CS 378: Computer Game Technology

Texture, Bump, Light, Environment Maps

Spring 2012

Texture Mapping

- The problem: Colors, normals, etc. are only specified at vertices. How do we add detail between vertices?
- Solution: Specify the details in an image (the texture) and specify how to apply the image to the geometry (the map)
- Works for shading parameters other than color, as we shall see
  - The basic underlying idea is the mapping

Basic Mapping

- The texture lives in a 2D space
  - Parameterize points in the texture with 2 coordinates: (s,t)
- Define the mapping from (x,y,z) in world space to (s,t) in texture space
- With polygons:
  - Specify (s,t) coordinates at vertices
  - Interpolate (s,t) for other points based on given vertices

I assume you recall…

- Texture sampling (aliasing) is a big problem
  - Mipmaps and other filtering techniques are the solution
- The texture value for points that map outside the texture image can be generated in various ways
  - Repeat, Clamp, …
- Texture coordinates are specified at vertices and interpolated across triangles
- Width and height of texture images is constrained (powers of two, sometimes must be square)

Multitexturing

- Some effects are easier to implement if multiple textures can be applied
  - Future lectures: Light maps, bump maps, shadows, …
- Multitexturing hardware provides a pipeline of texture units, each of which applies a standard texture map operation
  - Fragments are passed through the pipeline with each step working on the result of the previous stage
  - Texture parameters are specified independently for each unit, further improving functionality
  - For example, the first stage applies a color map, the next modifies the illumination to simulate bumps, the third modifies opacity
  - Not the same as multi-pass rendering - all applied in one pass

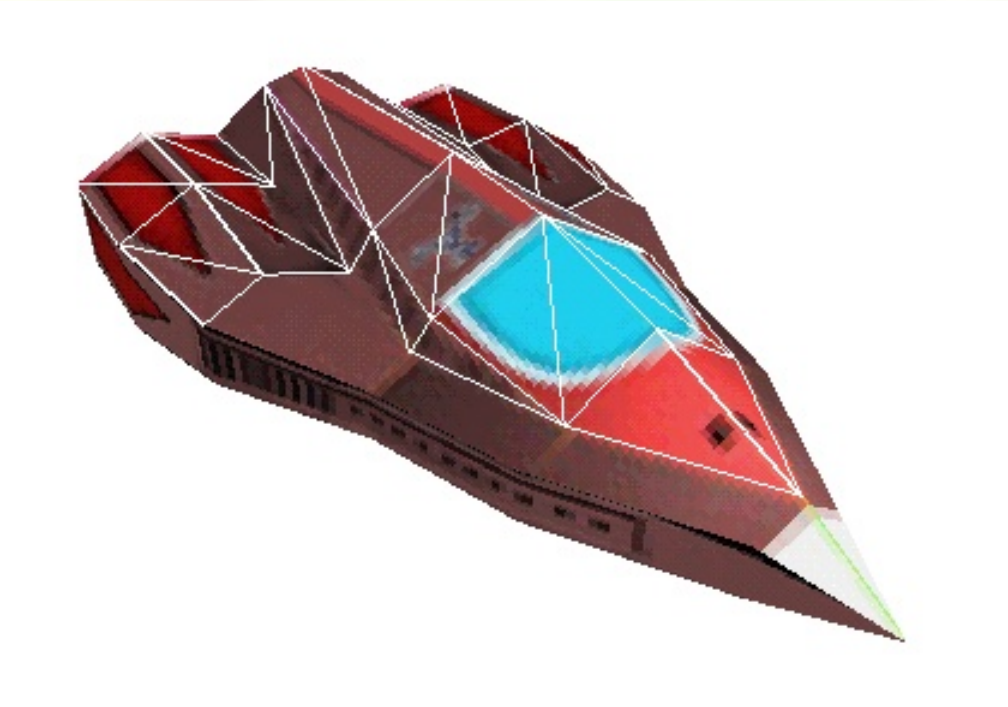
Pixel Shaders

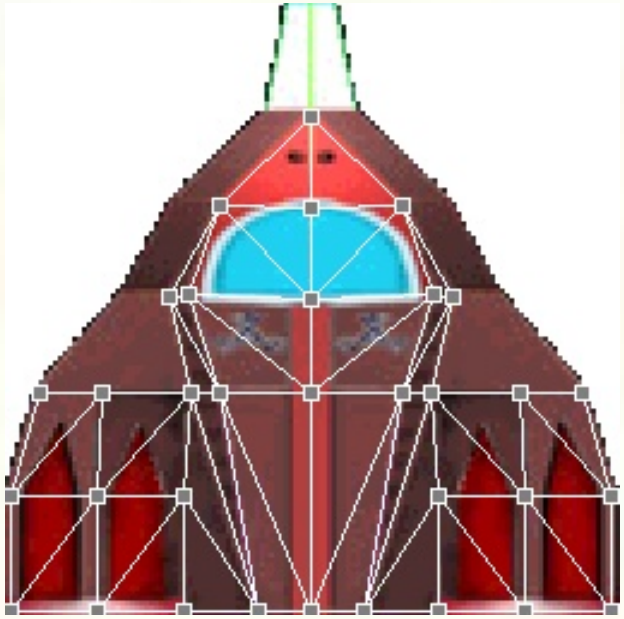
- Current generation hardware provides pixel shaders
- A pixel shader operates on a fragment
  - A single pixel (or sub-pixel) that has already been "lit"
- It can compute texture coordinates, do general texture look-ups, modify color/depth/opacity, and some other functions
- More general than multi-texturing and very powerful

Textures in Games

- The game engine provides some amount of texture support
- Artists are supplied with tools to exploit this support
  - They design the texture images
  - They specify how to apply the image to the object
- Commonly, textures are supplied at varying resolutions to support different hardware performance
  - Note that the texture mapping code does not need to be changed - just load different sized maps at run time
- Textures are, without doubt, the most important part of a game's look

Example Texture Tool





Packing Textures

- Problem: The limits on texture width/height make it inefficient to store many textures
  - For example: long, thin objects
- Solution: Artists pack the textures for many objects into one image
  - The texture coordinates for a given object may only index into a small part of the image
  - Care must be taken at the boundary between sub-images to achieve correct blending
  - Mipmapping is restricted
  - Best for objects that will be at known resolution (weapons, for instance)

Combining Textures

Texture Matrix

- Normally, the texture coordinates given at vertices are interpolated and directly used to index the texture
- The texture matrix applies a homogeneous transform to the texture coordinates before indexing the texture
- What use is this?

Animating Texture (method 1)

- Loading a texture onto the graphics card is very expensive
- But once there, the texture matrix can be used to "transform" the texture
  - For example, changing the translation can select different parts of the texture
- If the texture matrix is changed from frame to frame, the texture will appear to move on the object
- This is particularly useful for things like flame, or swirling vortices, or pulsing entrances, …

Projective Texturing

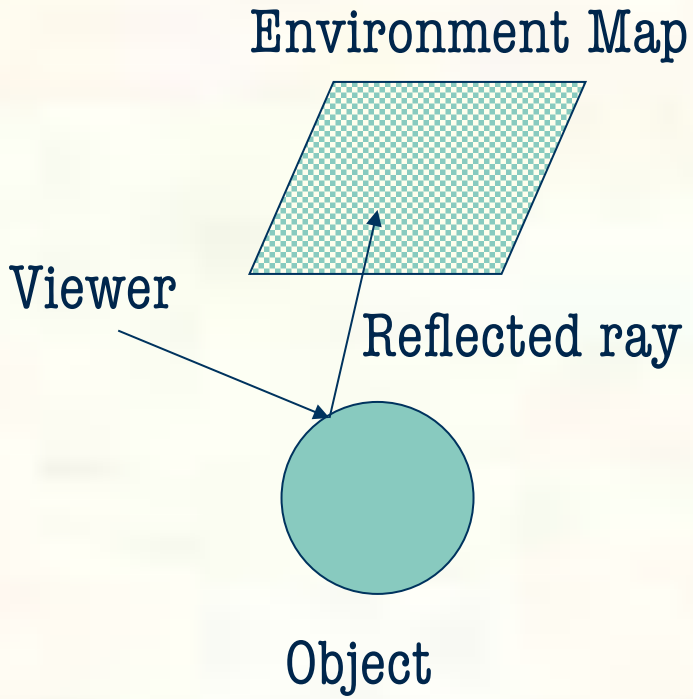
- The texture should appear to be projected onto the scene, as if from a slide projector
- Solution:
  - Equate texture coordinates with world coordinates
  - Think about it from the projector's point of view: wherever a world point appears in the projector's view, it should pick up the texture
  - Use a texture matrix equivalent to the projection matrix for the projector – maps world points into texture image points
- Details available in many places
- Problems? What else could you do with it?

What's in a Texture?

- The graphics hardware doesn't know what is in a texture
  - It applies a set of operations using values it finds in the texture, the existing value of the fragment (pixel), and maybe another color
  - The programmer gets to decide what the operations are, within some set of choices provided by the hardware
  - Examples:
    - the texture may contain scalar "luminance" information, which simply multiplies the fragment color. What use is this?
    - the texture might contain "alpha" data that multiplies the fragment's alpha channel but leaves the fragment color alone. What use is this?

Environment Mapping

- Environment mapping produces reflections on shiny objects
- Texture is transferred in the direction of the reflected ray from the environment map onto the object
- Reflected ray: R=2(N·V)N-V
- What is in the map?



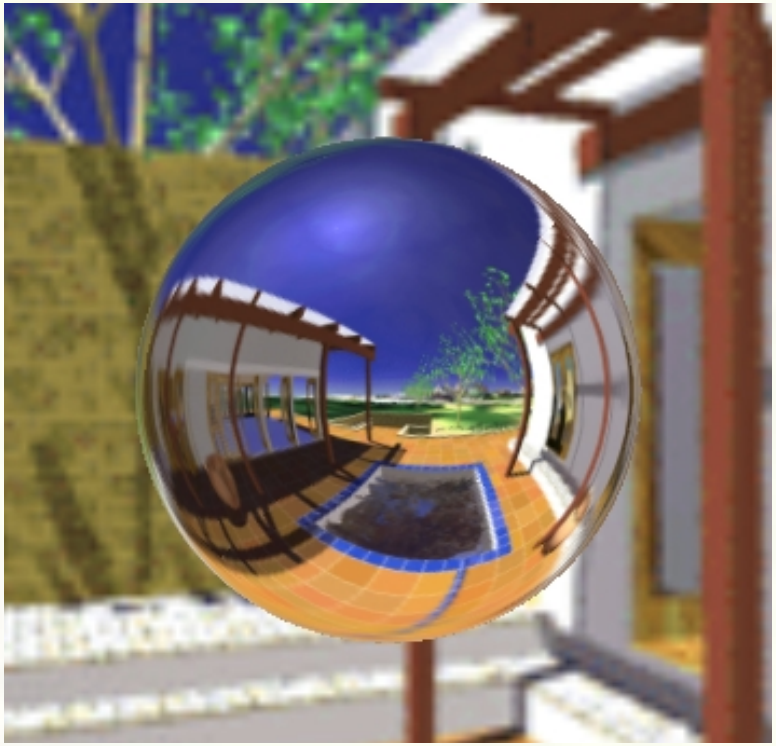
Approximations Made

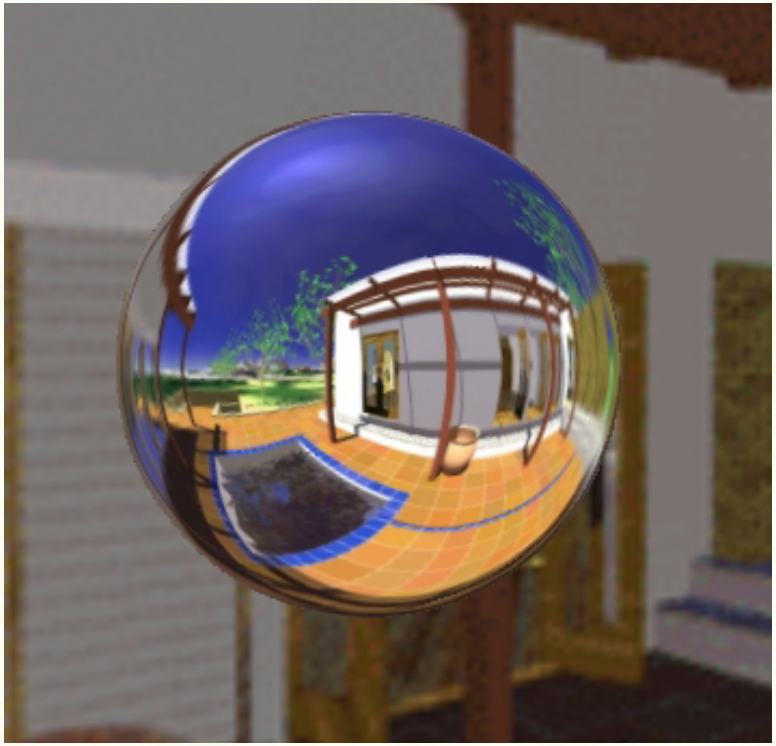
- The map should contain a view of the world with the point of interest on the object as the eye
  - We can't store a separate map for each point, so one map is used with the eye at the center of the object
  - Introduces distortions in the reflection, but the eye doesn't notice
  - Distortions are minimized for a small object in a large room
- The object will not reflect itself
- The mapping can be computed at each pixel, or only at the vertices

Environment Maps

- The environment map may take one of several forms:
  - Cubic mapping
  - Spherical mapping (two variants)
  - Parabolic mapping
- Describes the shape of the surface on which the map "resides"
- Determines how the map is generated and how it is indexed
- What are some of the issues in choosing the map?

Example

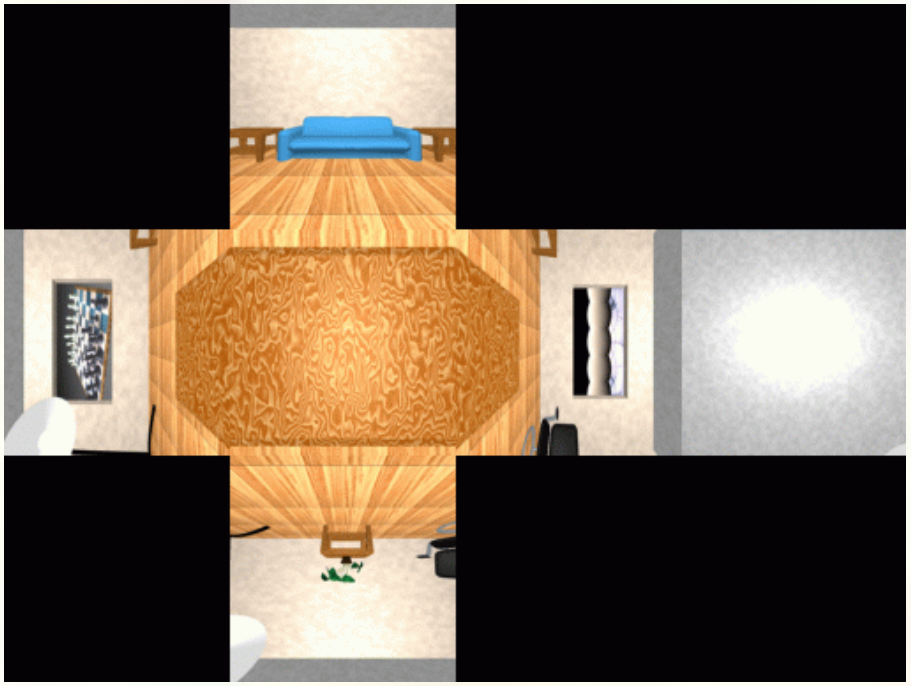




Cube Mapping

- The map resides on the surfaces of a cube around the object
  - Typically, align the faces of the cube with the coordinate axes
- To generate the map:
  - For each face of the cube, render the world from the center of the object with the cube face as the image plane
    - Rendering can be arbitrarily complex (it's off-line)
  - Or, take 6 photos of a real environment with a camera in the object's position
    - Actually, take many more photos from different places the object might be
    - Warp them to approximate map for all intermediate points
- Remember The Abyss and Terminator 2?

Cube Map Example



Indexing Cubic Maps

- Assume you have R and the cube's faces are aligned with the coordinate axes, and have texture coordinates in [0,1]x[0,1]
  - How do you decide which face to use?
  - How do you decide which texture coordinates to use?
- What is the problem using cubic maps when texture coordinates are only computed at vertices?