Crafting a Next-Gen Material Pipeline for The Order: 1886

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About Our Project

- Brand-new IP
- Alternate history 19th-century London
- Exclusive to PlayStation 4
- In-house engine
- ~80 developers
Core Shading Model

- Default specular BRDF is Cook-Torrance
  - D term is GGX distribution from Walter et al.
  - Matching Smith G term derived in same paper
  - Schlick’s approximation for Fresnel
  - Lambertian diffuse, balanced with specular intensity
Core Shading Model

• Other BRDFs available
  – Beckmann (also taken from Walter et al.)
  – Anisotropic GGX
  – Hair (Kajiya-Kay)
  – Skin (pre-integrated diffuse)
  – Cloth
Pre-integrated skin diffuse with SH

\[ D(\theta, r) = \frac{\int_{-\pi}^{\pi} \cos(\theta + x)R(2r \sin(x/2))dx}{\int_{-\pi}^{\pi} R(2r \sin(x/2))dx} \]

\[ D_n(r) = 2\pi \int_0^{\pi/2} Y_{n,0}(\theta)D(\theta, r)\sin(\theta)d\theta \]

\[ f_{\text{skinSH}}(n, r) = \sum_{l=0}^{2} \sum_{m=-1}^{l} \sqrt{\frac{4\pi}{2l+1}} D_l(r)L_{l,m}Y_{l,m}(n) \]
Ambient Skin (Diffuse only)

Left is using normal SH lighting convolved with cosine kernel
Right is using SH lighting convolved with the scattering kernel
Cloth Shading
Cloth Shading

Observations from photo reference:

- Soft specular lobe with large smooth falloffs
- Fuzz on the rim from asperity scattering
- Low specular contribution at front facing angles
- Some fabrics have two toned specular colors
Cloth Shading

- Inverted Gaussian for asperity scattering
- Translation from origin to give more specular at front facing angles
- No geometry term
Specular Aliasing

\[ f(l, v) = \frac{\mathbf{F}(v, h) \mathbf{G}(l, v, h) D(h)}{4 (\mathbf{n} \cdot \mathbf{l}) (\mathbf{n} \cdot \mathbf{v})} \]
Specular Aliasing

• Modify roughness maps to reduce aliasing
• Using technique based on “Frequency Domain Normal Map Filtering” by Han et al.

\[ f_{\text{eff}}(1, v; \gamma) = \int_{\Omega} f(1, v)\gamma(n)dn \]

\[ f_{lm}^{\text{eff}} = \sqrt{\frac{4\pi}{2l + 1}} f_{l} \gamma_{lm} \]
Specular Aliasing

- Represent NDF as spherical Gaussian (vMF distribution)
- Approximate BRDF in SH as a Gaussian
- Convolution of two Gaussians is a new Gaussian
- Use relationship to compute new roughness

\[
\Lambda_l f_l^{\text{eff}} = e^{(\alpha l)^2} e^{-\frac{l^2}{2\kappa}} = e^{(\alpha' l)^2}
\]

\[
\alpha' = \sqrt{\alpha^2 + (2\kappa)^{-1}}
\]
• Play 3d Material Scanning Video
Scanning Calibration

- Errors in calibration caused low frequency errors in solved normal map
- Better estimation of parameters = better normals
  - Light direction
  - Light intensity
  - Geometric distortion
  - Radial distortion
  - Chromatic aberration
Material Authoring Pipeline

- 3 pillars of the material pipeline
  - Inheritance-based data format
  - Compositing
  - Run-time layering
Inheritance-based Materials

- Common parameters shared in base material
- Derived material only stores changes from base
- Quicker asset creation
- Global changes can be made in a single asset
Global Material Templates: Sample Glass Subset
Global Material Templates: Sample Metal Subset
Global Material Templates: Sample Masonry Subset
Common Materials: Production Samples
Material Compositing

• Mostly offline process
• Generates parameter maps from materials and blending maps
• Support compositing subset of BRDFs
  – Cloth, GGX, and Anisotropic
  – Compositing cloth requires applying 2 BRDFs
<table>
<thead>
<tr>
<th>Map</th>
<th>R Channel</th>
<th>G Channel</th>
<th>B Channel</th>
<th>A Channel</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normals X</td>
<td>Normals Y</td>
<td>N/A</td>
<td>N/A</td>
<td>BC5</td>
</tr>
<tr>
<td>2</td>
<td>Diffuse R</td>
<td>Diffuse G</td>
<td>Diffuse B</td>
<td>Alpha (Optional)</td>
<td>BC1 or BC3</td>
</tr>
<tr>
<td>3</td>
<td>Specular R</td>
<td>Specular G</td>
<td>Specular B</td>
<td>Specular Intensity</td>
<td>BC3</td>
</tr>
<tr>
<td>4</td>
<td>Roughness</td>
<td>AO</td>
<td>BRDF Blend</td>
<td>Anisotropy</td>
<td>BC3</td>
</tr>
</tbody>
</table>
base game asset as received back from outsource artist
Sample support maps baked from highres asset
texture artist adds markings and additional micro detail to the normal using Mari
In the material editor the texture artist adds our compositing feature
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The artist then adds one composite layer, using a generic solid white mask as default.
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blend parameters such as additive surface, scaling, and per-pass contribution can be adjusted
A second composite layer is then added, using a worn copper material and existing generic mask.
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Many other generic masks are maintained in the common texture library. These can be used directly in the material editor as variation maps in the compositing stack.
Another composite layer is added for further wear
mat: cmn_tarnished_a_tile_light  mask: prp_well_pump_c_worn_msk

This mask is tailored for the prop, using the baked support maps as channels in Mari for 3d paint.
Another composite of a more worn metal is used to further eat away into the tarnished areas.
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Recent scratches are indicated by another custom Mari mask, linked to a pristine copper
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Another composite layer is added for dirt accumulation
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Wetness on the object is conveyed with two more composite layers and masks.
The first is broader and blurred for slight dampness, and the second is sharp for standing water.
High quality custom materials are created very quickly, since the relationship of surface masks and materials is decoupled.
Variant materials can also be created with no texture painting and in virtually no time, simply by switching composite settings.
• Up to 4 layers
  – Derived from base materials
  – Separate compositing chain per layer
  – Driven by vertex colors
Future Work

- Compositing of other BRDF types
- Cheaper compositing of multiple BRDFs
- Improved Specular AA approximations
- Multiple specular lobes
- Better diffuse BRDFs
Specular AA Sample App

• https://mjp.codeplex.com/releases/view/109905
Credits

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