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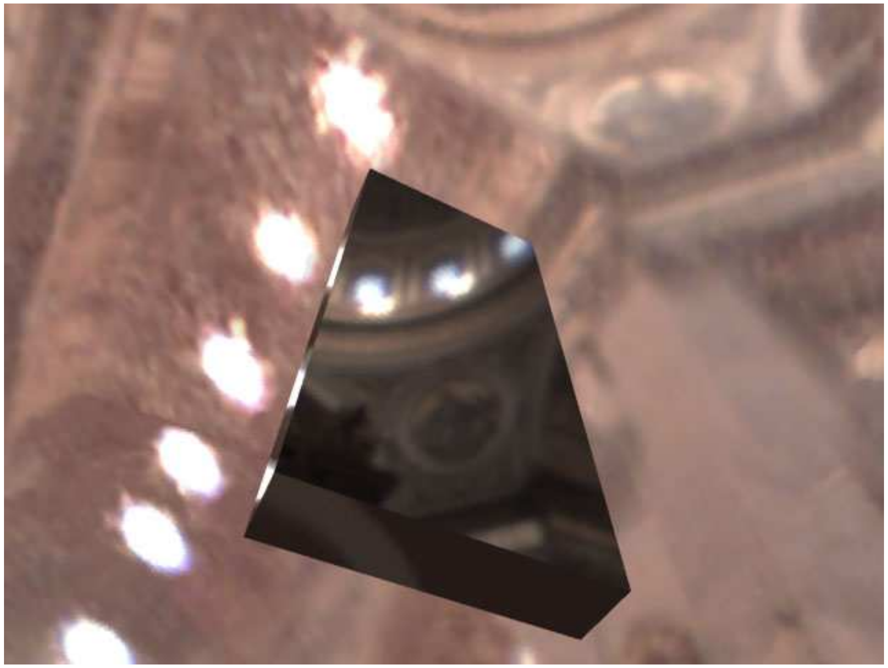

High Dynamic Range Images

Kenneth Hurley - CEO

What we're going to cover

- Introduction to High Dynamic Range (HDR)
- DX7 implementation
- DX8 implementations
  - Fake HDR
  - Using HDR for Image Based Lighting
- DX9 Implementations
  - Fake HDR
  - Encoding Formats
  - HLSL implementations
- More Information

HDR Intro

- Developed by Paul E. Debevec and Jitendra Malik
  - http://www.debevec.org
- Radiance can vary beyond precision of 8 bits
- Encodes radiance in floating point values
- Demo at site uses Geforce2
- Commercial Licensing Required

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HDR Intro

- The human visual system adapts automatically to changes in brightness
- In photography, shutter speed and lens aperture are used to control the amount of light that reaches the film
- HDR imagery attempts to capture the full dynamic range of light in real world scenes
- Measures *radiance = amount of energy per unit time per unit solid angle per unit area* $W / (sr * m^2)$
  - W = *Radiant flux*
  - sr = *solid angle*
  - m^2 = area
- 8 bits is not enough!

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Why do we need HDR

- It effectively allows us to change the exposure *after* we've taken/rendered the picture
- Dynamic adaptation effects – e.g. moving from a bright outdoor environment to indoors
- Allows physically plausible image-based lighting
- BRDFs may need high dynamic range
- Enables realistic optical effects – glows around bright light sources, more accurate motion blurs

HDR Terminology

- Gaussian (Blur)
  - Blurs image
    - averages pixels around a pixel by sampling
- Exposure
  - Similar to photograph chemical process
  - Digitial photographs clamp captured light values
  - Multiple photographs are taken (exposures)
  - Recombined with software for fuller range of luminance values

HDR Terminology Continued

Tone Mapping

- Tone mapping scales the RGB values of an image, which might be too bright or too dark to be displayed
  - Techniques used to map HDR images to RGB 8 bit monitor images
- “key value” or “neutral value
  - The log-average luminance of the scene
  - DX9 Demos allow changing this value

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HDR Encoding

- Eyes sensitivity to luminance suggests we must encode 9,900 values if we use linear steps for luminance
- If not linear then only 460 values are requires (9 bits)
- Eye is very sensitive to luminance changes
- Less sensitive to color changes
- OpenEXR Format

HDR on DX7

- "Real-Time High Dynamic Range Imagery", Cohen, Tchou, Hawkins, Debevec, Eurographics 2001
- Splits HDR images into several 8-bit textures
  - Recombines using register combiners on DX7 capable hardware
- Doesn't automatically adjust exposure
  - Requires different combiner setups for different exposure ranges, so exposure can only be changed on a per-primitive basis

HDR on DX7

HDR on DX8 class hardware

- Developed by Simon Green at NVIDIA
- DX8 that supports a 16-bit format known as HILO can be used
- Stores 2 16-bit components: (HI, LO, 1)
- Filtered by hardware at 16-bit precision
- We can also use this format to store high(er) dynamic range imagery
- Remap floating point HDR data to gamma encoded 16-bit fixed-point range [0, 65535]
- HILO only stores two components so we need two HILO textures to store RGB

HDR on DX8 class hardware

- To display the image, we need to multiply the HDR radiance values by the exposure factor, and then re-map them to the displayable [0,255] range
- This can be achieved using the texm3x2tex pixel shader operation
- Exposure is sent as texture coordinates, the dot product performs the multiply for both channels
- We create a 2D texture that maps the result back to displayable values

HDR on DX8 class hardware

- Psuedo Code

```
0: hilo = texture_cube_map(hdr_texture, s0, t0, r0)
1: dot1 = s1*hi + t1*lo + r1*1.0;   // = r_exposure*r + 0 + r_bias
2: dot2 = s2*hi + t2*lo + r2*1.0;   // = 0 + g_exposure*g + g_bias
   color = texture_2d(lut_texture, dot1, dot2)
```

- Pixel Shader code

```
ps_1_1
tex t0                    // Grab hilo data from cubemap
texm3x2pad  t1, t0   // = r_exposure*r + 0 + r_bias
texm3x2tex  t2, t0   // 0 + g_exposure*g + g_bias
mov r0, t2
```

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HDR on DX8 class hardware

- Requires 2 passes to render RGB, using D3DRS_COLORWRITEENABLE to mask off color channels
- First pass renders R and G:
  - texcoord1 = (r_exposure, 0.0, r_bias)
  - texcoord2 = (0.0, g_exposure, g_bias)
- Second pass renders B:
  - texcoord1 = (0, 0, 0)
  - texcoord2 = (b_exposure, 0.0, b_bias)

HDR on DX8 class hardware

Exposure .25

Exposure 0.0625

Exposure 0.015625

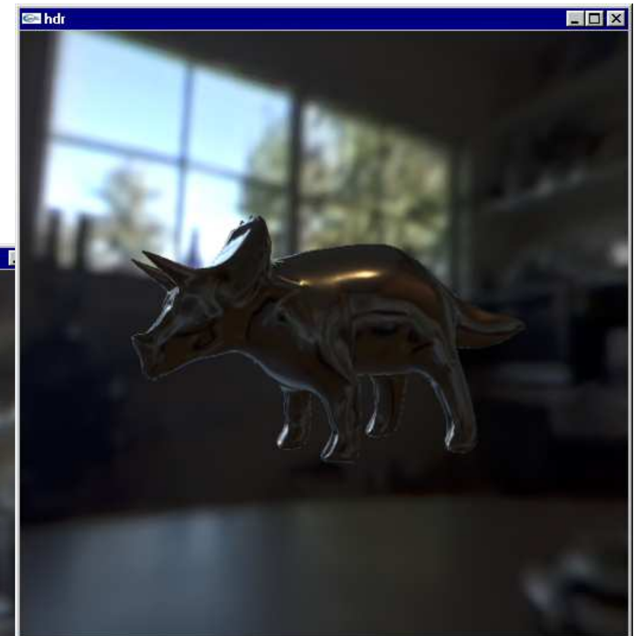

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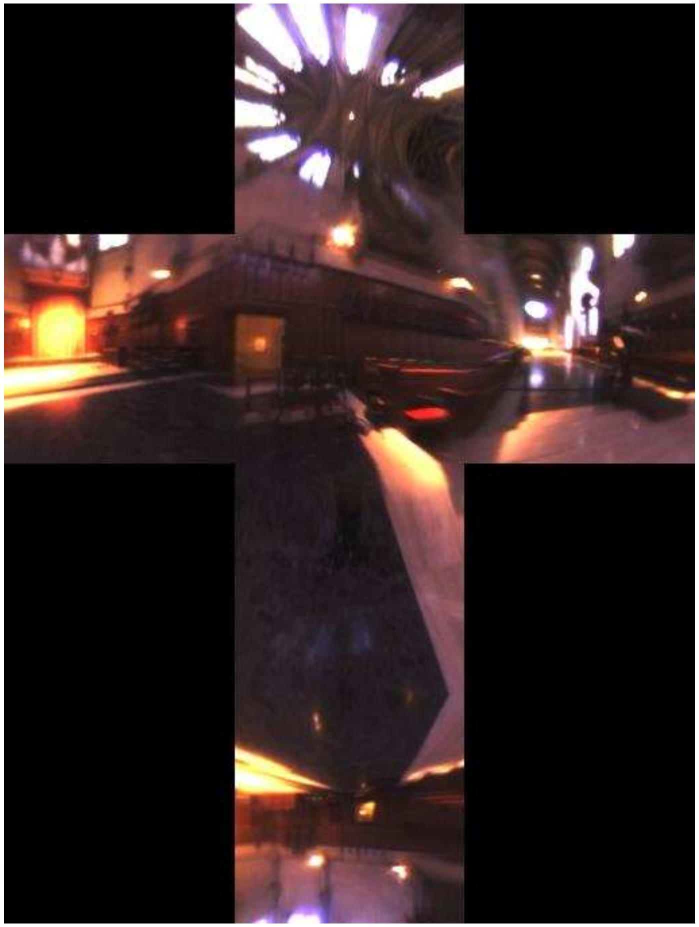
Image Based Lighting use HDR on DX8 class hardware

- Lighting synthetic objects with “real” light
- An environment map represents all light arriving at a point for each incoming direction
- By convolving (blurring) an environment map with the diffuse reflection function (N.L) we can create a diffuse reflection map
- Indexed by surface normal N, this gives the sum of N.L for all light sources in the hemisphere
- Low freq - cube map can be small - e.g. 32x32x6
- HDRShop will do this for you

Image Based Lighting use HDR on DX8 class hardware



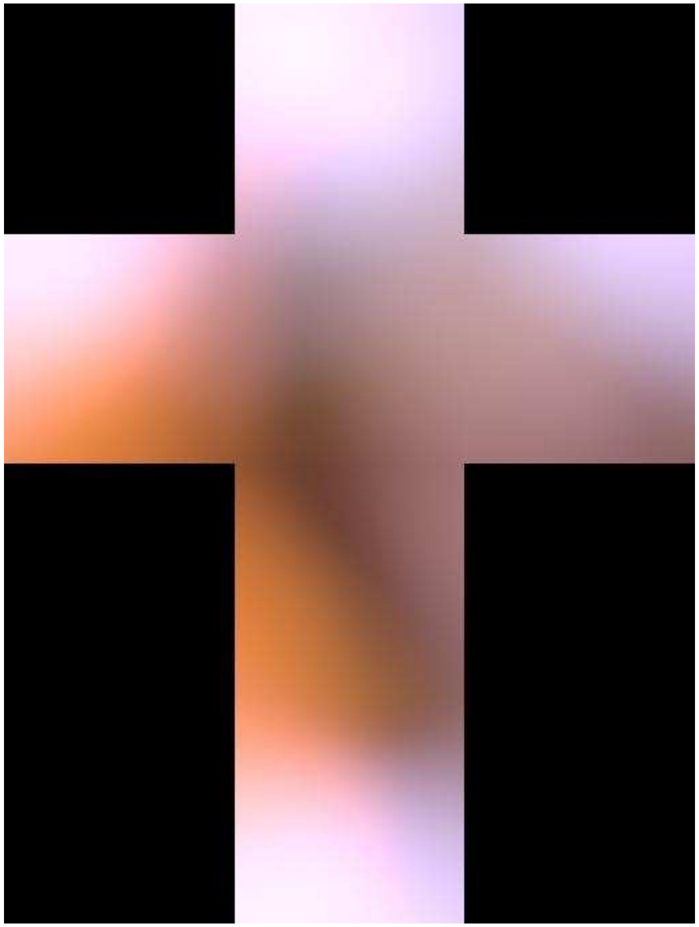


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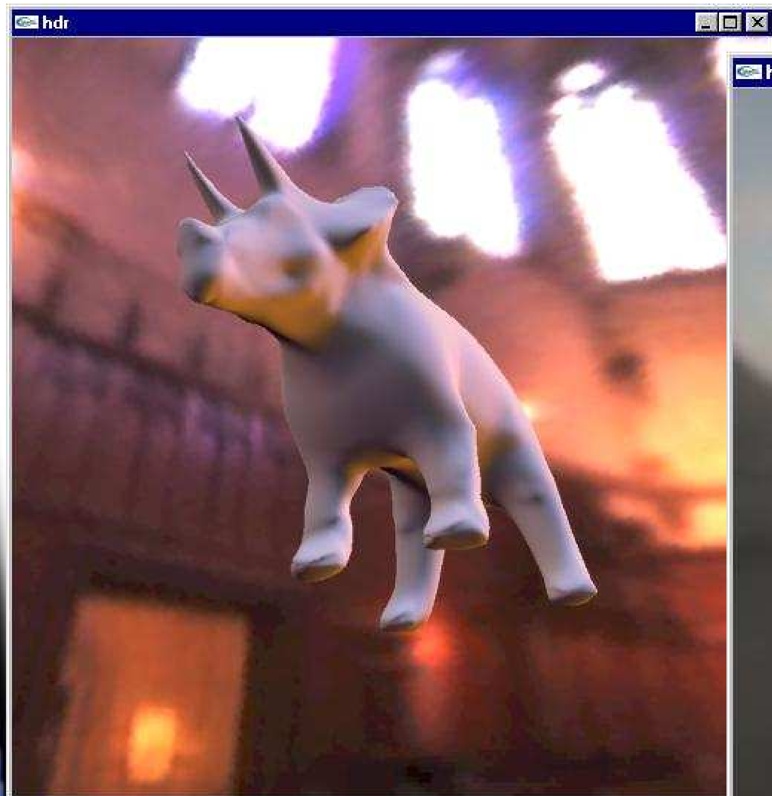
Image Based Lighting use HDR on DX8 class hardware



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Fake HDR on DX8 class hardware

- Masaki Kawase techinque
  - Used in XBOX Wreckless: Yakuza Missions
  - Can be implemented in 1.1 shader
- Blur filters up to 8 passes
- Simple Tone map
  - LERPS between original and blurred image
- DEMO, RGBA and RGBE

HDR on DX9 class hardware

- Easier to implement
- Floating point buffers
- HLSL available

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Realtime HDR on DX9 class hardware

- Masaki Kawase is at it again
- Demo

HDR on DX9 class hardware

- Format possibilities
  - RGB16
    - 16-bit per channel integer format
      - decoded.rgb = encoded.rgb dot max_value
  - RGBE
    - Compressed logarithmic values with E being shared exponent calculated from RGB
      - decoded.rgb = encoded.rgb * $2^{encoded.a}$
  - FP16
    - Partial precision floating point values
  - FP32
    - Full Precision floating point values

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HDR on DX9 class hardware

- Simple Code (ATI RenderMonkey Sample)
  - Render the scene with HDR values into a floating point buffer.
  - Down-sample this buffer to 1/4th size (1/2 width and 1/2 height) and optionally suppress low values to get only brightest parts
  - Blur image (bloom filter) Best to do it X then Y, to reduce texture lookups
  - Tone map the blurred image after compositing it with the original image.

Generic Vertex Shader

```
float4x4 matViewProjection;

struct VS_INPUT
{
   float3 Pos:      POSITION;
};

struct VS_OUTPUT
{
   float4 Pos:       POSITION;
   float2 TexCoord : TEXCOORD0;
};

VS_OUTPUT vs_main( VS_INPUT In )
{
   VS_OUTPUT Out;

   Out.Pos.xy = sign(In.Pos);
   Out.Pos.z = 1.0;
   Out.Pos.w = 1.0;

   Out.TexCoord.x = Out.Pos.x * 0.5 + 0.5;
   Out.TexCoord.y = 1.0 - (Out.Pos.y * 0.5 + 0.5);

   return Out;
}
```

HLSL Blur Horizontal Pixel Shader

```
sampler2D Src;

float4 gaussFilter[7] =
{
  -3.0, 0.0, 0.0,  1.0/64.0,
  -2.0, 0.0, 0.0,  6.0/64.0,
  -1.0, 0.0, 0.0, 15.0/64.0,
   0.0, 0.0, 0.0, 20.0/64.0,
   1.0, 0.0, 0.0, 15.0/64.0,
   2.0, 0.0, 0.0,  6.0/64.0,
   3.0, 0.0, 0.0,  1.0/64.0
 };

float texScaler = 1.0/128.0;
float texOffset = 0.0;

struct PS_INPUT
{
   float2 TexCoord : TEXCOORD0;
};
```

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HLSL Blur Horizontal Pixel Shader (Cont)

```
struct PS_OUTPUT
{
   float4 Color : COLOR;
};

PS_OUTPUT ps_main( PS_INPUT In )
{
   PS_OUTPUT Out;

   float4 color = 0.0;

   int i;
   for (i=0;i<7;i++)
   {
      color += tex2D(Src,float2(In.TexCoord.x + gaussFilter[i].x * texScaler +
    texOffset,
                              In.TexCoord.y + gaussFilter[i].y * texScaler +
    texOffset)) *
                     gaussFilter[i].w;
   } // End for

   Out.Color = color * 4.0;

   return Out;
}
```

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Final Pixel Shader Tone Mapping

```
float Exposure;
sampler2D SrcHDR;
sampler2D SrcColor;

struct PS_INPUT
{
  float2 TexCoord : TEXCOORD0;
};

struct PS_OUTPUT
{
  float4 Color : COLOR;
};

PS_OUTPUT ps_main( PS_INPUT In )
{
  PS_OUTPUT Out;

  float4 color  = tex2D(SrcColor,In.TexCoord);
  float4 scaler = tex2D(SrcHDR,In.TexCoord) * 2.0;

  Out.Color = color * ( ( 1.0 + scaler.a ) * Exposure );

  return Out;
}
```

Optimizations

- Down-sample image first
  - Reduces the texture samples from 32 pixels to 8 samples
- Blur in X, then in Y
  - 2n texture look-ups rather than n*n

Render Monkey Demo

- DEMO

Final Thoughts

- High Dynamic Range can be accomplished on all current hardware
  - Implementations available for DX7
  - Implementations available for DX8
  - Implementations available for DX9
  - So no excuses.
- IBL or IBR
  - Can make use of HDR tools
  - Look very good
- Precomputed Radiance Transfer

More information on HDR

- Programming Vertex and Pixel Shader, Wolfgang Engel ISBN 1-58450-349-1
- http://developer.nvidia.com
- http://www.ati.com/developer
- DX9 Summer 2004 SDK
- http://www.debevec.org
- Masaka Kawase website http://www.daionet.gr.jp/~masa/rthdribl/

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Software support for HDR

- HDRShop - http://www.ict.usc.edu/graphics/HDRShop/
- Rendermonkey – http://www.ati.com/developer
- NVSDK – http://developer.nvidia.com
- OpenEXR http://www.openexr.net/
- DX9 Summer 2004 SDK

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Questions

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