Lecture 16: Hardware Rendering and Projects

Fall 2004
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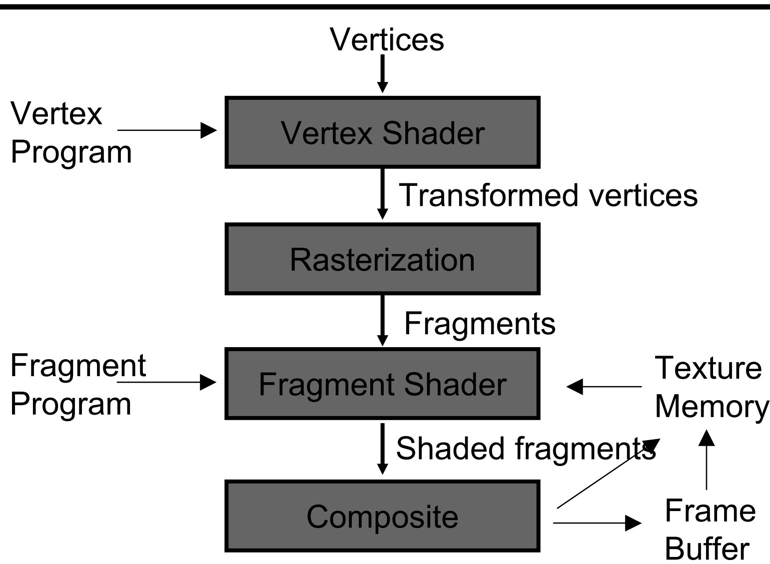
Announcements

- Project proposal due Oct 26
- Contact me if you are still unsure

New Programmable GPUs

- Pipelined and parallel
  - Current pipeline 600-800 stages deep!
- Branching/looping??
- Floating point arithmetic
- Programmable Vertex and Shader programs
- Essentially writing assembly/C code

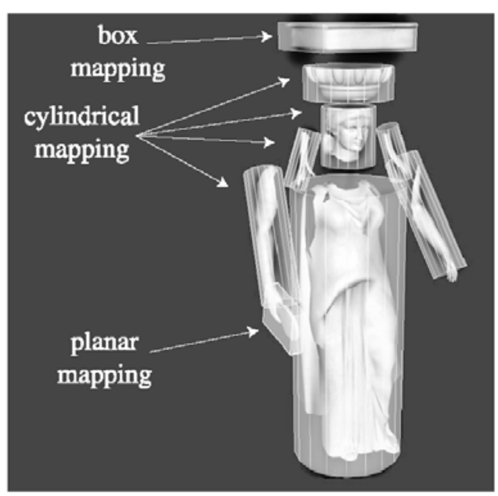
New OpenGL



Key Hardware Capabilities

- Z-Buffering
- Accumulation Buffer
- Antialiasing
- Transparency/Compositing
- Stencil Buffer
- Filtered Texturing

Texture Mapping



Images courtesy Tito Pagan

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Many types of Texture Maps

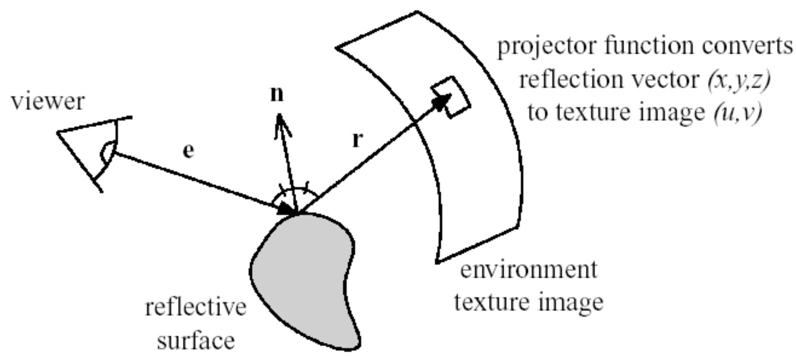
- Texture modulates diffuse coefficients in shading model
- Textures can modulate
  - Normals: bump mapping and normal mapping
  - Positions: displacement mapping
  - Lighting: environment mapping

Environment Map

- Want to compute reflections of environment on surfaces
  - Planar surfaces?
  - Curved surfaces

- Assumptions:
  - Environment Map represents objects at infinity
- Index into EM using reflection vector

Environment Mapping



- EM gives reflections in curved surfaces
  - Not very good for flat surfaces

Env Map Algorithm

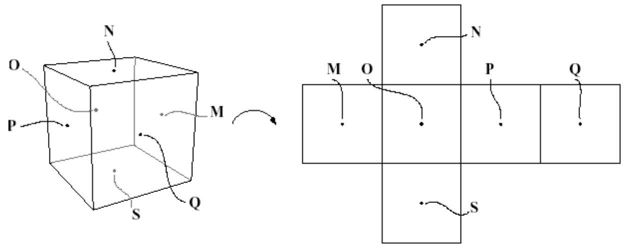
- Generate 2D environment map
  - Spherical, cubical, paraboloid
- For each pixel on a reflective object
  - Find N on surface of object
  - Compute R from V and N: R = V – 2 (N.V) N
  - Index into EM using R
  - Modulate pixel color

Cube Mapping

- The norm on modern hardware
- Place camera in center of the environment
- Project environment onto cube sides
  - 90 degree field of view
  - Cost?

Picking the cube map

- Compute R
  - Don't need to normalize it
- Pick the largest component (magnitude)
  - What does it mean?
- Scale other two components to [0,1]

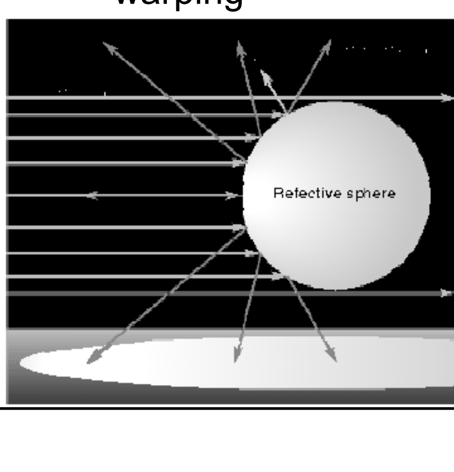


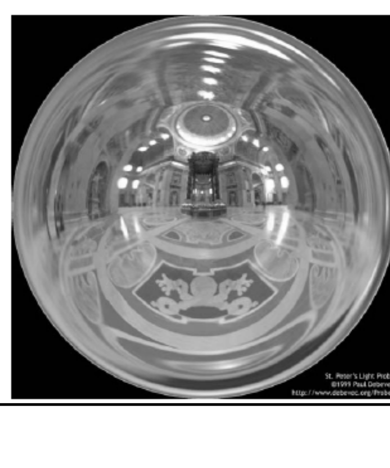
Looking up EM

- If triangle spans multiple EM faces?
- Per-pixel based

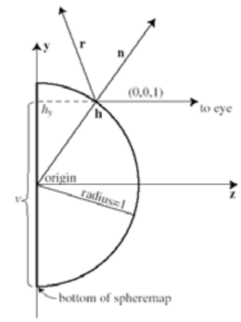
Sphere Maps

- Assume viewing is from infinity
- Capture reflections
  - Creation uses photographs or ray tracing or warping





Sphere Mapping Example

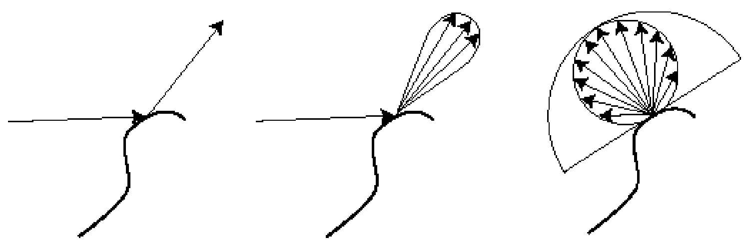


Irradiance Mapping

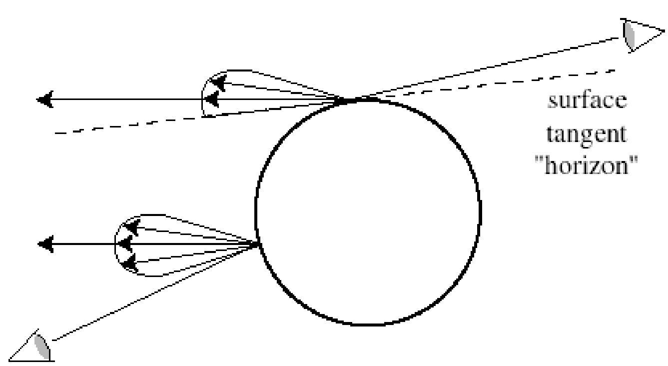
- Environment map → radiance
- Filter this map → irradiance (diffuse lighting)
- Fast diffuse and ambient (just a lookup, or eqn)

Filtered Reflection Mapping

- Blur EM for gloss



Lobe Filtering has problems



Techniques to Render with EM

- Ambient Occlusion
- Structured Importance Sampling

Use hardware for better illumination

- Multi-pass rendering
- Multi-texture rendering
  - Dependent texture reads

Multi-Pass Texturing

- Limits to what hardware can do in 1 pass
- So multi-pass texturing
  - Each pass does some part of shading
  - Outputs a "fragment": rgb, alpha, z
  - Add or blend with previous pass
- For example
  - 1^{st} pass: diffuse
  - 2^{nd} pass: specular

Why multi-pass?

- Scalable

Quake III Engine

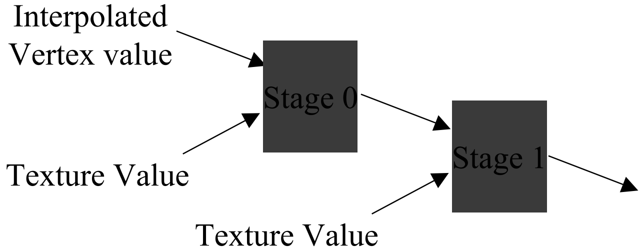
1. Passes 1-4: accumulate bump map
2. Pass 5: Diffuse lighting
3. Pass 6: Base texture
4. Pass 7: Specular lighting
5. Pass 8: Emissive lighting
6. Pass 9: Volumetric lighting

Multi-pass rendering

Diefenbach 1997

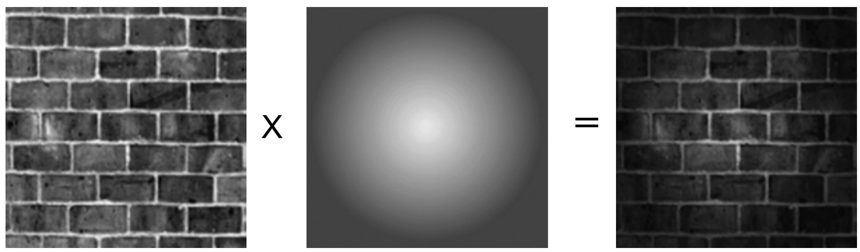
Multitexturing

- Modern hardware can apply multiple texture values in each pass
- Series of texture stages



Multitexture Example: Light Maps

- Two separate textures
  - Material and lighting
  - Can be different resolutions



J.L.Mitchell, M. Tatro, and I. Bullard

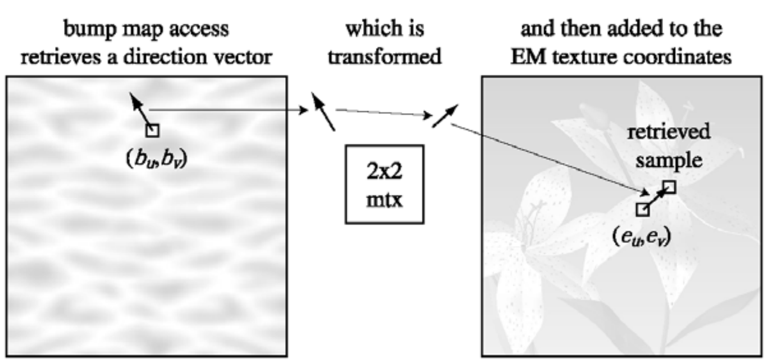
Light Maps

- Light Maps used in games
- Cost: extra texture read
- Benefit:
  - Can use it to capture global illumination
  - Can store different resolutions of textures
  - Maybe animate texture coordinates

Dependent Texture Reads

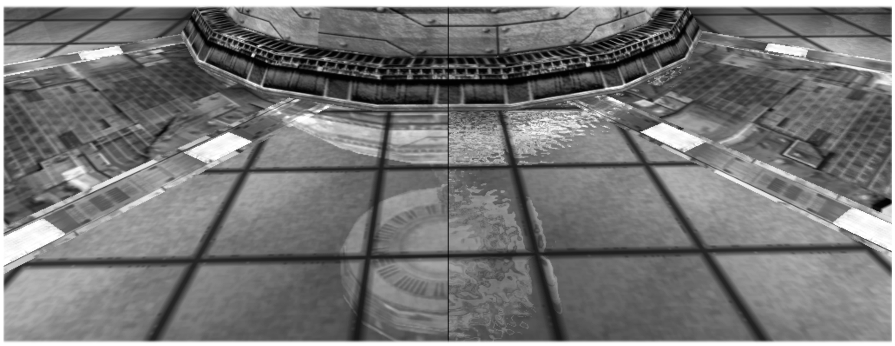
- Introduced in 1999
- Number of passes proportional to the longest "chain" of operations you need
- Dependent texture reads helps
  - Can read a texture
  - Transform it
  - And then read another texture based on transformed value!
  - Much more efficient

Dependent Texture Reads



Reflections and Normal Maps

Environment Map Bump Mapping (EMBM)



GPU Rendering

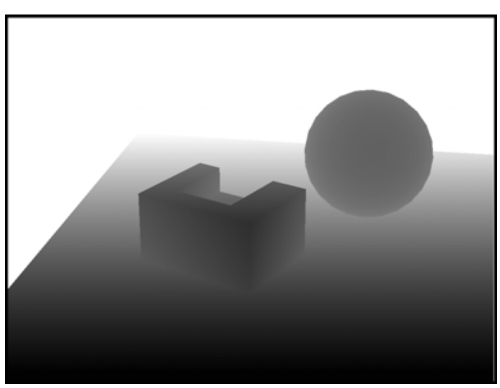
- Rendering high-quality illumination on GPUs is getting more effective
- Attempts at
  - Ray tracing on GPUs
  - Photon mapping on GPUs
  - …

Future Topics in Course

- Shadows
  - Shadow maps
  - Shadow volumes
  - Soft shadows
- Many lights
  - Rendering environment maps
- NPR

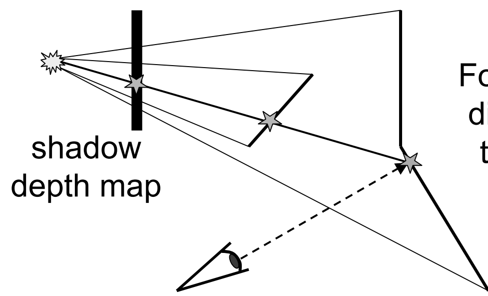
Shadow Maps

- Introduced by Lance Williams (SIGGRAPH 1978)



Using the Shadow Map

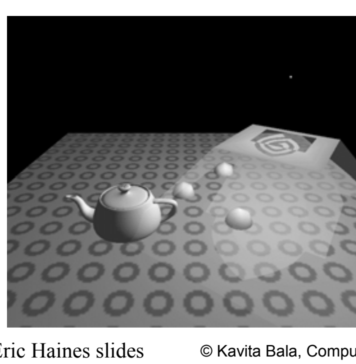
- When scene is viewed, check viewed location in light's shadow buffer
  - If point's depth is (epsilon) greater than shadow depth, object is in shadow

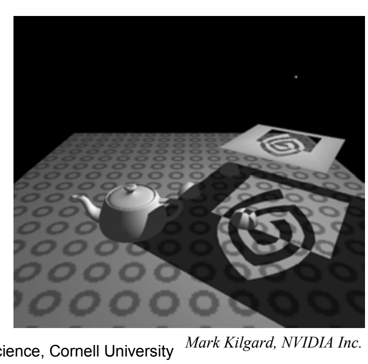


For each pixel, compare distance to light with the depth stored in the shadow map

Shadow Volumes

- Crow 1977
- Can cast shadows onto curved surfaces



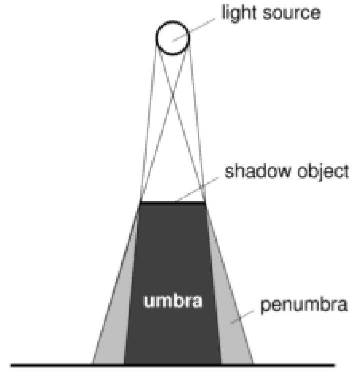


From Eric Haines slides

Mark Kilgard, NVIDIA Inc.

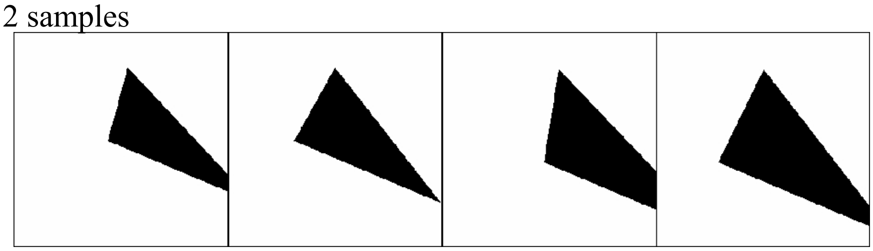
Soft Shadows

- Soft shadows appear natural
- Hard to get soft shadows in hardware
- Slow in software

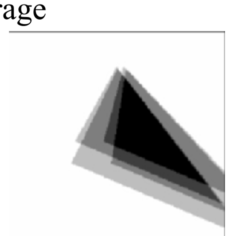


Soft Shadows: Heckbert/Herf

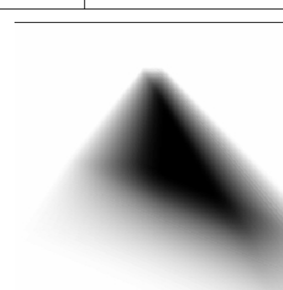
2 x 2 samples



average



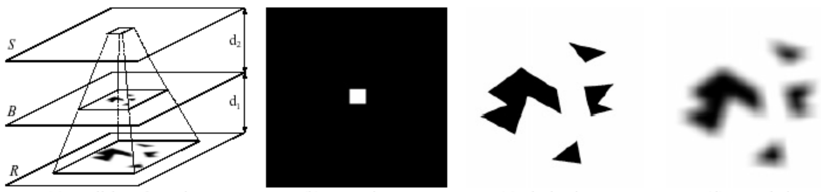
16 x 16 samples



Images courtesy of Michael Herf and Paul Heckbert

Soler and Sillion

- Shadows as convolution



(a) Parallel configuration (b) Source image (c) Blocker image (d) Convolution

Penumbra Maps

Uses fragment program

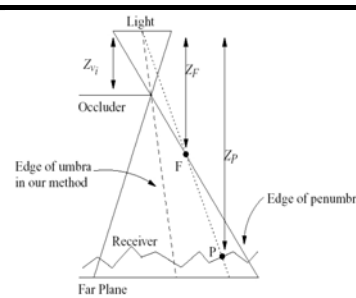
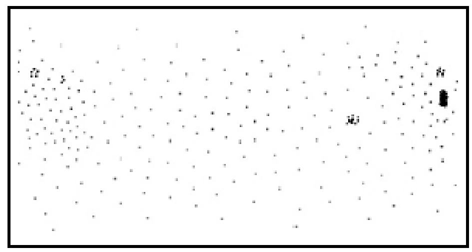


Figure 8: *Using a standard shadow map results in hard shadows (left), add a penumbra map to get soft shadows (right). Using a 10k polygon dragon model for the shadows and a 50k polygon model to render, we get 14.5 fps at 1024x1024.*

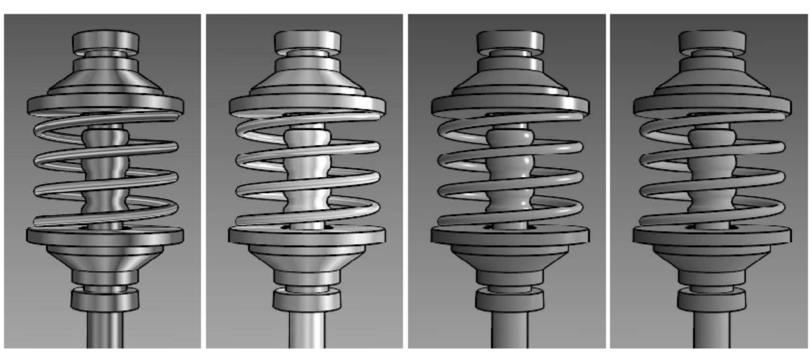
Environment Map Sampling

The Galileo map



Structured importance sampling w/ 300 samples

Other topics: NPR



- Non-photorealistic lighting model

Future Topics in Course

- High-complexity rendering
  - Points
- Image-based Rendering

Other topics: Point-based Rendering

- Use points instead of polygons
- Much more compact and robust
- How to render?
  - Splat points in hardware

Other topics: Image-Based Rendering

- Use photographs to capture complex scenes

Project Ideas

- Rendering:
  - Photon mapping
  - BRDF factorization for sampling
  - Shadow algorithms for soft shadows
  - Sampling and rendering with environment maps
  - Silhouette finding and rendering with modes
- NPR
  - Silhouette finding
  - Contour finding

Project Ideas

- High-complexity rendering
  - Point-based rendering
- Texture for complexity
  - Texture synthesis
- Acceleration structures
  - Support for dynamics