Three Swordsmen: Lighting Workflow and Production Pipeline

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Agenda

- Company and Product Introduction
- Lighting Techniques of Three Swordsmen
  - Design goals
  - Key technology and pipeline

风际游戏
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Company and Product Introduction

Lighting Techniques of Three Swordsmen

- Graphics
  - Next generation of p
- Performance
  - Smoothly running w
- Production
  - Efficient pipeline tools

Graphics(1)

- Realist style
- Scene Rendering base
  - Remove empirical ligh
    - Patchwork effect, poo
    - A lot of strange "mag
  - Conduct lighting acco
- Take full advantage o

Graphics(2)

- Physics-based lighting (PBL)
  - Energy Conserving Model, meaning that the energy of refection can not be greater than the energy of incidence. Most empirical models do not meet this.
  - HDR Lighting - lighting results must have sufficient and high precision
  - Linear Pipeline – must use near rendering pipeline, Gamma processing must be correct and color space of parameterized texture must be unified

Graphics (3)

- Offline Rendering
  - Static lights all use area light
  - Support global illumination (GI)
  - Introduce image-based lighting (IB

Performance challer

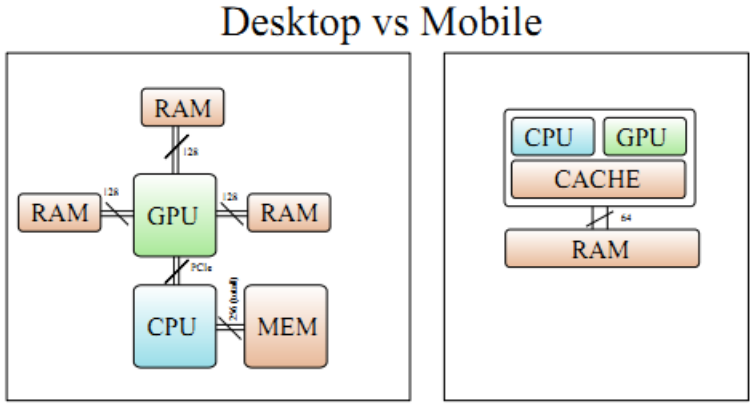
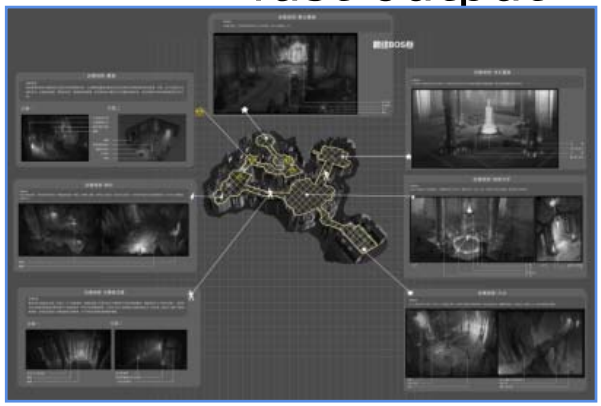


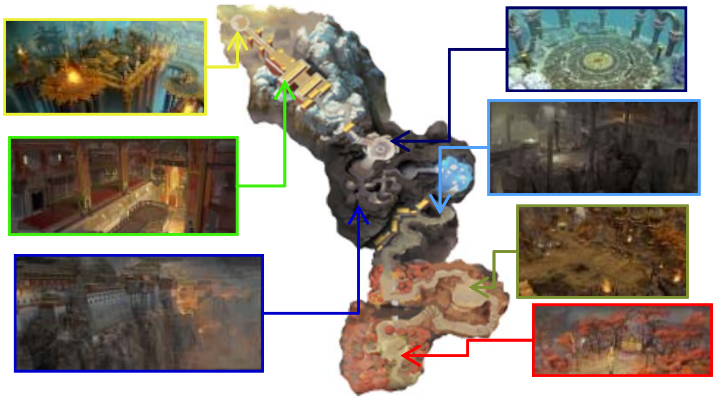
Image source: Moving Pictures: Making the Most of the Mobile, GDC GRAPH 2014

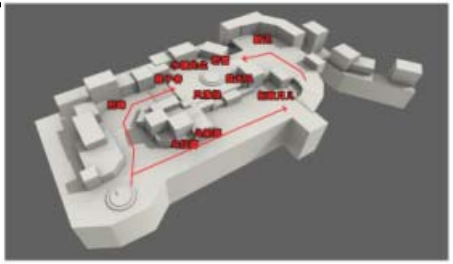
- Mobile GPU
  - Low bus bandwidth
  - Low computing capacity
- Power consumption of the data processing
- Offline baking technique is very important, a lot of calculations all conduct pretreatment
- Many effects need to rely on technology and art to achieve with Trick

Production

- 100+ complex scenes need to produce
  - Need to be able to quickly iterate and fast output

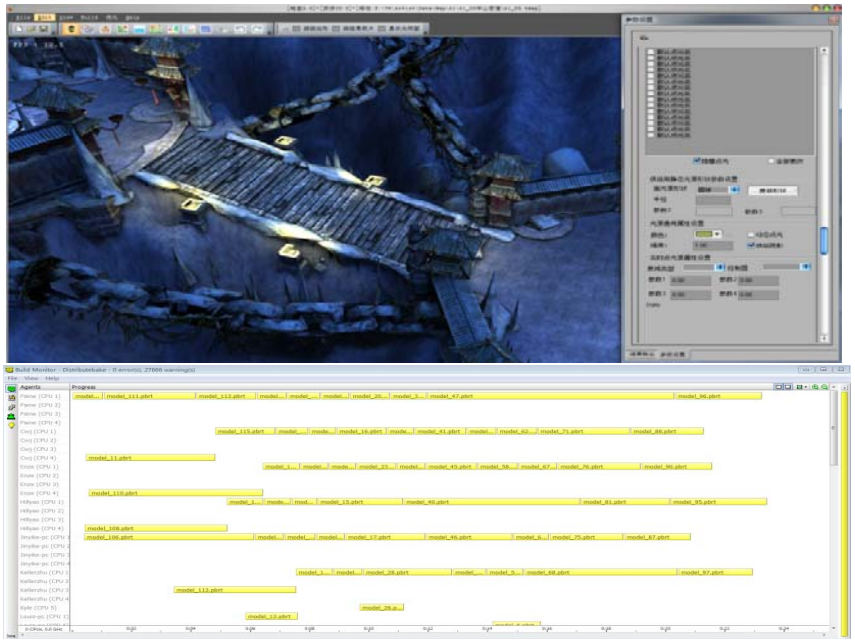






Production

- Use physics-based offline baking algorithm
  - GI baking has a huge amount of calculation
  - Support distributed rendering (render farm)



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Offline baking technique highlights

- Basic concepts
- Image Based Lighting
- Linear Lighting pipeline
- Storage and coding of High Dynamic Range light map
- Dynamic objects and static light sources

Basic concept review(1)

- Physics Fundamentals
  - Wave-particle duality of light
  - Regard light as the flow of photons, every photon carries a radiation energy
  - Use sophisticated Neutron transport and Thermodynamic theory for Modeling
    - Different particle , Same equation
    - neutron transport theory from the 1940s
    - ICTT

Basic concept review(2)

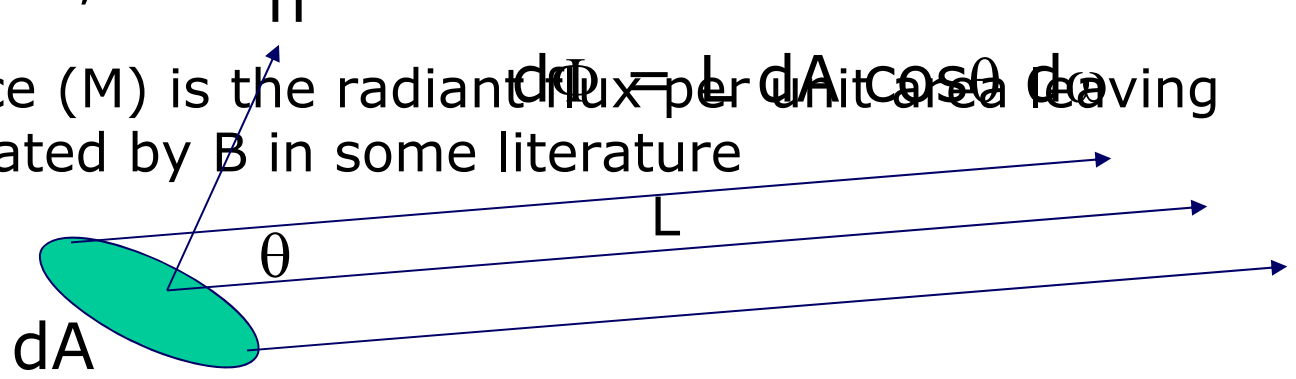
- Flux, generally indicated by Φ
- It is an energy unit, representing the radiant energy per unit time through unit area (w)
- Can also be seen as the number of photons passing through per per unit time
- $\Phi(p,\omega)$ represents the flux magnitude at p-point in the direction of ω

Basic concept review(3)

- Radiance (*L*) is the radiant flux magnitude per unit projected area per unit solid angle leaving the surface, L(p,ω)represents the radiance at P point in the direction of ω

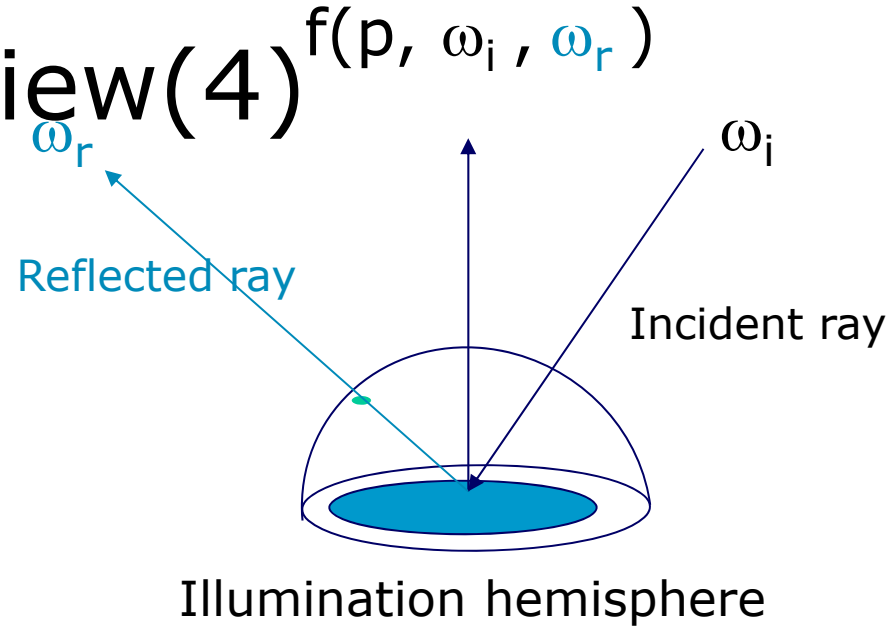
- Irradiance (E) is the radiant flux magnitude per unit area reaching the surface, $d\Phi = E\, dA$

- Radiant Exitance (M) is the radiant flux per unit area leaving the surface, indicated by B in some literature



Basic concept review(4)

- BRDF
  - Bi-directional
  - Reflectance
  - Distribution
  - Function

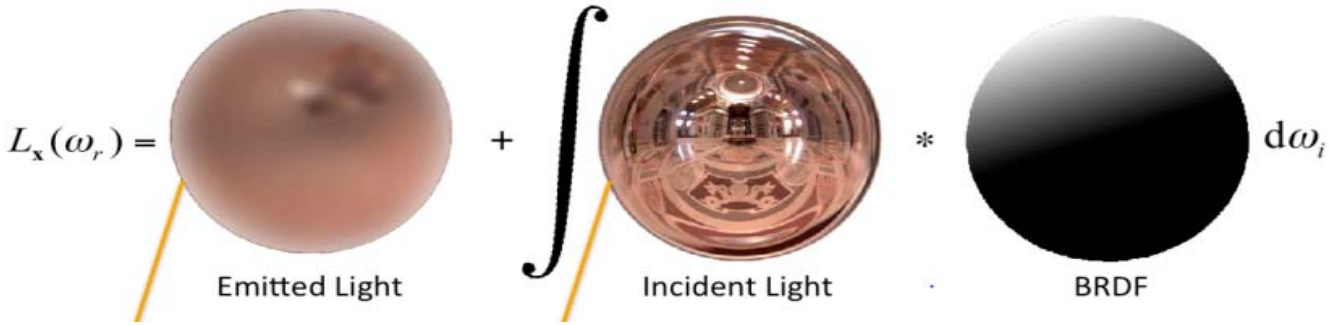


- Reflected Radiance = BRDF×Irradiance
- $L(p, \omega_r) = f(p, \omega_i, \omega_r) E(p, \omega_i)$

$$= f(p, \omega_i, \omega_r) L(p, \omega_i) \cos\theta_i \, d\omega_i$$

Basic concept review(5)

- Rendering equation
- Radiance = Emitted Radiance + Total Reflected Radiance
- $L(p, \omega) = L_e(p, \omega) + \int f(p, \omega_i, \omega) L(p, \omega_i) \cos\theta_i \, d\omega_I$



Offline Baker

- A tool for offline rendering equation solving
- Integrated in In-House scene editor
  - Support quick preview
  - Support high-quality global light baking
    - Based on Ray Tracing
    - Physically Unbiased GI Solver
- Output
  - LightMap
  - Irradiance Volume

Lighting System of Three Swordsmen

- Static baking lighting
  - Diffuse Interreflection of scenes
  - Traditional Lambertian lighting
  - An unlimited number of static surface light source
  - Apply to scene models
- Real-time lighting
  - Dynamic characters: Lambert Diffuse+Blinn-Phong Specular+Rim Light
  - Irradiance Volume

Offline baking technique highlights

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Image-based lighting

IMAGE: Turntable frame of C.G. Tow Truck (c) 2009 Industrial light and Magic. All rights reserved.

Reference: *Ben Snow: the evolution of ILM's lighting tools*

Image-based lighting

- A new way of lighting
- Allow scene art to use a HDR picture to control the color transition between bright and dark portions, more detail, soft baking shadows
- Scene lighting suitable for rebuild realistic scenes
- Can use your own SLR cameras to produce appropriate HDR textures for special scene lighting

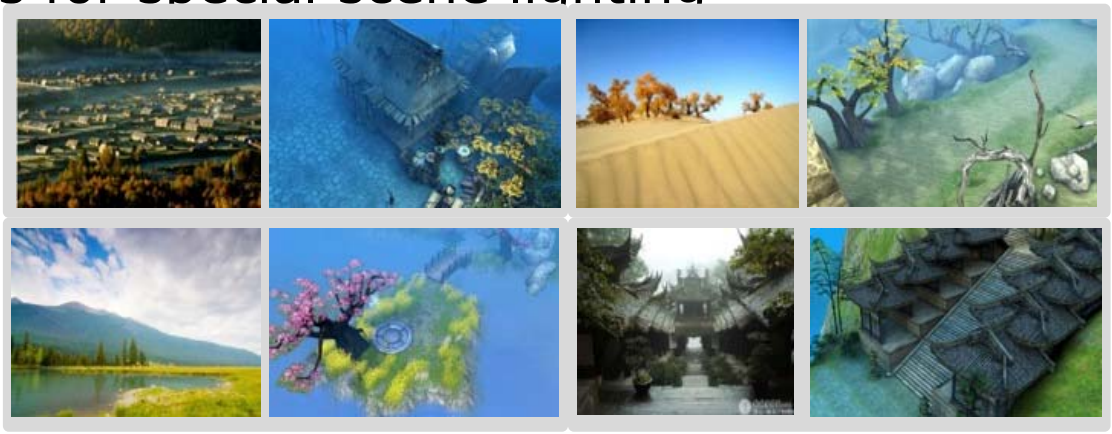
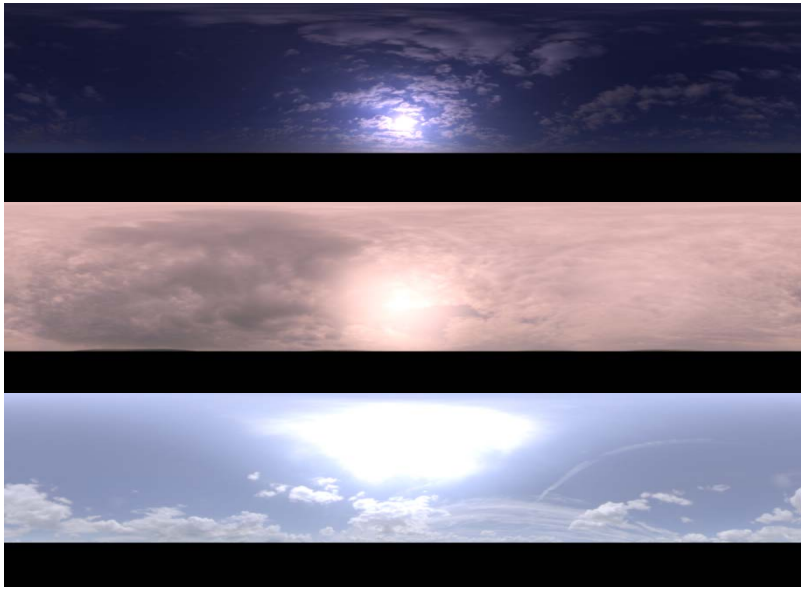


Image-based lighting

- Sky Lighting
- Infinite Area Light



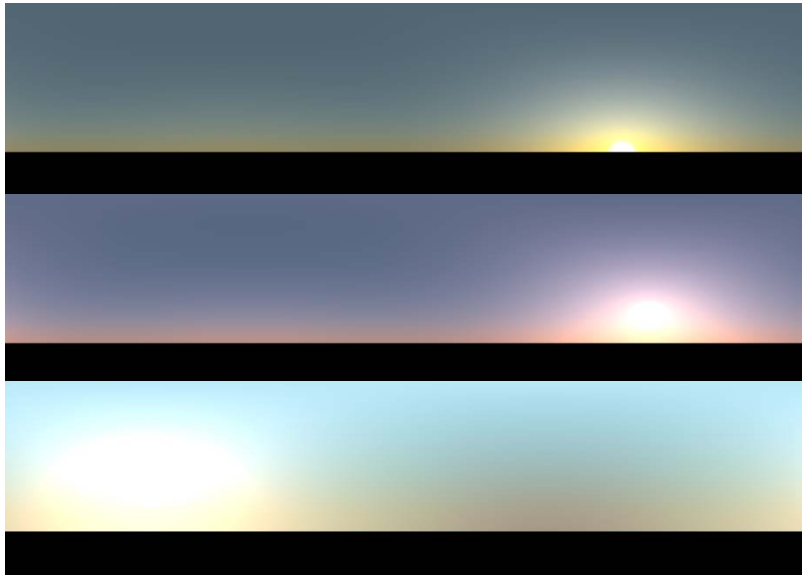
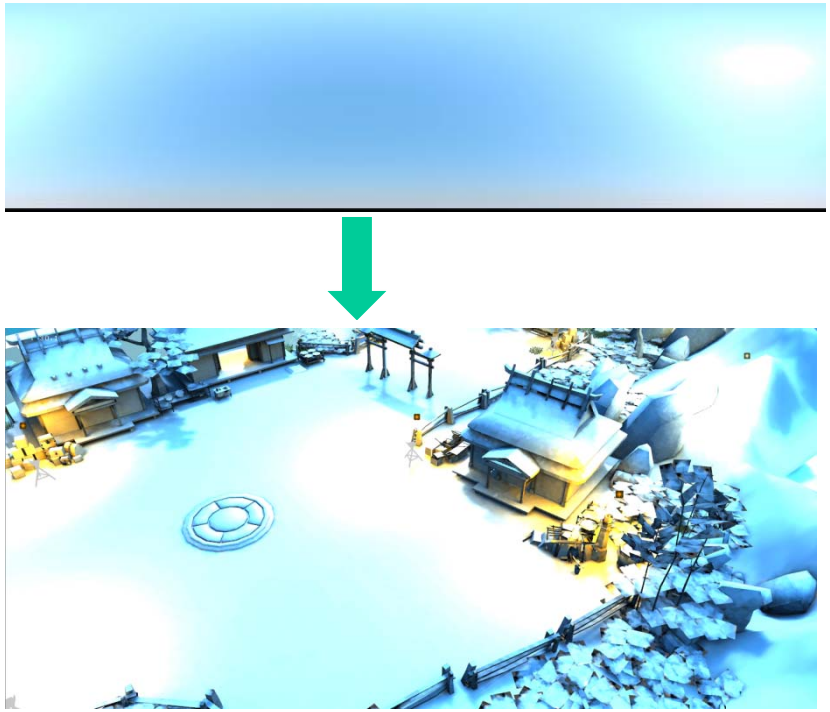


Image-based lighting

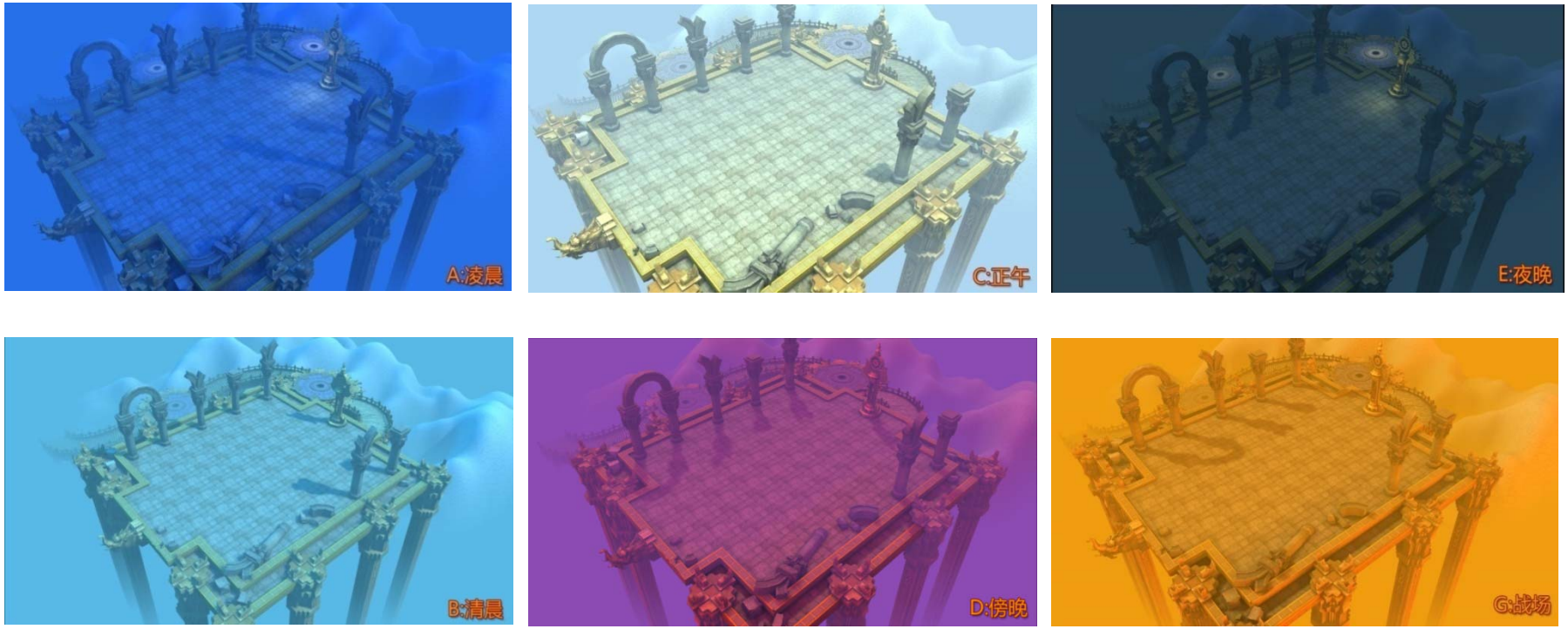
- latitude–longitude radiance map.

```
InfiniteAreaLight::Le(RayDifferential &r)
{
    Vector wh = Normalize(WorldToLight(r.d));
    float s = SphericalPhi(wh) * INV_TWOPI;
    float t = SphericalTheta(wh) * INV_PI;
    return Spectrum(radianceMap->Lookup(s, t), SPECTRUM_ILLUMINANT);
}
```

Image-based lighting



Light Makes Right



Offline baking technique highlights

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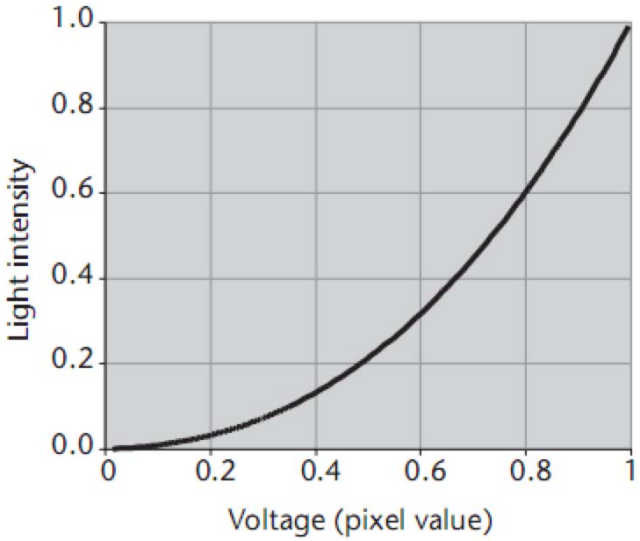
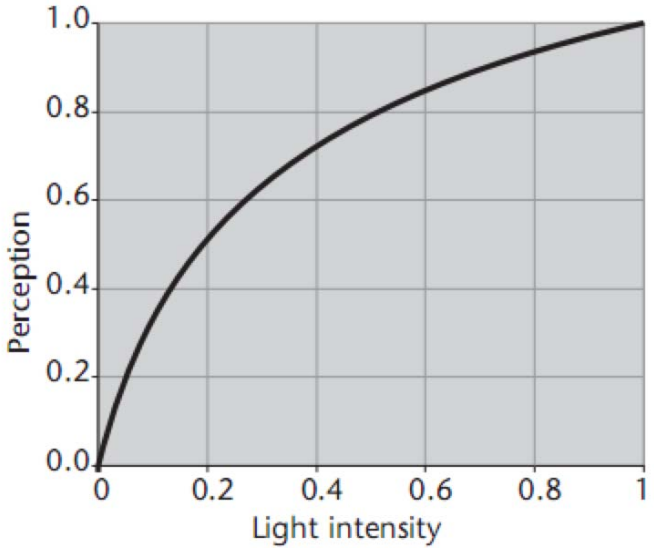
Gamma Correction





Jim Blinn’s corner:What is a Pixel?

Gamma Correction

- Human eye is more sensitive for dark details due to its characteristics, that is to say, human eye is a nonlinear sensory organ
- Directly using linear spatial encoding will cause a great waste
  - 5 vs. 6 : DIFFERENT
  - 205 vs. 206 : SAME!
- Sacrifice bright details and give more bits to dark details
- a combination of luck and engineering which simplified the electronics in early television sets

Linear Lighting

- The display is nonlinear while the renderer is linear
- Lighting calculations should be carried out within the linear space
- The space where to input textures should be unified
- Otherwise it will affect lighting effects

Jim Blinn's Corner: A Ghost in Snowstorm

Linear Lighting

- Offline renderer (Physically based unbiased)
- Input Texture
  - The RGB range of Albedo scene textures is between 32 and 243, sRGB space
- Material Parameter
- Interpolated Vertex Color

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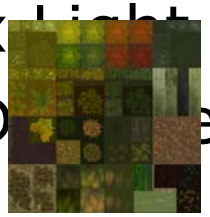
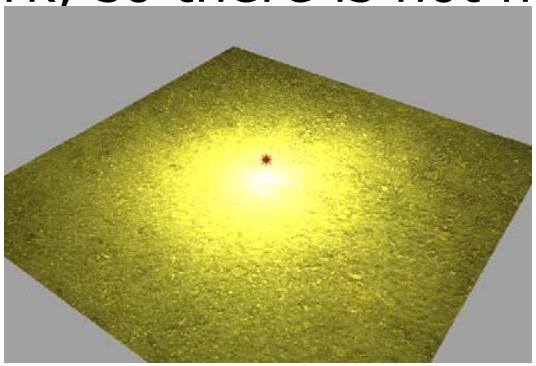
HDR Lightmap

- For Diffuse component, can only retain irradiance, so it also can be called **irradiance map**
- Resolution can be significantly lower than that of Albedo textures
- Offline finish the complex calculations of solving Radiance Equation
- Can solve very complex Light Transport equation
- Diffuse Radiance = BRD edo)×Ir e

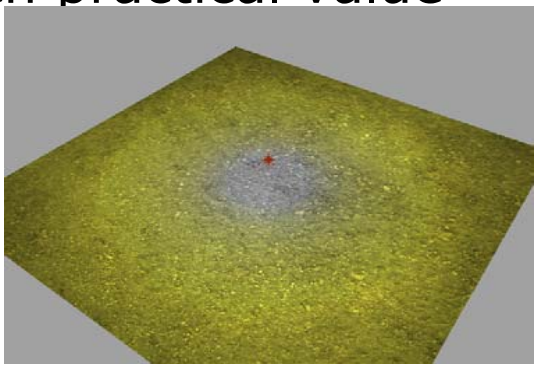


Precision loss problem

- The range of each component of ordinary A8R8G8B8 texture is 8bit, corresponding to a range of finite precision of 0.0-1.0
- If the precision of light map is not >1.0, the scene can only get dark, so there is not much practical value



Intensity not truncated



Intensity truncated

Solutions

- ToneMapping
- Encoding
  - Use two maps to save as RGBA + RGB format (Halo)
  - RGBM format, save high dynamic range lighting results

ToneMapping

- Brightness gap between objects in nature is very large
- The human eye has very high "tolerance", that is to say, the human eye will automatically adjust the color when seeing some objects with large brightness difference
- Lighting is of high dynamic range (HDR), it needs to map to low dynamic range (LDR) in order to use with the existing display devices
- The purpose is to simulate the human eye tolerance

RGBM Encoding

- Increase the range of light map without losing much precision
- RGB:normalized rgb color
- M(Alpha):intensity
- Support dynamic range from 0 to 8

RGBM Encoding

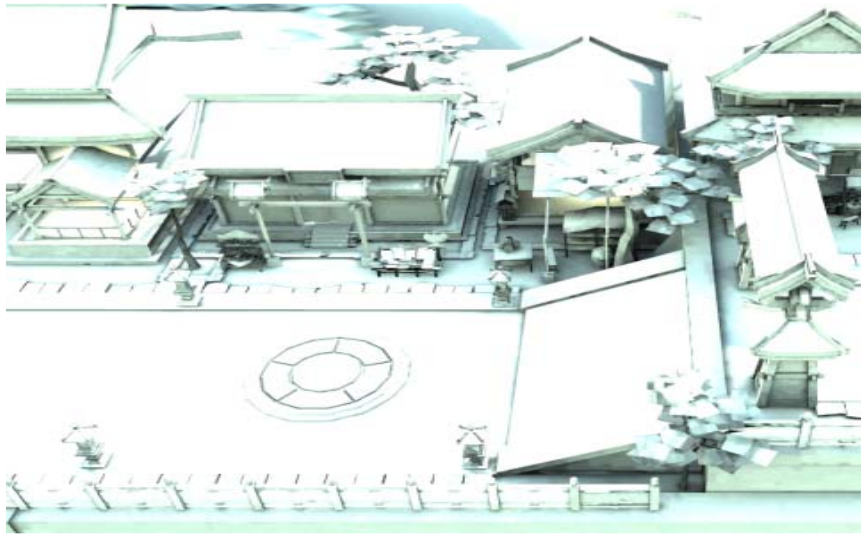
```
public static Color EncodeRGBM(float R, float G, float B, float MaxRange)
{
      R        = Math.Max(0,R);
      G        = Math.Max(0,G);
      B        = Math.Max(0,B);
      float maxRGB  = Math.Max(R,Math.Max(G,B));
      float M       = Math.Min(maxRGB / MaxRange, 1.0f);
      M             = (float)Math.Ceiling(M * 255.0f);
      byte m   = (byte)M;
      M        = (M / 255.0f) * (MaxRange / 255.0f);
      R        = R / M;
      G        = G / M;
      B        = B / M;
      R        = Math.Min(255.25f, R);
      G        = Math.Min(255.25f, G);
      B        = Math.Min(255.25f, B);
      byte r      = (byte)(R + 0.5f);
      byte g      = (byte)(G + 0.5f);
      byte b      = (byte)(B + 0.5f);
      return new Color(r, g, b, m);
}
```

PS Decode:

```
float4 rgbm = tex2D(Sampler,texCoord);
float3 rgb = rgbm.rgb * rgbm.a * MaxRange;
```

Light Map of Three Swordsmen

- Effects of actual scenes:



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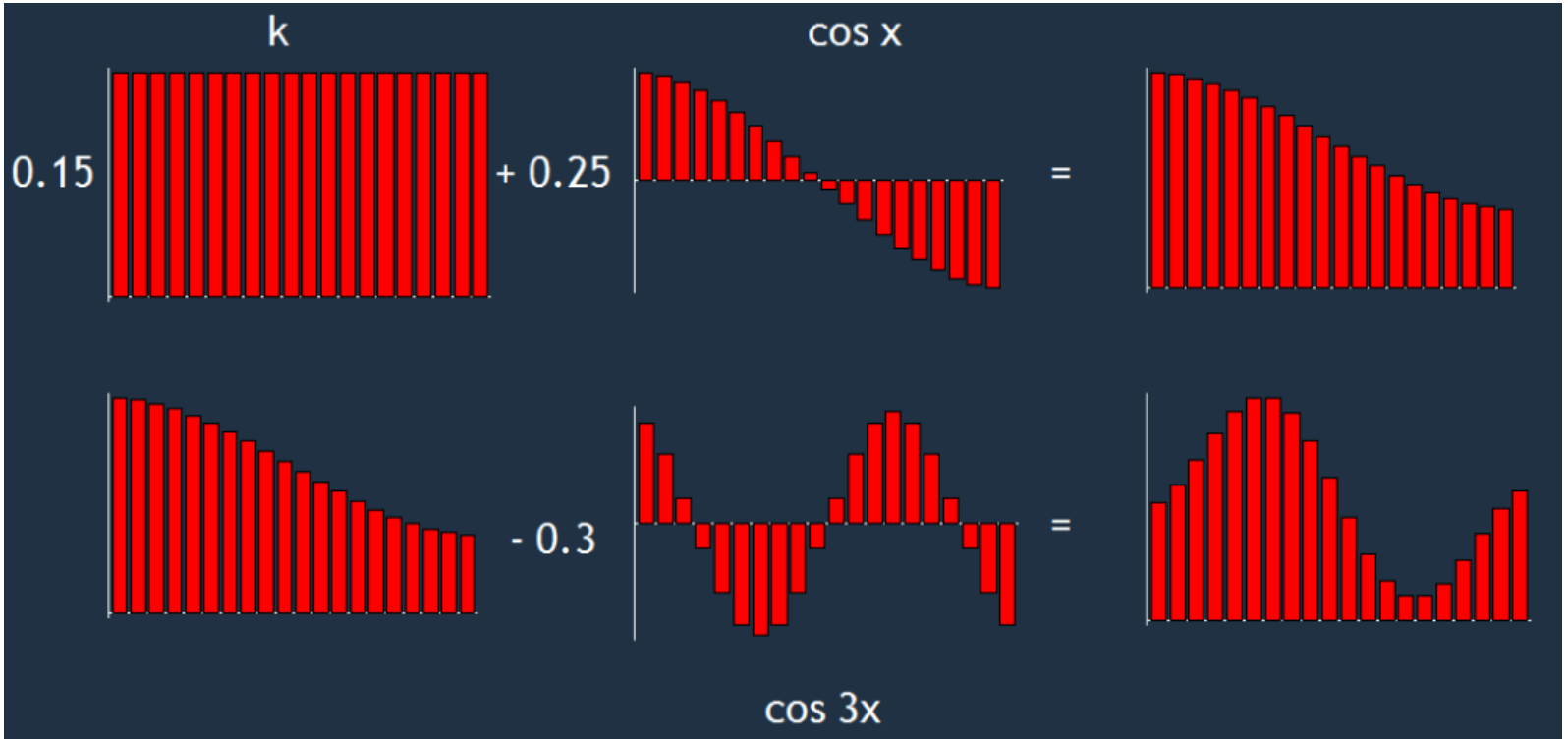
Integration of dynamic characters and static lighting

- Use SH Lighting to solve
- Small dynamic objects are affected by static light (mainly the characters can be better integrated into the environment)

Spherical Harmonics



Spherical Harmonics

- SH(Spherical Harmonics)
  - A 2D spherical extension of Fourier series, can expand the lighting function into superposition of SH basis functions, similar to the Fourier transform expanding any function into sine wave superposition
  - Compress storage by using the high-frequency details

Irradiance Volume

- Sample point boxes manually placing by artist
- Encoding methods
  - Low resolution CubeMap,1 pixel per side = 6 coefficients per color channel
  - Converted to SH，generally 3 Bands = 9 coefficients per color channel
- At run time, obtain the most recent sampling point to conduct linear interpolation (performed in the Vertex Shader) on the dynamic object (character, etc.), so the character can be affected by static lighting source

Summary

- The synergy between technique and art is very important
- Generic engines can only provide mechanisms, Strategies still rely on developers to achieve by themselves
- Achieve pipelines that maximize production efficiency based on the actual needs of the project
- Physics-based lighting is the future


Questions?
Btw, we are recruiting: hr@windplay.cn