CSE 167:
Introduction to Computer Graphics
Lecture #13: Environment Mapping

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Fall Quarter 2010

Announcements

- Homework assignment #6 due Friday, Nov 12
- No class this Thursday (Veterans Day)
- This Thursday's lab office hours moved to:
  - Haili: Wed 5-6pm
  - Han: Fri 9:30-11:30am
  - Phi: Fri 1-2pm
- CAPE: on-line, email notification at beginning of week 9
  - http://www.cape.ucsd.edu

Final Project

- Problem description will go on-line this Thursday
- Must be done in teams of two or three
- Application design description (min. 300 words) due Friday, November 19. Email to the instructor at: `jschulze@ucsd.edu`
- Project due to be presented on **Friday, Dec 3rd, between 3 and 5pm, venue TBD**
- No late submissions accepted!

StarCAVE Tour

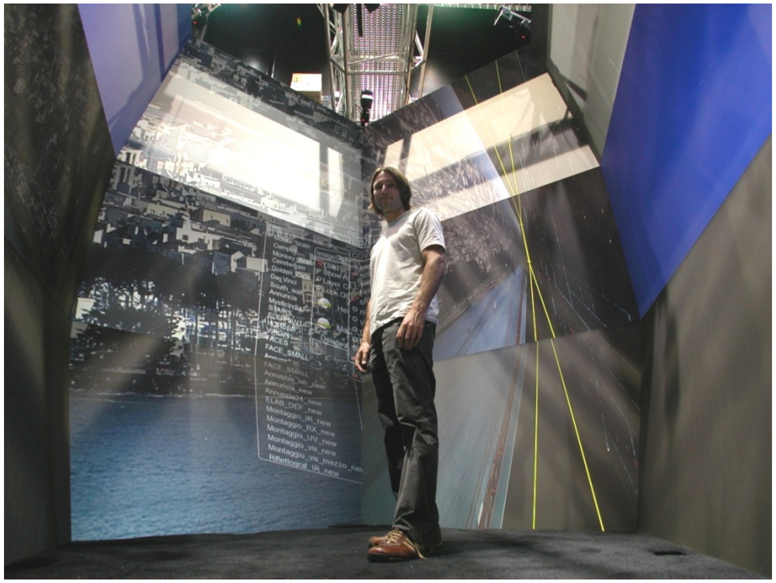
- Location: Atkinson Hall, 1st floor
- 18 Dell XPS PCs with Quad Core Intel CPUs
- CentOS 5.3 Linux
- Dual Nvidia Quadro 5600 graphics cards per node
- 34 JVC HD2k projectors (1920x1080 pixels): ~34 megapixels per eye
- Passive stereo with circular polarization filters
- 15 screens, ~8 x 4 feet each
- Floor projection
- Optical, wireless tracking system
- Software: COVISE
- Programming Language: C++

Tour Date:

- Friday, Nov 19, 4:00-5:00pm

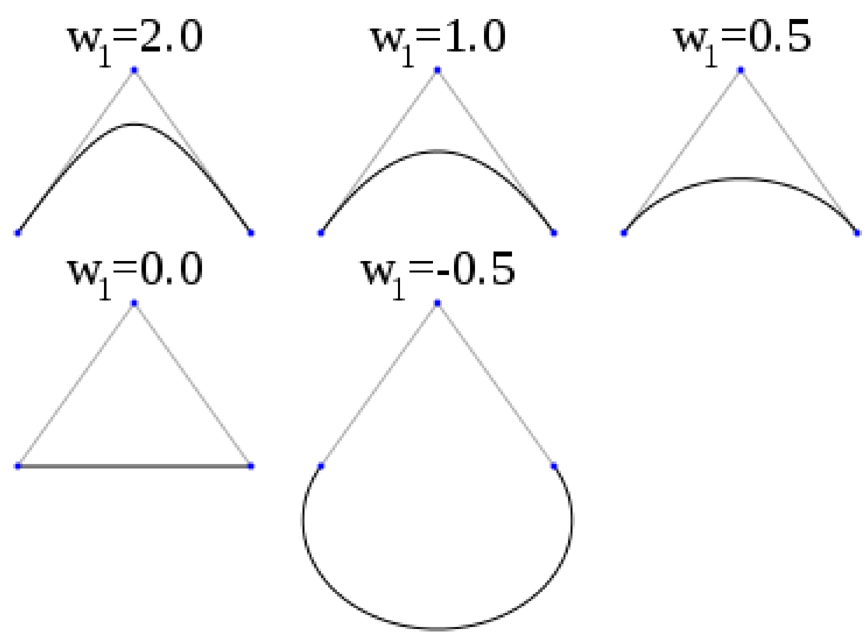
Location:

Immersive Visualization Laboratory
1st floor Atkinson Hall
Turn right at main entrance



Rational Curves

- Weight causes point to "pull" more (or less)
- Can model circles with proper points and weights,
- Below: rational quadratic Bézier curve with three control points



Lecture Overview

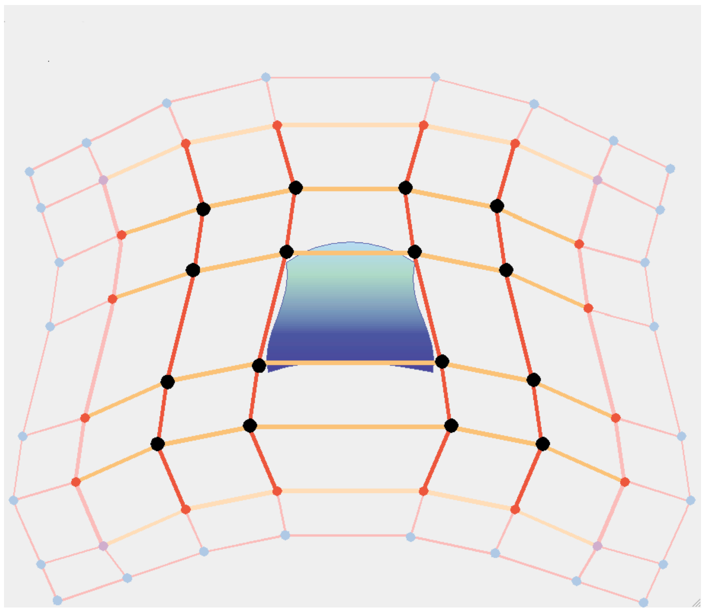
- Advanced surface modeling

Advanced Shader Effects

- Environment mapping
- Toon shading

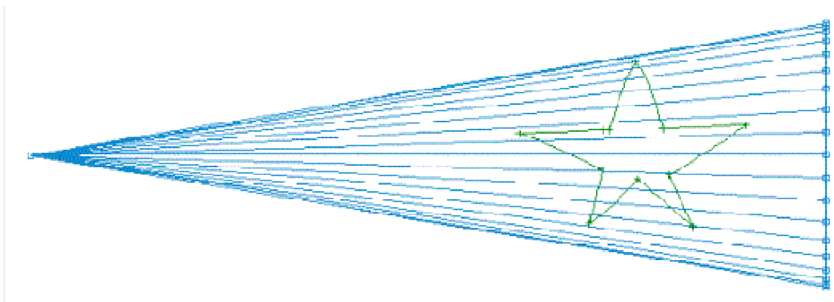
Advanced Surface Modeling

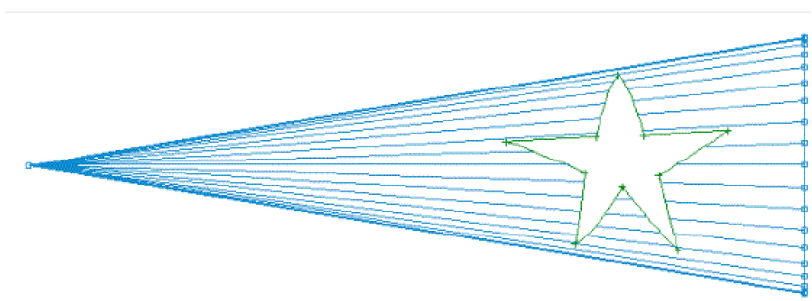
- B-spline/NURBS patches
- For the same reason as using B-spline/NURBS curves
  - More flexible (can model spheres)
  - Better mathematical properties, continuity

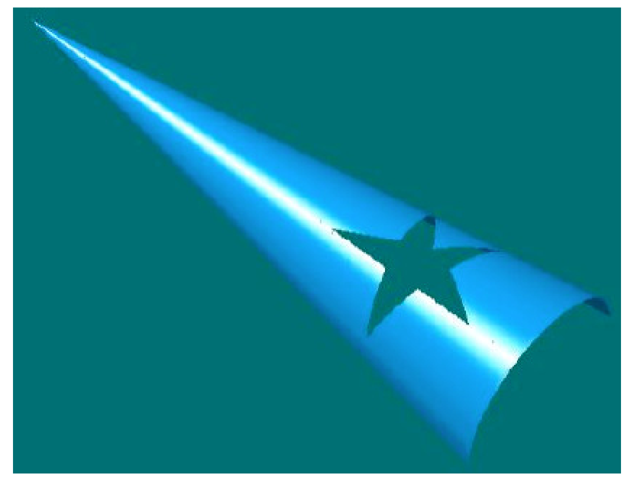


Advanced Surface Modeling

- Trim curves: cut away part of surface
  - Implement as part of tessellation/rendering

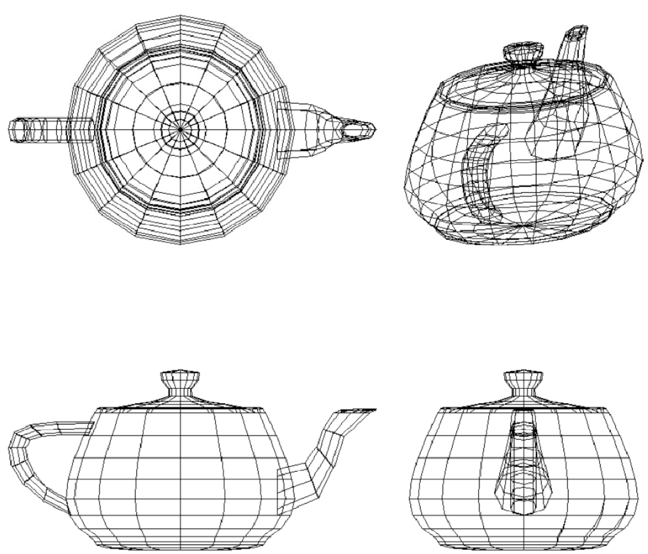


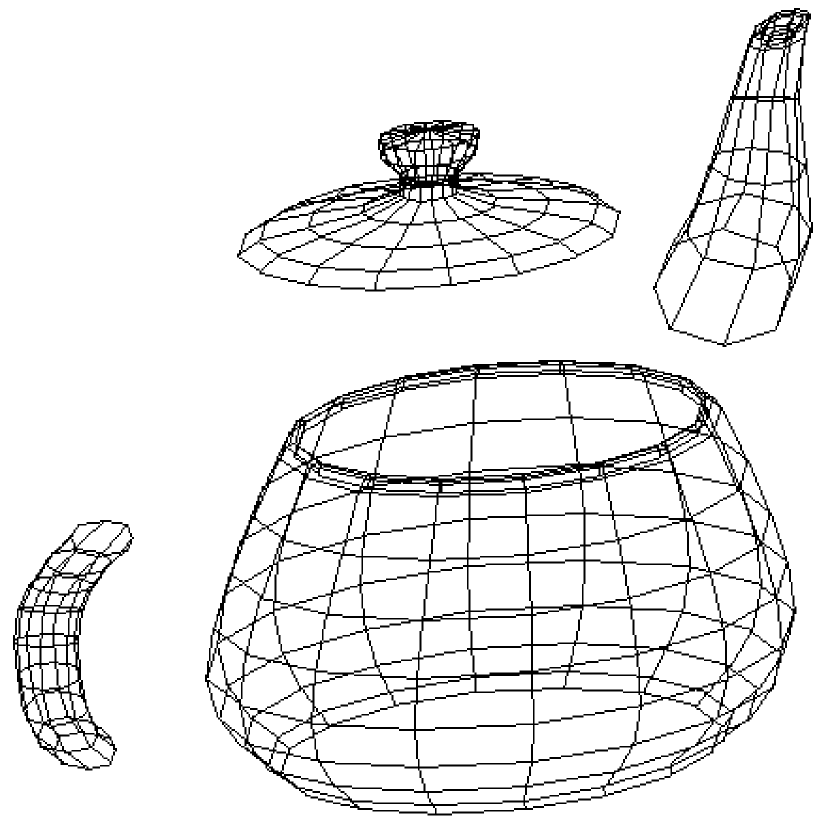




Modeling Headaches

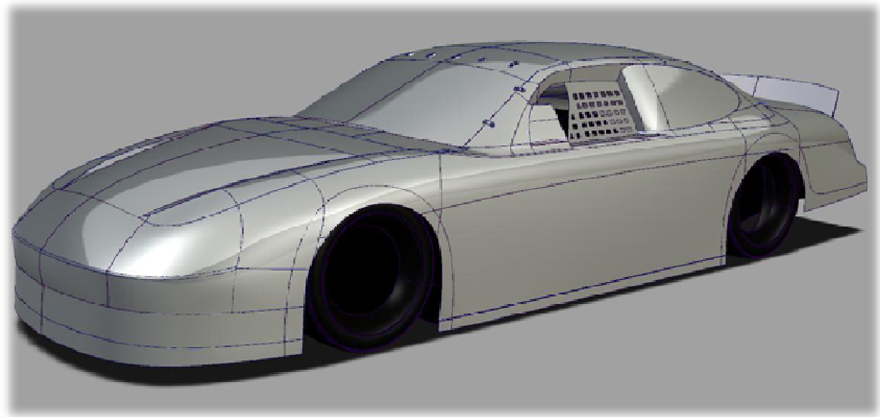
- Original teapot is not "water tight"
  - spout & handle intersect with body
  - no bottom
  - hole in spout
  - gap between lid and body



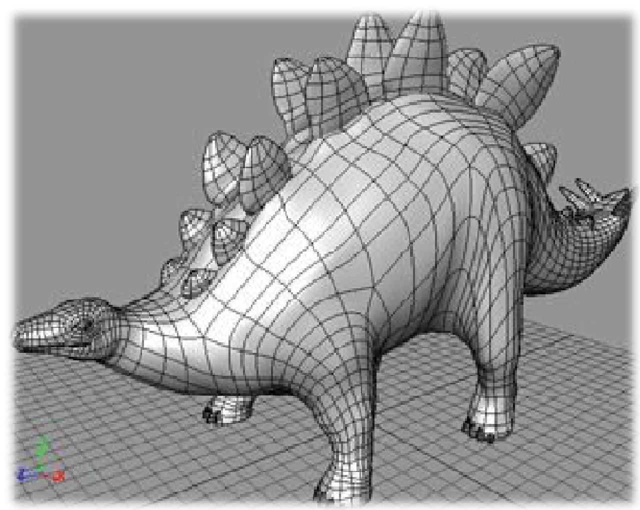


Modeling Headaches

- **NURBS surfaces are versatile**
  - Conic sections
  - Can blend, merge, trim…



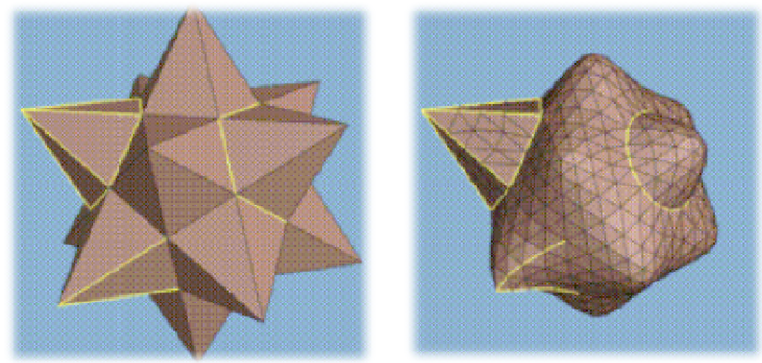
- **But:**
  - Any surface will be made of quadrilateral patches (quadrilateral topology)

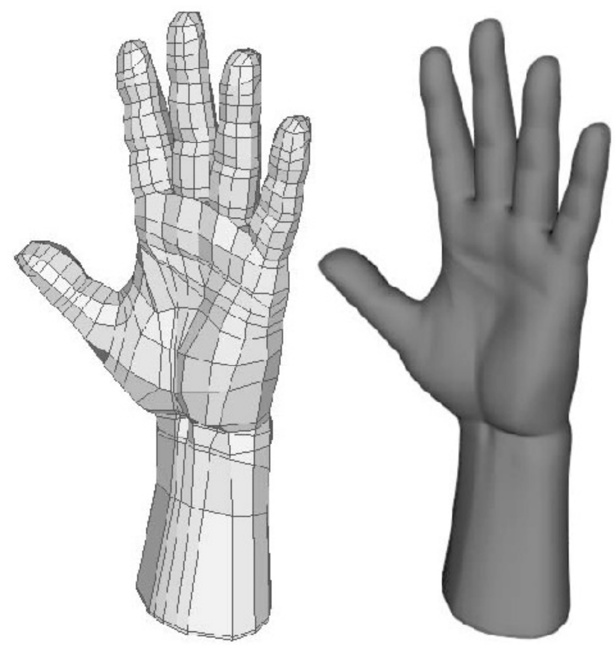


- **This makes it hard to**
  - Join or abut curved pieces
  - Build surfaces with complex topology or structure

Subdivision Surfaces

- Arbitrary mesh of control points, not quadrilateral topology
  - No global u, v parameters
- Can make surfaces with arbitrary topology or connectivity
- Work by recursively subdividing mesh faces
  - Per-vertex annotation for weights, corners, creases
- Used in particular for character animation
  - One surface rather than collection of patches
  - Can deform geometry without creating cracks





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More Realistic Illumination

- In real world:
  At each point in scene light arrives from all directions
  - Not just from point light sources
  - → Global Illumination is a solution but computationally expensive
- Environment maps
  - Store "omni-directional" illumination as images
  - Each pixel corresponds to light from a certain direction

Capturing Environment Maps

- "360 degrees" panoramic image
- Instead of 360 degrees panoramic image, take picture of mirror ball (light probe)

Light Probes by Paul Debevec
http://www.debevec.org/Probes/

Environment Maps as Light Sources

Simplifying Assumption

- Assume light captured by environment map is emitted from infinitely far away
- Environment map consists of directional light sources
  - Value of environment map is defined for each **direction**, independent of position in scene
- Approach uses same environment map at each point in scene
  → Approximation!

Applications for Environment Maps

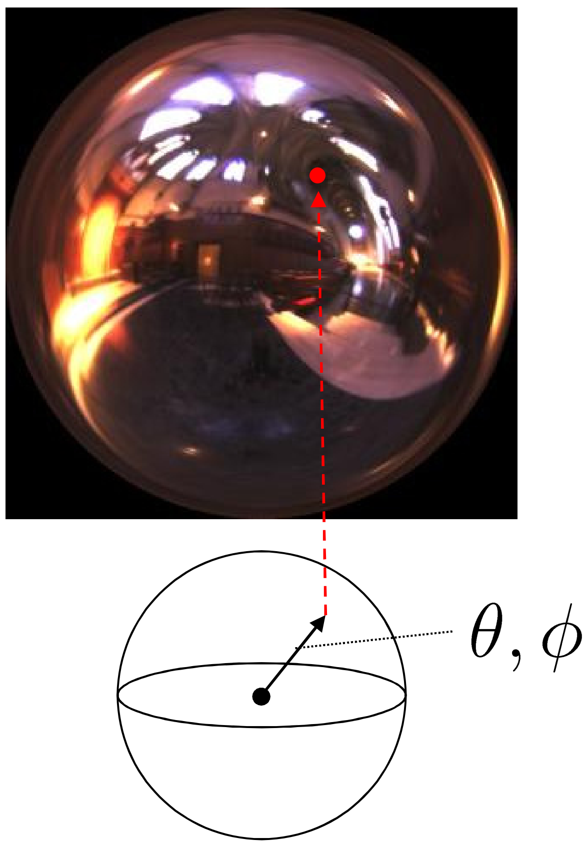
- Use environment map as "light source"

Global illumination
[Sloan et al.]

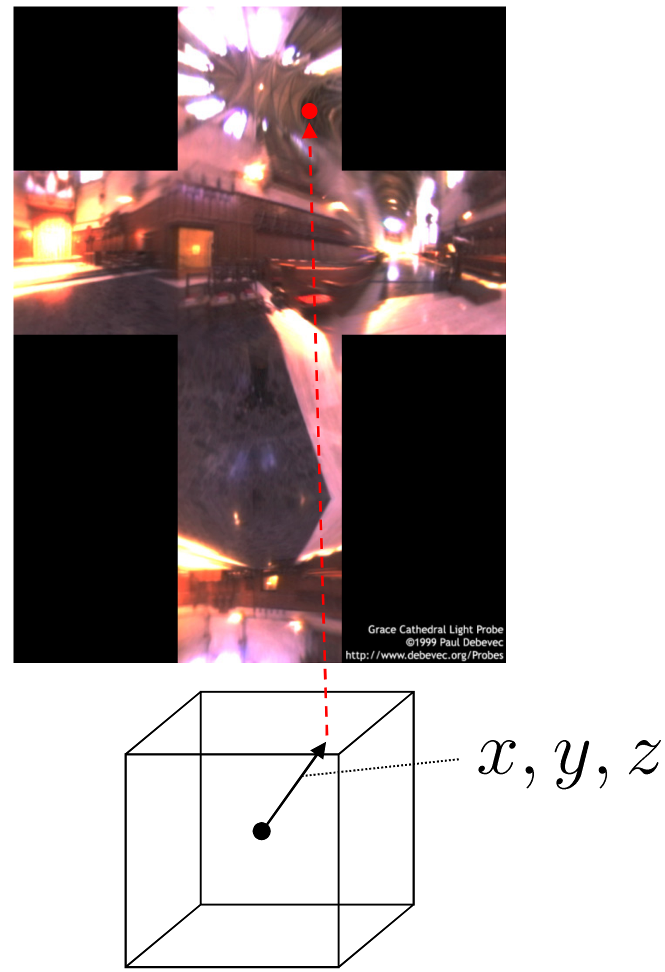
Reflection mapping

Cubic Environment Maps

- Store incident light on six faces of a cube instead of on sphere



Spherical map

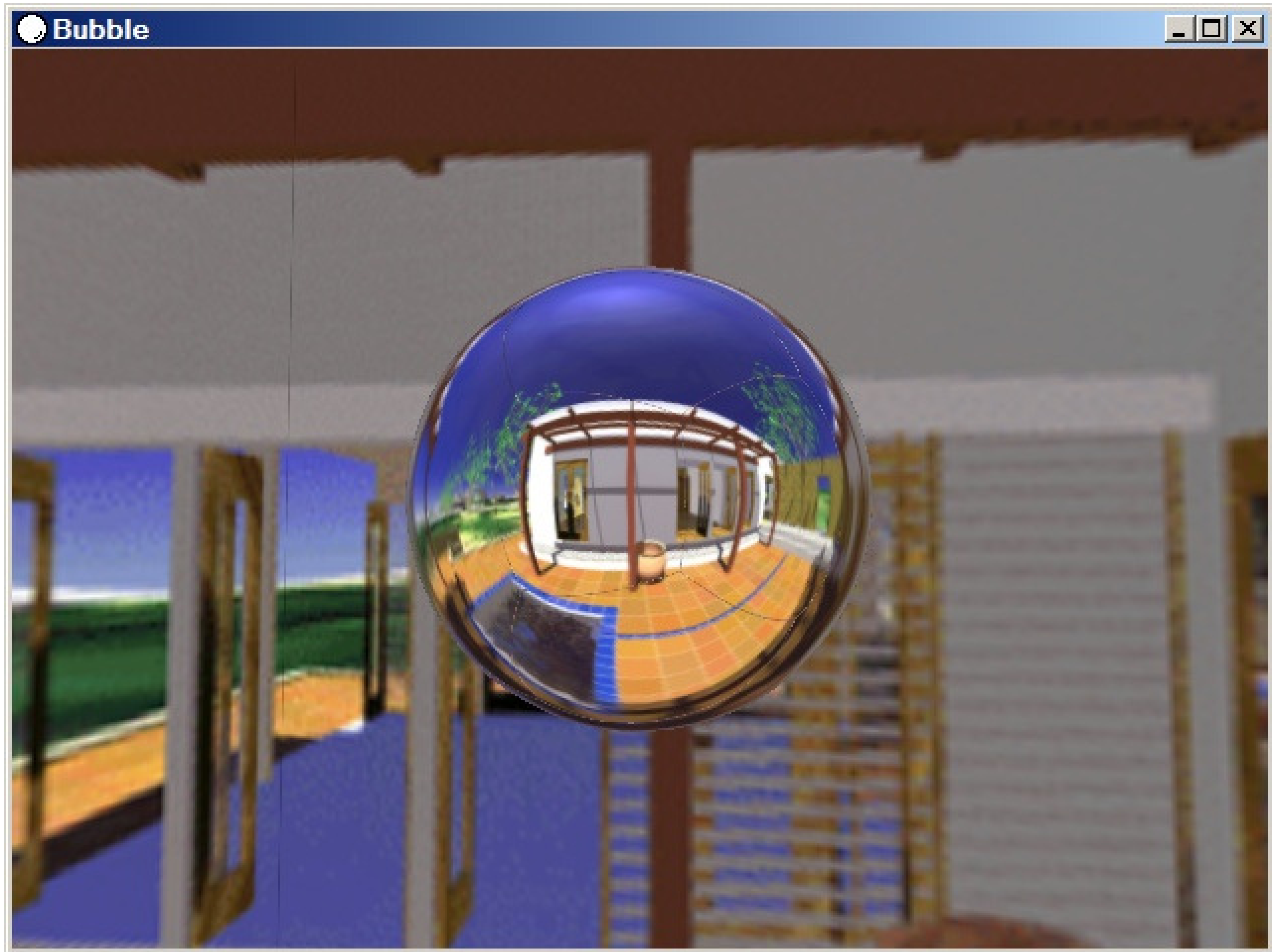


Cube map

Cubic vs. Spherical Maps

- Advantages of cube maps:
  - More even texel sample density causes less distortion, allowing for lower resolution maps
  - Easier to dynamically generate cube maps for real-time simulated reflections

Bubble Demo



http://download.nvidia.com/downloads/nZone/demos/nvidia/Bubble.zip

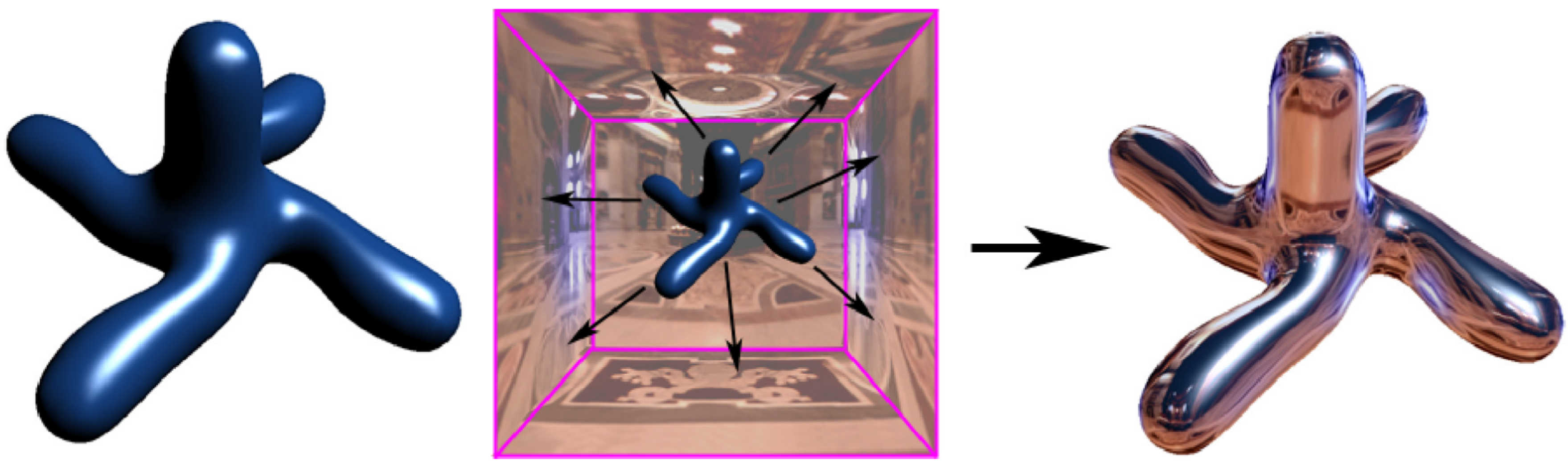
Cubic Environment Maps

Cube map look-up

- Given: light direction (x,y,z)
- Largest coordinate component determines cube map face
- Dividing by magnitude of largest component yields coordinates within face
- In GLSL:
  - Use (x,y,z) direction as texture coordinates to `samplerCube`

Reflection Mapping

- Simulates mirror reflection
- Computes reflection vector at each pixel
- Use reflection vector to look up cube map
- Rendering cube map itself is optional (application dependent)



Reflection mapping

Reflection Mapping in GLSL

Application Setup

- Load and bind a cube environment map

```
glBindTexture(GL_TEXTURE_CUBE_MAP, …);
glTexImage2D(GL_TEXTURE_CUBE_MAP_POSITIVE_X,…);
glTexImage2D(GL_TEXTURE_CUBE_MAP_NEGATIVE_X,…);
glTexImage2D(GL_TEXTURE_CUBE_MAP_POSITIVE_Y,…);
…
glEnable(GL_TEXTURE_CUBE_MAP);
```

Reflection Mapping in GLSL

Vertex shader

- Compute viewing direction
- Reflection direction
  - Use `reflect` function
- Pass reflection direction to fragment shader

Fragment shader

- Look up cube map using interpolated reflection direction

```
varying float3 refl;
uniform samplerCube envMap;
textureCube(envMap, refl);
```

Environment Maps as Light Sources

- Covered so far: shading of a specular surface

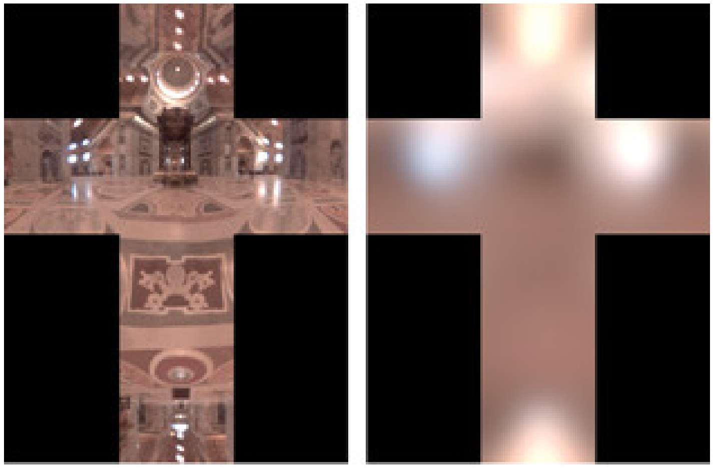
→ How do you compute shading of a diffuse surface?

Diffuse Irradiace Environment Map

- Given a scene with *k* directional lights, light directions $d_1..d_k$ and intensities $i_1..i_k$, illuminating a diffuse surface with normal *n* and color *c*
- Pixel intensity *B* is computed as: $B = c \sum_{j=1..k} \max(0, d_j \cdot n) i_j$
- Cost of computing *B* proportional to number of texels in environment map!
- → Precomputation of diffuse reflection
- Observations:
  - All surfaces with normal direction *n* will return the same value for the sum
  - The sum is dependent on just the lights in the scene and the surface normal
- Precompute sum for any normal *n* and store result in a second environment map, indexed by surface normal
- Second environment map is called *diffuse irradiance environment map*
- Allows to illuminate objects with arbitrarily complex lighting environments with single texture lookup

Diffuse Irradiace Environment Map

- Two cubic environment maps:
  - reflection map
  - diffuse map



- Diffuse shading vs. shading w/diffuse map

Source: http://http.developer.nvidia.com/GPUGems2/gpugems2_chapter10.html

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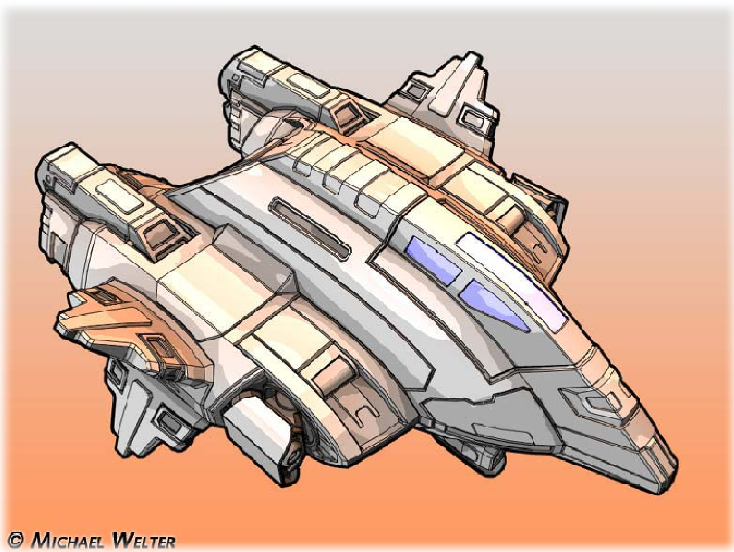
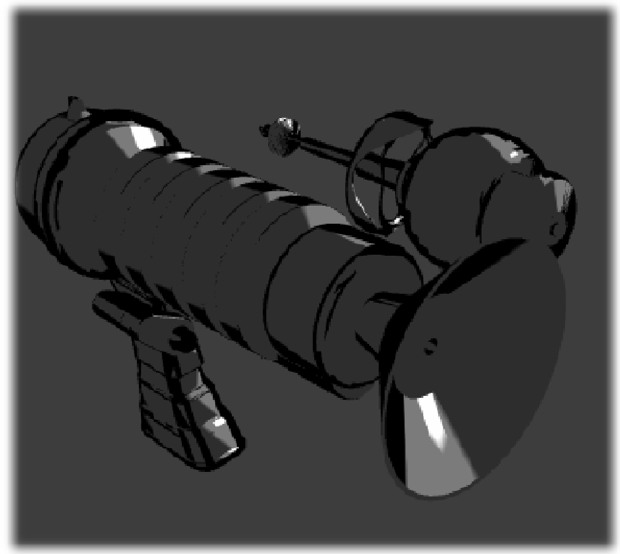
Toon Shading

- A.k.a. Cel Shading
- Simple cartoon-style shader
- Emphasizes silhouettes
- Discrete steps for diffuse shading, highlights
- Non-photorealistic rendering method (NPR)



Off-line toon shader



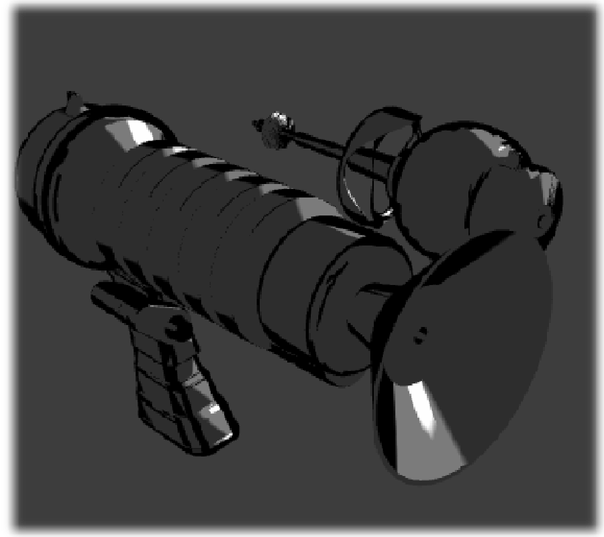
GLSL toon shader

Toon Shading Demo

http://www.bonzaisoftware.com/npr.html

Toon Shading

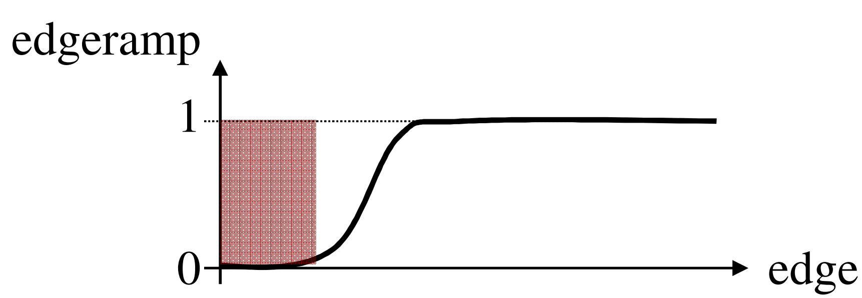
- Silhouette edge detection
  - Compute dot product of viewing direction $\mathbf{v}$ and normal $\mathbf{n}$



$$\text{edge} = \max(0, \mathbf{n} \cdot \mathbf{v})$$

  - Use 1D texture to define edge ramp

uniform sample1D edgeramp; e=texture1D(edgeramp,edge);



Toon Shading

- Compute diffuse and specular shading

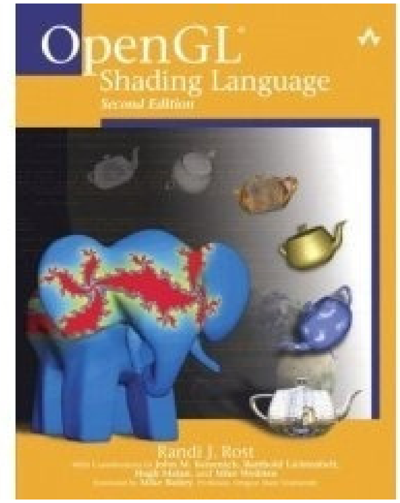
$$\text{diffuse} = \mathbf{n} \cdot \mathbf{L} \qquad \text{specular} = (\mathbf{n} \cdot \mathbf{h})^s$$

- Use 1D textures diffuseramp, specularramp to map diffuse and specular shading to colors
- Final color:

```
uniform sampler1D diffuseramp;
uniform sampler1D specularramp;
c = e * (texture1D(diffuse,diffuseramp) +

texture1D(specular,specularramp));
```

More on Shaders



- OpenGL shading language book
- NVidia shader library
  - Most shaders are in HLSL (DirectX's shader language)
  - http://developer.download.nvidia.com/shaderlibrary/webpages/shader_library.html
- NVidia Cg toolkit
  - Current version: Cg 2.1
  - Predecessor of GLSL
  - Lots of example shaders

  http://developer.nvidia.com/object/cg_toolkit.html

Next Lecture (Tuesday November 16th)

- Shadow mapping
- Shadow volumes