In-Game Special Effects and Lighting

Introduction

- Tomas Arce

- *Special Thanks*
  - Matthias Wloka
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What Is Per-Pixel Lighting

- Bad name
  - Texel-lighting is more accurate
- Texture resolution matters -- tiling helps
- Complex operation done per-pixel basis
  - Texture lookups, dp3, and pixel shaders
- Use colors as data

What Is Per-Pixel Lighting *2 of 2*

- Encode pixel-normals in texture, fill RGB as:
  R=Normal.X, G=Normal.Y, B=Normal.Z
- Light dir is also encoded, fill vertex color as:
  R=LightDir.X, G = LightDir.Y, B = LightDir.Z
- Now we can do:
  (Texture.Texel) dot (Vertex.Color)

Why Is Per-Pixel Better?

- Per-vertex light is faster and more flexible but lacks resolution

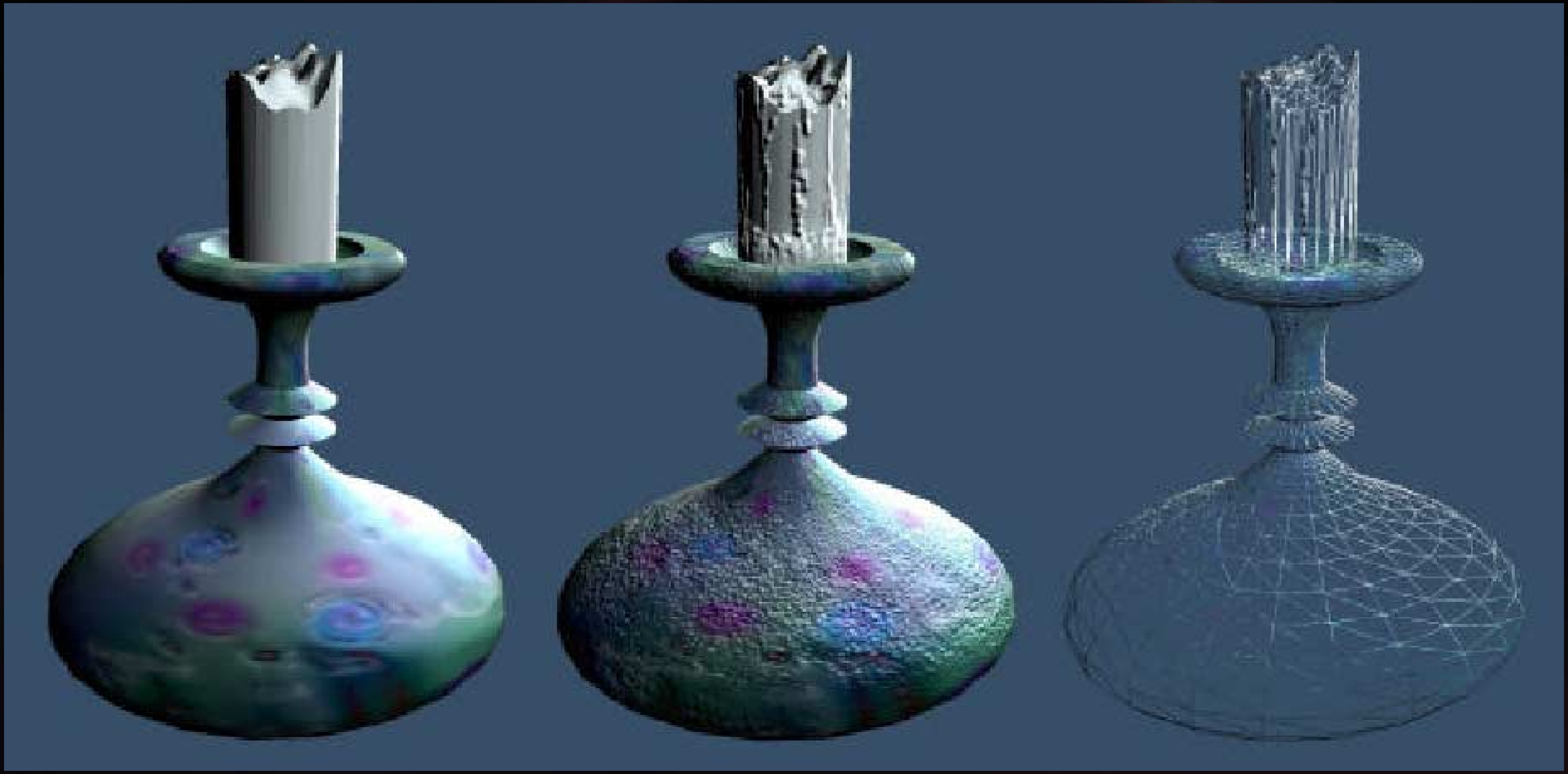
- Light-maps have pit-falls
  - No real specular
  - Low resolution
  - Doesn’t work for dynamic objects

- Projected textures don’t give much detail for the surface

Why Is Per-Pixel Better? *2 of 3*

- Detail. Detail. Detail.
- ppLighting needs few polygons per-mesh
  - Simplifies collision, stencil shadows, and memory
- Bump mapping is a subset of the ppLighting
  - “Normal maps”
- Normal maps handle different types of lights and surfaces well

Why Is Per-Pixel Better?

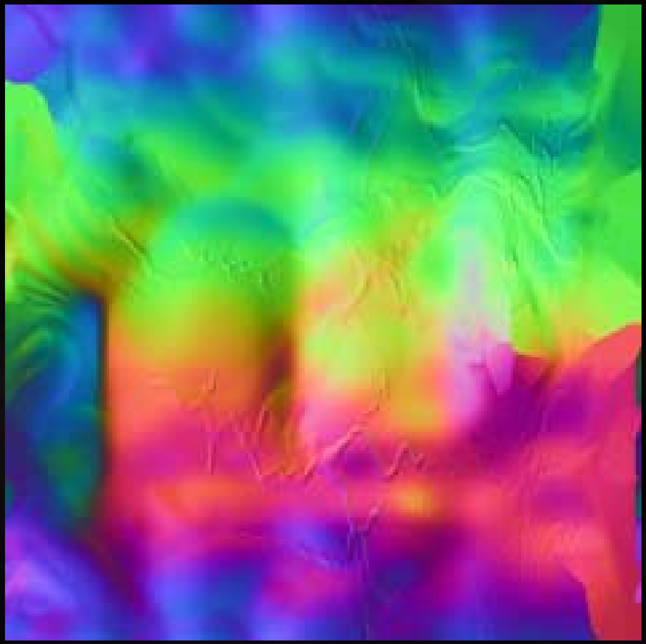


How to Store Normals in Texels *1 of 3*

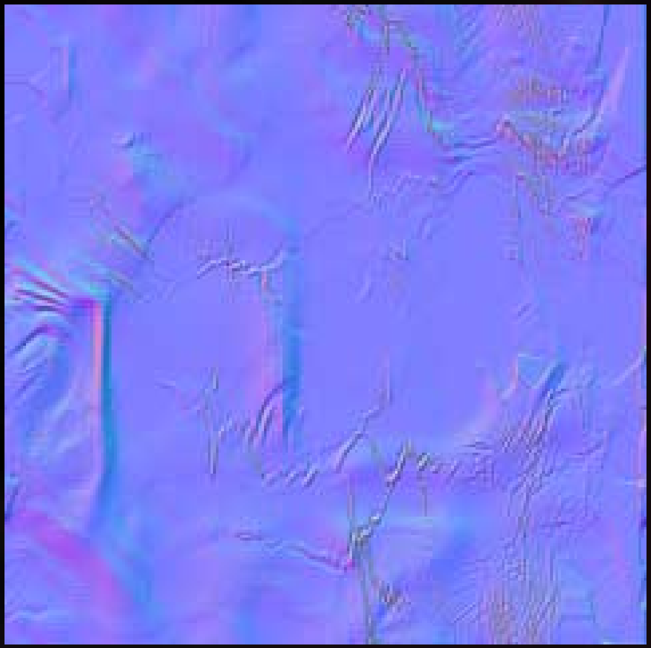
- What space?
  - Local-Space vs Texture Space
- Local Space Normals (LS)
  - Use the origin of the object to extract normals
- Texture Space Normals (TS)
  - Store normals in generic space, e.g., Tangent Space
  - Store a matrix per vertex that takes the light from local-space to texture space

How to Store Normals in Texels

Local Space



Texture Space



How to Store Normals in Texels *3 of 3*

- LS is simple to work with and can be very fast
  - But cannot be compressed
  - Good for characters and objects such as cars
- TS is more complex to work with but has 2 advantages
  - Tileable maps
  - Palletized textures
  - Good for big things like terrain with detail textures

Different Types of Lights *1 of 2*

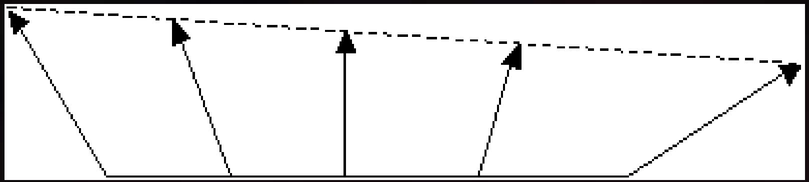
- 3 typical light types
  - Directional
  - Point
  - Spot
- Point and spot lighting usually have attenuation coefficients
- Store spot lighting attenuation function in a texture
  - X is a function of the distance
  - Y is a function of the angle
    The dot-product direction of the light with the vertex

Different Types of Lights

- Implementing attenuation function (1/(k1+d*k2 +d*d*k3)) directly in the vertex shader
  - Takes few instructions, but has issues going towards zero

- Light vector normalization is usually not needed but...
  - Use cube-map lookup (32x32 or so)
  - Or use Newton-Raphson approximation in pixel-shader:

```
mul r0,  LightDir, 0.5
dp3 r1,  LightDir, LightDir
mad r0, 1-r1, r0, LightDir
```



LS vs TS Standard Comparison

```
; LS Directional Light
; Transform position to clip space and output it
dp4 oPos.x, V_POSITION, c[CV_WORLDVIEWPROJ_0]
dp4 oPos.y, V_POSITION, c[CV_WORLDVIEWPROJ_1]
dp4 oPos.z, V_POSITION, c[CV_WORLDVIEWPROJ_2]
dp4 oPos.w, V_POSITION, c[CV_WORLDVIEWPROJ_3]

; Output tex coords
mov oT0, V_TEXTURE
mov oT1, V_TEXTURE
```

LS vs TS Standard Comparison


```
; TS Directional Light
; Transform position to clip space and output it
dp4 oPos.x, V_POSITION, c[CV_WORLDVIEWPROJ_0]
dp4 oPos.y, V_POSITION, c[CV_WORLDVIEWPROJ_1]
dp4 oPos.z, V_POSITION, c[CV_WORLDVIEWPROJ_2]
dp4 oPos.w, V_POSITION, c[CV_WORLDVIEWPROJ_3]

; Transform local space light by basis vectors to put it
; into texture space
dp3 LIGHT_T.x, V_S, c[L_DIR_LOCAL]
dp3 LIGHT_T.y, V_T, c[L_DIR_LOCAL]
dp3 LIGHT_T.z, V_Q, c[L_DIR_LOCAL]

; Scale to 0-1
add LIGHT_T, LIGHT_T, c[CV_ONE]
mul oD0, LIGHT_T, c[CV_HALF]

; Output tex coords
mov oT0, V_TEXTURE
mov oT1, V_TEXTURE
```

LS vs TS Standard Comparison

- This example is mostly for rigid geometry
  - Optimized TS: 11 instructions
  - Optimizes LS: 6 instructions
- Note that the LS could do up to 5 lights
  - All light directions in local space are loaded into the pixel-shader constants
- The TS uses light direction in local space
  - Faster than transforming the basis vectors

LS vs TS Soft-Skin

LS vs TS Soft-Skin


```
// Transform pos with Weight 1
mov a0.x, V_INDICES.x

dp4 r1.x, V_POSITION, c[a0.x + CV_BONESTART + 0]
dp4 r1.y, V_POSITION, c[a0.x + CV_BONESTART + 1]
dp4 r1.z, V_POSITION, c[a0.x + CV_BONESTART + 2]

// Weight the light part 1
mul r7, c[a0.x + CV_LDIR_LOCALSPACE], V_WEIGHT0.x

// Transform pos with Weight 2
mov a0.x, V_INDICES.y

dp4 r2.x, V_POSITION, c[a0.x + CV_BONESTART + 0]
dp4 r2.y, V_POSITION, c[a0.x + CV_BONESTART + 1]
dp4 r2.z, V_POSITION, c[a0.x + CV_BONESTART + 2]

// Weight the 2 part of the light
mad r8, c[a0.x + CV_LDIR_LOCALSPACE], V_WEIGHT1.x, r7
```

LS vs TS Soft-Skin


```
// Blend between r1 and r2
mul r1.xyz, r1.xyz, V_WEIGHT0.x
mad r2, r2.xyz, V_WEIGHT1.x, r1.xyz

mov r2.w, c[CV_CONSTANTS].z //set w to one

// r2 now contains final position

; Do the texture compression by multiplying
; 1 or –1 as needed
mul r1.x, r1.x, V_MIRROR_FLAG

// Normalize light vector
dp3 r1.w, r1, r1
rsq r1.w, r1.w
mul r1, r1, r1.w
```

LS vs TS Soft-Skin


```
// Transform to clip space
dp4 oPos.x, r2, c[CV_WORLDVIEWPROJ_0]
dp4 oPos.y, r2, c[CV_WORLDVIEWPROJ_1]
dp4 oPos.z, r2, c[CV_WORLDVIEWPROJ_2]
dp4 oPos.w, r2, c[CV_WORLDVIEWPROJ_3]

// Scale to 0-1

// [-1, 1] --> [0, 1]
add r1, r1, c[CV_CONSTANTS].z
mul oD0, r1, c[CV_CONSTANTS].y

// Pass through texcoords
mov oT0.xy, V_TEX
mov oT1.xy, V_TEX
```

LS vs TS Soft-Skin (T.S.) *4 of 7*

```
// Transform pos with Weight 1
mov a0.x, V_INDICES.x

dp4 r1.x, V_POSITION, c[a0.x + CV_BONESTART + 0]
dp4 r1.y, V_POSITION, c[a0.x + CV_BONESTART + 1]
dp4 r1.z, V_POSITION, c[a0.x + CV_BONESTART + 2]

// Transform the light from the bone local space to the TS
dp3 r7.x, V_S,   c[a0.x + CV_LDIR_LOCALSPACE]
dp3 r7.y, V_T,   c[a0.x + CV_LDIR_LOCALSPACE]
dp3 r7.z, V_SxT, c[a0.x + CV_LDIR_LOCALSPACE]

// Transform pos with Weight 2
mov a0.x, V_INDICES.y

dp4 r2.x, V_POSITION, c[a0.x + CV_BONESTART + 0]
dp4 r2.y, V_POSITION, c[a0.x + CV_BONESTART + 1]
dp4 r2.z, V_POSITION, c[a0.x + CV_BONESTART + 2]
```

LS vs TS Soft-Skin (T.S.) *5 of 7*

```
// Transform the light from the bone local space to the
// texture space
dp3 r8.x, V_S,   c[a0.x + CV_LDIR_LOCALSPACE]
dp3 r8.y, V_T,   c[a0.x + CV_LDIR_LOCALSPACE]
dp3 r8.z, V_SXT, c[a0.x + CV_LDIR_LOCALSPACE]

// Blend between r1 and r2, r2 now contains final position
mul r1.xyz, r1.xyz, V_WEIGHT0.x
mad r2,     r2.xyz, V_WEIGHT1.x, r1.xyz
mov r2.w,   c[CV_CONSTANTS].z                // set w to one

// Blend the light
mul r7, r7.xyz, V_WEIGHT0.x
mad r8, r8.xyz, V_WEIGHT1.x, r7

// Normalize light vector
dp3 r1.w, r1, r1
rsq r1.w, r1.w
mul r1,   r1, r1.w
```

LS vs TS Soft-Skin (T.S.)

```
// Transform to clip space
dp4 oPos.x, r2, c[CV_WORLDVIEWPROJ_0]
dp4 oPos.y, r2, c[CV_WORLDVIEWPROJ_1]
dp4 oPos.z, r2, c[CV_WORLDVIEWPROJ_2]
dp4 oPos.w, r2, c[CV_WORLDVIEWPROJ_3]

// [-1, 1] --> [0, 1]
add r1,  r1, c[CV_CONSTANTS].z
mul oD0, r1, c[CV_CONSTANTS].y

// Pass through texcoords
mov oT0.xy, V_TEX
mov oT1.xy, V_TEX
```

LS vs TS Soft-Skin

- Optimized LS: 25 instructions
- Optimized TS: 30 instructions
- Skinning the light direction is as good as skinning a normal
- The LS technique works well for characters
  - Unique pixel per polygon and symmetrical
- Passing the light in the local space for each bone for the TS is a good idea
  - Standard TS technique is about 50 instructions

LS vs TS Soft-Skin

- Evolution demo shader is 42 instructions
  - Vertex-shader was the first bottle neck that we hit
- Geforce3 Ti500 runs a 240Mhz
  - 1 clock per instruction = 240M instruction/sec
  - @ 60fps is 4M so 4M/25 = 160K Peak
- The Geforce4 can do 600M instruction/sec
  - Step in the right direction

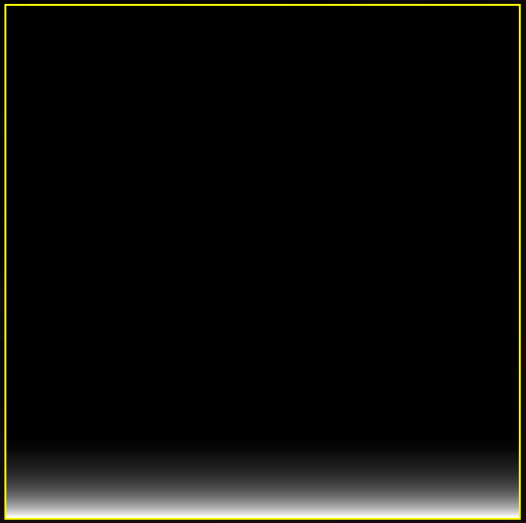
Working with Shaders *1 of 4*

- 1 to n lights and different types of lights
  - Compile and cache vertex/pixel shaders on the fly
  - Layout code so they can be combined
  - DoomIII does 1 light per pass

- Geforce3 has max. 8 instructions in the pixel-shader
  - But can use an off-screen texture as a temporary register
  - Then project texture in consequent passes
  - Allows for unlimited length of pixel shaders (with extra cost of course)

Working with Shaders *2 of 4*

- “Anisotropic” textures are a good way to do complex lighting equations based on the specular and diffuse angles



Working with Shaders *3 of 4*

- Use UVs to set the lightDir and half-vector
  - Then use “texm3x2pad” and “texm3x2tex” to compute the look up UVs
- Pre-scale the lightDir and the half-vector by 0.5 to get the full range –1 to 1 of the light equation
  - Useful for back-lighting
- Be creative with your lighting equation
  - “Diffuse + Specular” pretty much sucks
  - Try: “Diffuse + **X** * Specular * Diffuse”

Working with Shaders *4 of 4*

- Use multiple layers to achieve complex lighting
  - Evolution demo had 3: Diffuse, Anisotropic, and ppSpecular
- Make sure to use all channels in your textures
  - Don't forget about the alpha channel
- Compress textures (DXT1, DXT3)
- Post-Effects are becoming part of the shading technology; don't miss that (check out Wreckless)

Wreckless

Nice job guys!

Shadows *1 of 3*

- Two main techniques projected textures (nVidia/ATI/plain) and stencil volumes

- Projected textures are easier to implement
  - Self-shadow
  - Can do 4 lights/shadows at a time
  - But can only do spot and directional lights

- Hint: try to use orthogonal projections
  - Do per-object projected textures

Shadows *2 of 3*

- Stencils are a more generic solution
  - But fill rate is an issue
- Worth looking at
  - SVBSP and order tree structures
  - As well as Cut and Continue type of techniques
- Make sure to cache shadow volumes
- For perfect lighting, use stencil to *not* write lit pixels
  - vs darkening them

Shadows *3 of 3*

Massive over-draw!

The Future 1 of 2

- In the near future new versions of vertex/pixel shaders will make another big leap
- Expect to see lighting independent of geometry complexity, and a final generalized lighting solution
- Shadows will still be a thing to try to achieve efficiently
  - Although it may be helped via fill-rate increases etc.
- Post-effects will be very important as they start to became part of the final shader render

The Future *2 of 2*

We still live in very exciting times, but it would be more exciting if they do a real time ray-tracer!