLSL; feedback servers (including code), UCSD Online, …
- Separately, please also evaluate the TAs

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Outline

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

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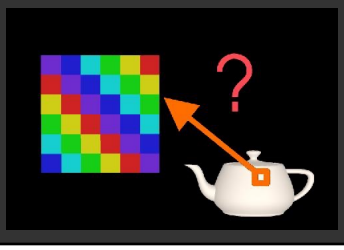
How to map object to texture?

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



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Idea: Use Map Shape

- Map shapes correspond to various projections
  - Planar, Cylindrical, Spherical
- 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, sphere well defined
  - Maps from object to these are simply spherical, cylindrical, cartesian coordinate systems

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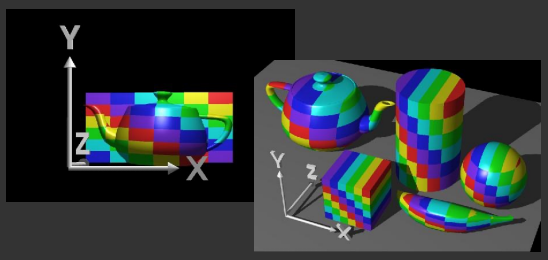
Planar mapping

- Like projections, drop z coord (s,t) = (x,y)
- Problems: what happens near z = 0?



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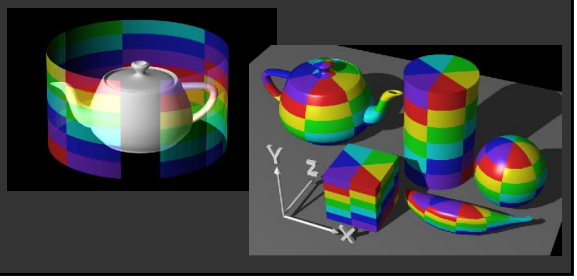
Cylindrical Mapping

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



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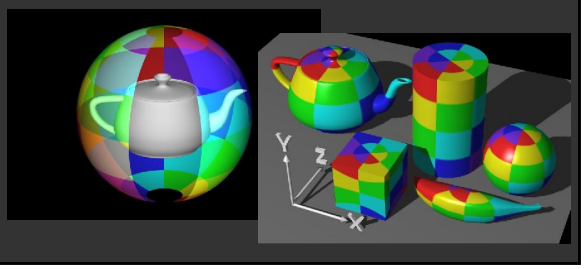
Spherical Mapping

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



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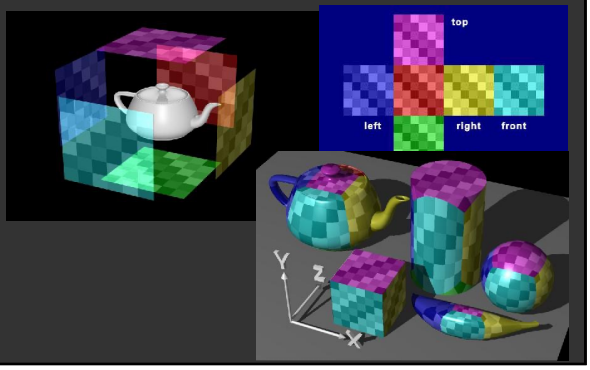
Cube Mapping



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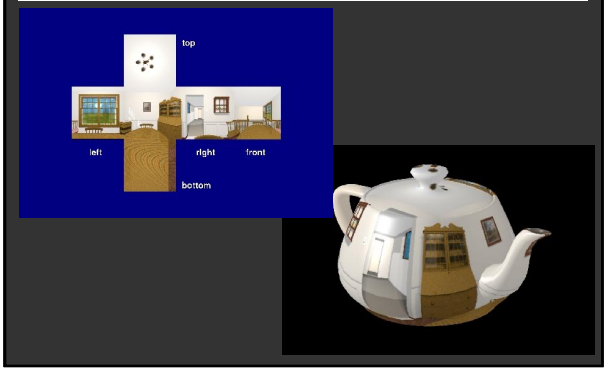
Cube Mapping



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- Broader use of textures

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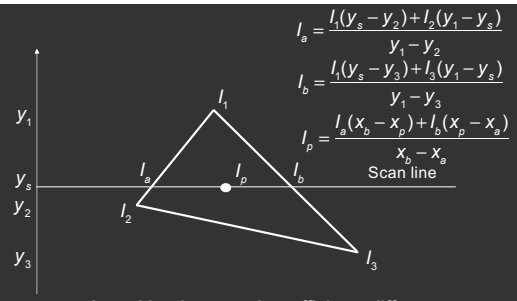
Gouraud Shading – Details



Actual implementation efficient: difference equations while scan converting

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Artifacts

- Wikipedia page
  https://en.wikipedia.org/wiki/File:Perspective_correct_texture_mapping.jpg
- What artifacts do you see?
- Why?
- Why not in standard Gouraud shading?
- Hint: problem is in interpolating parameters

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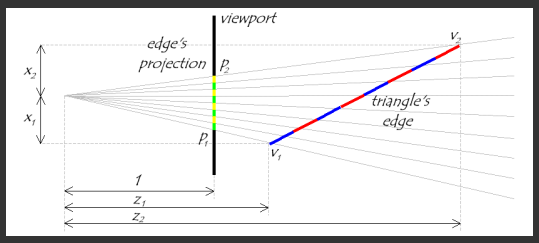
Interpolating Parameters

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



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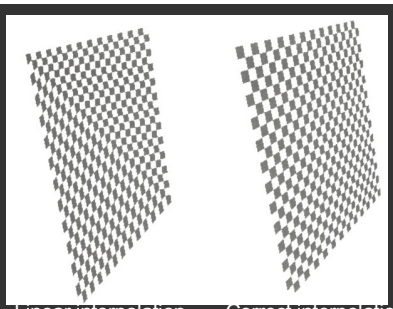
Texture Mapping



Linear interpolation of texture coordinates

Correct interpolation with perspective divide

Hill Figure 8.42

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Interpolating Parameters

- Perspective foreshortening is not getting applied to our interpolated parameters
  - Parameters should be compressed with distance
  - Linearly interpolating them in screen-space doesn't do this

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Perspective-Correct Interpolation

- Skipping a bit of math to make a long story short…
  - Rather than interpolating *u* and *v* directly, interpolate *u/z* and *v/z*
    - These do interpolate correctly in screen space
    - Also need to interpolate *Z* and multiply per-pixel
  - Problem: we don't know *z* anymore
  - Solution: we do know *w ~ 1/z*
  - So…interpolate *uw* and *vw* and *w*, and compute *u = uw/w* and *v = vw/w* for each pixel
    - This unfortunately involves a divide per pixel
- Wikipedia page

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Texture Map Filtering

- Naive texture mapping aliases badly
- Look familiar?

```
int uval = (int) (u * denom + 0.5f);
int vval = (int) (v * denom + 0.5f);
int pix = texture.getPixel(uval, vval);
```

- Actually, each pixel maps to a region in texture
  - |PIX| < |TEX|
    - Easy: interpolate (bilinear) between texel values
  - |PIX| > |TEX|
    - Hard: average the contribution from multiple texels
  - |PIX| ~ |TEX|
    - Still need interpolation!

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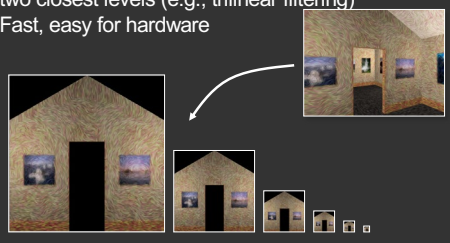
Mip Maps

- Keep textures prefiltered at multiple resolutions
  - For each pixel, linearly interpolate between two closest levels (e.g., trilinear filtering)
  - Fast, easy for hardware



- Why "Mip" maps?

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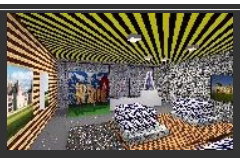
MIP-map Example

- No filtering:



AAAAAAAGH
MY EYES ARE BURNING

- MIP-map texturing:

Where are my glasses?

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Outline

- Types of projections
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Texture Mapping Applications

- Modulation, light maps
- Bump mapping
- Displacement mapping
- Illumination or Environment Mapping
- Procedural texturing
- And many more

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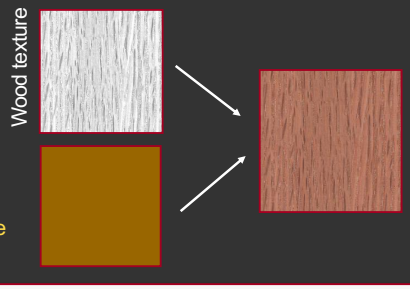
Modulation textures

Map texture values to scale factor



$$I = T(s,t)(I_E + K_A I_A + \sum_L (K_D (N \bullet L) + K_S (V \bullet R)^n) S_L I_L + K_T I_T + K_S I_S)$$

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Bump Mapping

- Texture = change in surface normal!

Sphere w/ diffuse texture | *Swirly bump map* | *Sphere w/ diffuse texture and swirly bump map*

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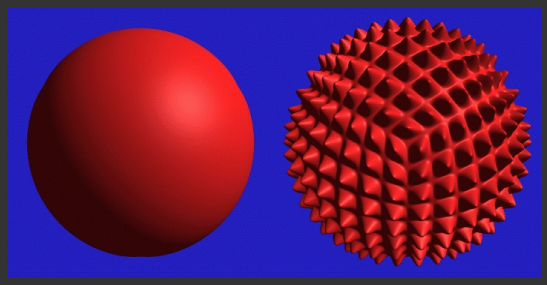
Displacement Mapping



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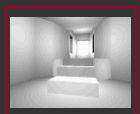
Illumination Maps

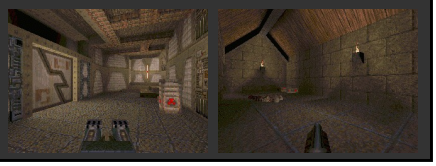
- Quake introduced *illumination maps* or *light maps* to capture lighting effects in video games

Texture map:



Light map

Texture map + light map:



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Environment Maps

Images from *Illumination and Reflection Maps: Simulated Objects in Simulated and Real Environments*
Gene Miller and C. Robert Hoffman
SIGGRAPH 1984 "Advanced Computer Graphics Animation" Course Notes

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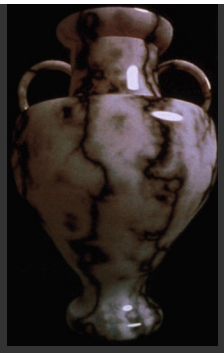
Solid textures

Texture values indexed by 3D location (x,y,z)

- Expensive storage, or
- Compute on the fly, e.g. Perlin noise →



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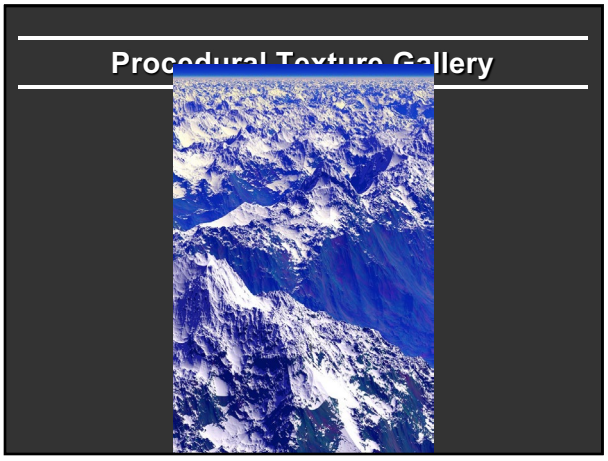

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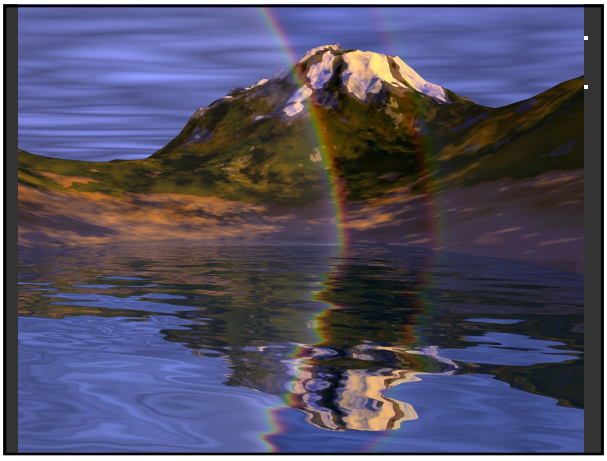

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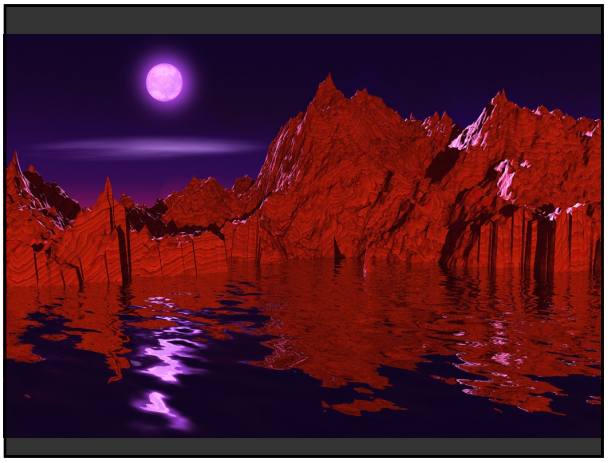

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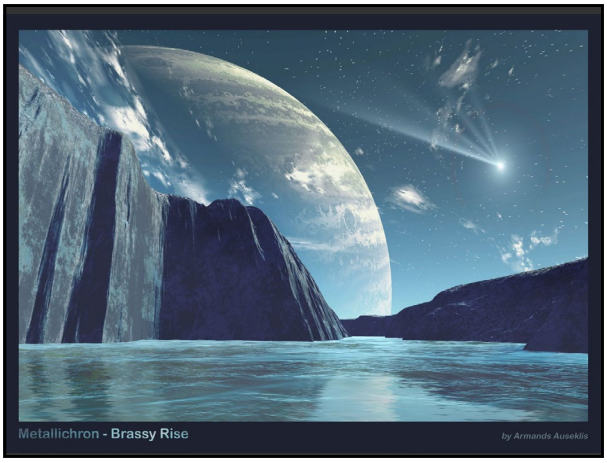

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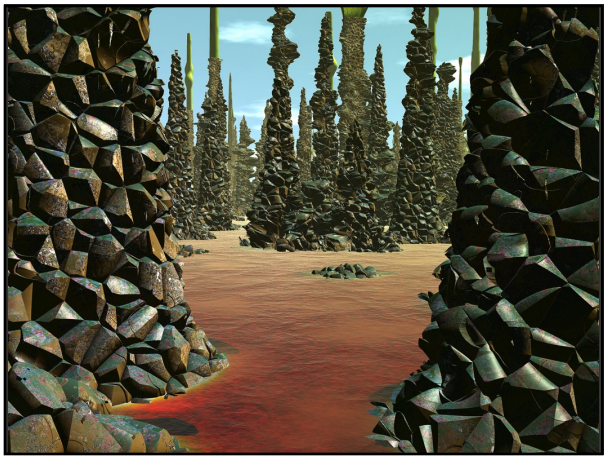

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