Deferred Shading

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CLIMAX

Overview

- Don’t bother with any lighting while drawing scene geometry
- Render to a “fat” framebuffer format, using multiple rendertargets to store data such as the position and normal of each pixel
- Apply lighting as a 2D postprocess, using these buffers as input

Comparison: Single Pass Lighting

```
For each object:
   Render mesh, applying all lights in one shader
```

- Good for scenes with small numbers of lights (eg. outdoor sunlight)
- Difficult to organize if there are many lights
- Easy to overflow shader length limitations

Comparison: Multipass Lighting

```
For each light:
   For each object affected by the light:
       framebuffer += object * light
```

- Worst case complexity is *num_objects* * *num_lights*
- Sorting by light or by object are mutually exclusive: hard to maintain good batching
- Ideally the scene should be split exactly along light boundaries, but getting this right for dynamic lights can be a lot of CPU work

Deferred Shading

```
For each object:
   Render to multiple targets

For each light:
   Apply light as a 2D postprocess
```

- Worst case complexity is *num_objects* + *num_lights*
- Perfect batching
- Many small lights are just as cheap as a few big ones

Multiple Render Targets

- Required outputs from the geometry rendering are:
  - Position
  - Normal
  - Material parameters (diffuse color, emissive, specular amount, specular power, etc)
- This is not good if your lighting needs many input values! (spherical harmonics would be difficult)

Fat Framebuffers

- The obvious rendertarget layout goes something like:
  - Position A32B32G32R32F
  - Normal A16B16G16R16F
  - Diffuse color A8R8G8B8
  - Material parameters A8R8G8B8
- This adds up to 256 bits per pixel. At 1024x768, that is 24 meg, even without antialiasing!
- Also, current hardware doesn't support mixing different bit depths for multiple rendertargets

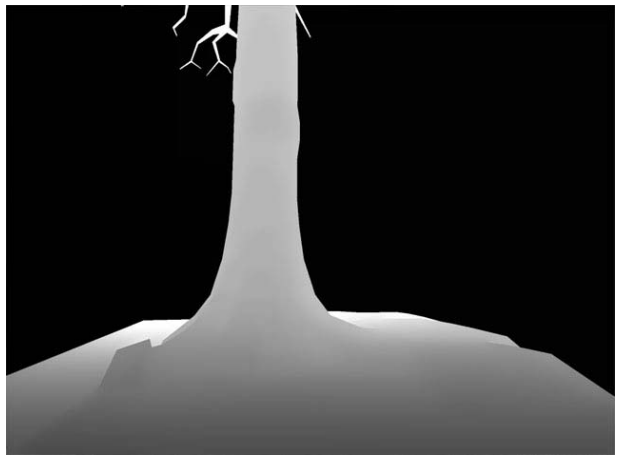
Framebuffer Size Optimizations

- Store normals in A2R10G10B10 format
- Material attributes could be palettized, then looked up in shader constants or a texture
- No need to store position as a vector3:
  - Each 2D screen pixel corresponds to a ray from the eyepoint into the 3D world (think raytracing)
  - You inherently know the 2D position of each screen pixel, and you know the camera settings
  - So if you write out the distance along this ray, you can reconstruct the original worldspace position

My Framebuffer Choices

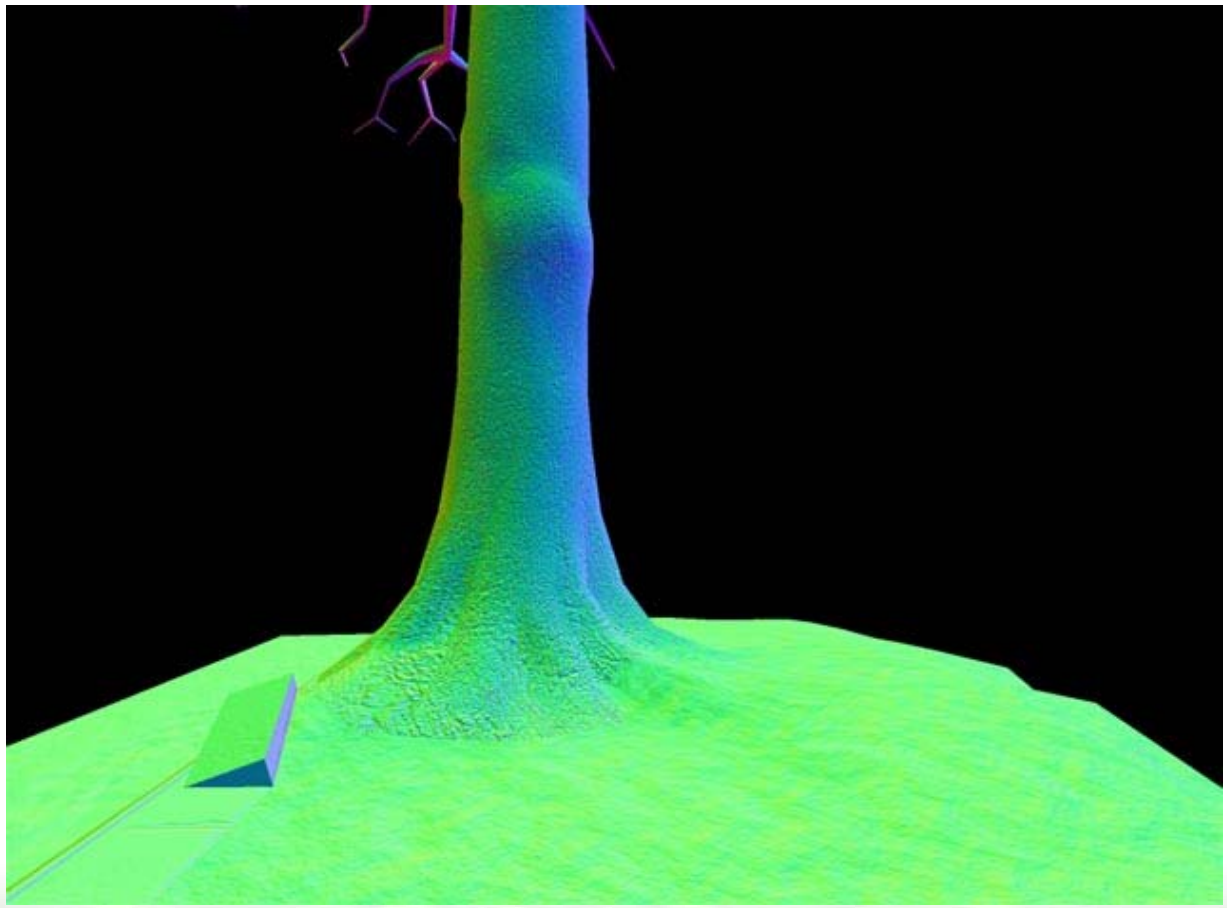
- 128 bits per pixel = 12 meg @ 1024x768:
  - Depth — R32F
  - Normal + scattering — A2R10G10B10
  - Diffuse color + emissive — A8R8G8B8
  - Other material parameters — A8R8G8B8
- My material parameters are specular intensity, specular power, occlusion factor, and shadow amount. I store a 2-bit subsurface scattering control in the alpha channel of the normal buffer

Depth Buffer



Specular Intensity / Power

Normal Buffer



Diffuse Color Buffer

Deferred Lighting Results

How Wasteful…

- One of my 32 bit buffers holds depth values
- But the hardware is already doing this for me!
- It would be nice if there was an efficient way to get access to the existing contents of the Z buffer
- Pretty please? ☺

Global Lights

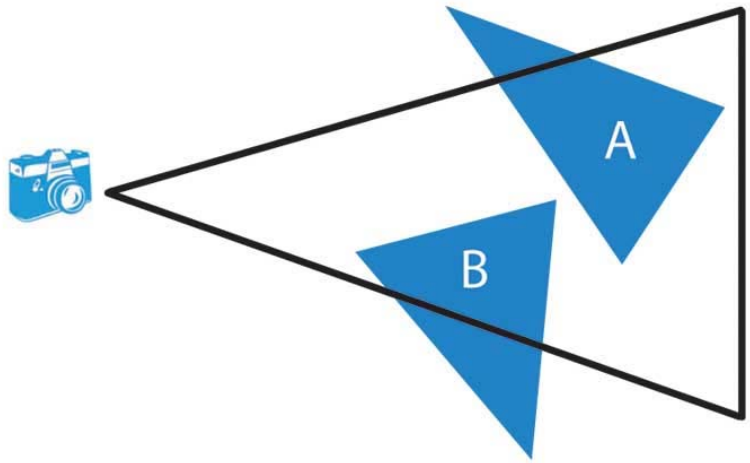
- Things like sunlight and fog affect the entire scene
- Draw them as a fullscreen quad
- Position, normal, color, and material settings are read from texture inputs
- Lighting calculation is evaluated in the pixel shader
- Output goes to an intermediate lighting buffer

Local Lights

- These only affect part of the scene
- We only want to render to the affected pixels
- This requires projecting the light volume into screenspace. The GPU is very good at that sort of thing…
- At author time, build a simple mesh that bounds the area affected by the light. At runtime, draw this in 3D space, running your lighting shader over each pixel that it covers

Convex Light Hulls

- The light bounding mesh will have two sides, but it is important that each pixel only gets lit once
- As long as the mesh is convex, backface culling can take care of this



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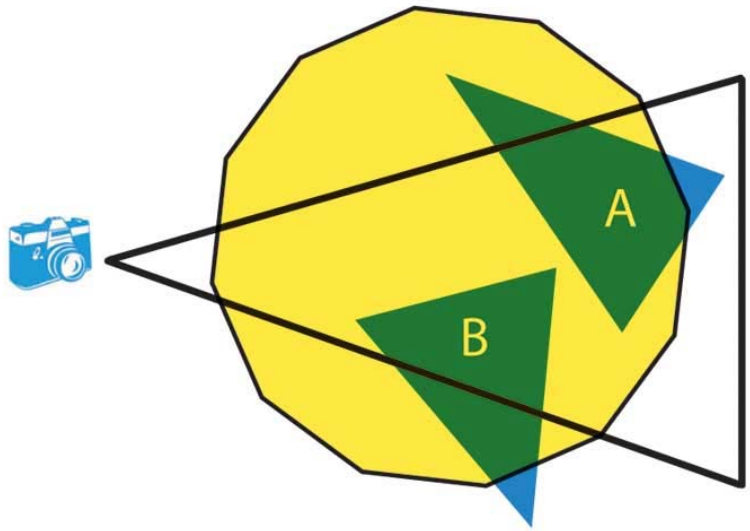
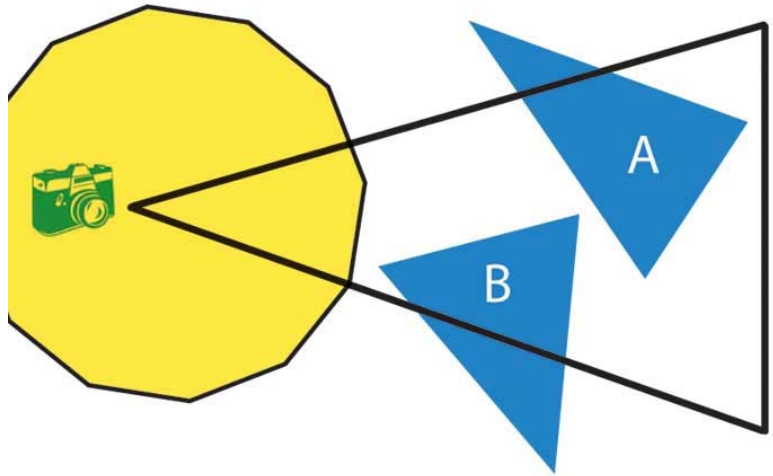


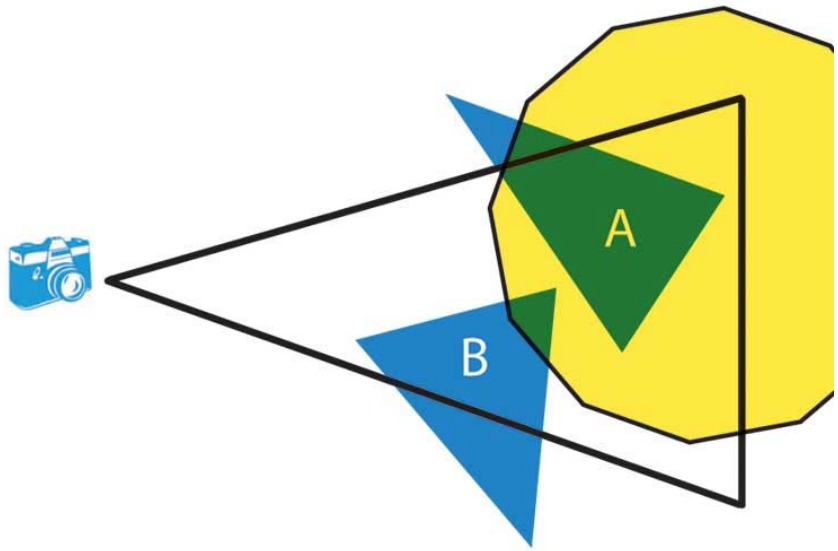
Convex Light Hulls #2

- If the camera is inside the light volume, draw backfaces



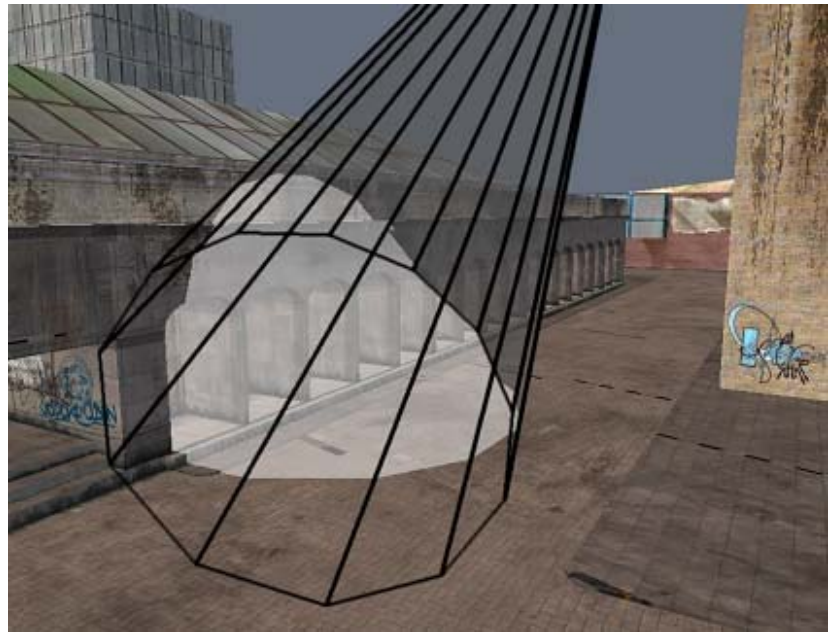
Convex Light Hulls #3

- If the light volume intersects the far clip plane, draw frontfaces
- If the light volume intersects both near and far clip planes, your light is too big!



Volume Optimization

- We only want to shade the area where the light volume intersects scene geometry
- There is no need to shade where the volume is suspended in midair
- Or where it is buried beneath the ground

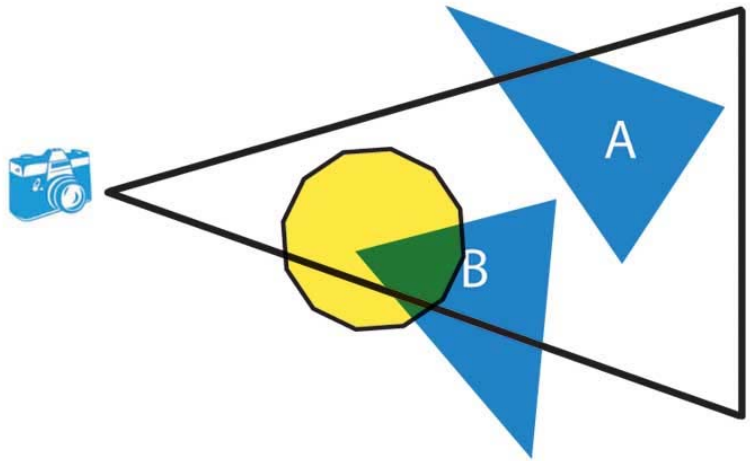


Stencil Light Volumes

- This is exactly the same problem as finding the intersection between scene geometry and an extruded shadow volume
- The standard stencil buffer solution applies
- But using stencil requires changing renderstate for each light, which prevents batching up multiple lights into a single draw call
- Using stencil may or may not be a performance win, depending on context

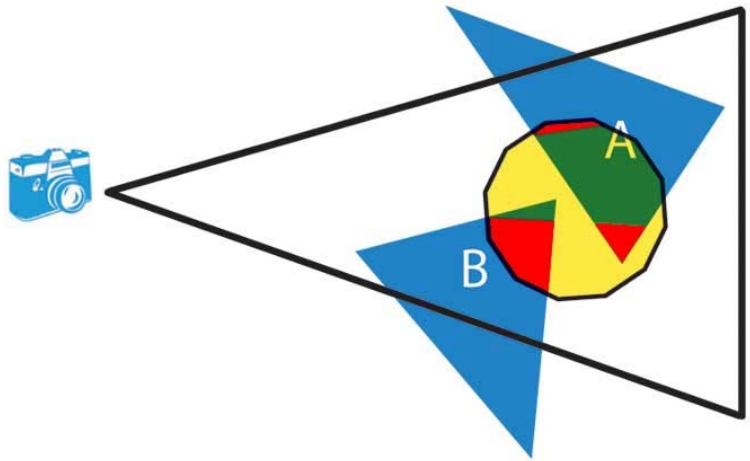
Light Volume Z Tests

- A simple Z test can get things half-right, without the overhead of using stencil
- When drawing light volume backfaces, use D3DCMP_GREATER to reject “floating in the air” portions of the light



Light Volume Z Tests #2

- If drawing frontfaces, use D3DCMP_LESS to reject “buried underground” light regions
- Which is faster depends on the ratio of aboveground vs. underground pixels: use a heuristic to make a guess



Alpha Blending

- This is a big problem!
- You could simply not do any lighting on alpha blended things, and draw them after the deferred shading is complete. The emissive and occlusion material controls are useful for crossfading between lit and non-lit geometry
- The return of stippling?
- Depth peeling is the ultimate solution, but is prohibitively expensive at least for the time being

High Dynamic Range

- You can do deferred shading without HDR, but that wouldn’t be so much fun
- Render your scene to multiple 32 bit buffers, then use a 64 bit accumulation buffer during the lighting phase
- Unfortunately, current hardware doesn’t support additive blending into 64 bit rendertargets
- Workaround: use a pair of HDR buffers, and simulate alpha blending in the pixel shader

DIY Alpha Blending

- Initialize buffers A and B to the same contents
- Set buffer A as a shader input, while rendering to B, and roll your own blend at the end of the shader
- This only works as long as your geometry doesn't overlap in screenspace
- When things do overlap, you have to copy all modified pixels from B back into A, to make sure the input and output buffers stay in sync
- This is slow, but not totally impractical as long as you sort your lights to minimize screenspace overlaps

HDR Results

Volumetric Depth Tests

- Neat side effect of having scene depth available as a shader input
- Gradually fade out alpha as a polygon approaches the Z fail threshold
- No more hard edges where alpha blended particles intersect world geometry!

Deferred Shading Advantages

- Excellent batching
- Render each triangle exactly once
- Shade each visible pixel exactly once
- Easy to add new types of lighting shader
- Other kinds of postprocessing (blur, heathaze) are just special lights, and fit neatly into the existing framework

The Dark Side

- Alpha blending is a nightmare!
- Framebuffer bandwidth can easily get out of hand
- Can’t take advantage of hardware multisampling
- Forces a single lighting model across the entire scene (everything has to be 100% per-pixel)
- Not a good approach for older hardware
- But will be increasingly attractive in the future…

The End

- Any questions?