Production Friendly Microfacet Sheen BRDF

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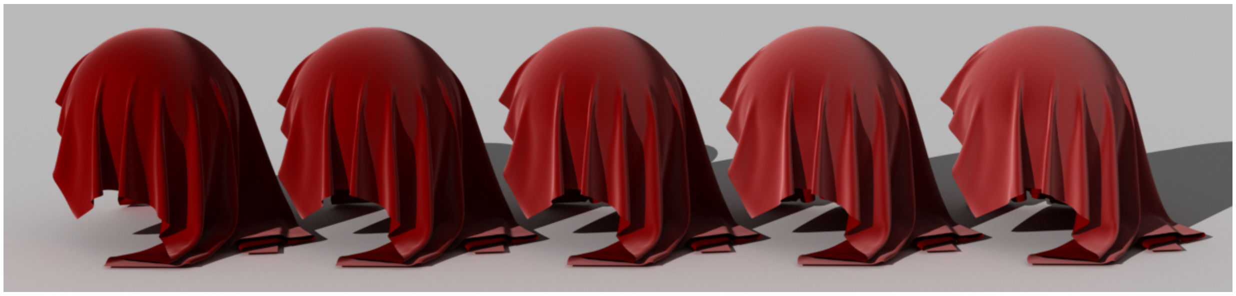

Figure 1: *Our sheen specular lobe layered over a red diffuse BRDF with increasing roughness. From left to right* $r = 0.15, 0.25, 0.40, 0.65$ and 1.0. *Low roughness keeps the specular highlight at the grazing angle, and as it grows the sheen reflection dominates. Our lobe keeps the terminator soft even at high roughness values at the cost of a small non-physical adjustment.*

Abstract

We present a microfacet distribution to simulate the back-scattering properties of cloth-like materials. This distribution is computationally inexpensive and produces a softer, more artist-friendly look than existing solutions. We also provide a good fit for the physically-based shadowing term, a straight-forward way of layering as an OSL building block for shaders, and some non-physical artistic adjustment for a softer light terminator.

Keywords: rendering, shading, BRDF

Concepts: •**Computing methodologies** → **Reflectance modeling;**

1 Overview

This BRDF is based on the usual microfacet equation where the scattering is defined as a function of some micronormal density. We follow up on the approach of using cylindrical microfibers [Ashikmin et al. 2000] as the main source of scattering. We propose a convenient and inexpensive distribution D with a better look, and a good shadowing term approximation G. Our BRDF uses the common form:

$$f(\omega_o, \omega_i) = \frac{F\,G\,D}{4\,|\omega_o \cdot N|\,|\omega_i \cdot N|}. \tag{1}$$

In order to layer this BRDF as a specular response on top of other substrates, we follow an albedo-scaling [Kelemen and Szirmay-Kalos 2001] technique. Using albedo from a look-up table we avoid energy gain in the mix. As a final touch we apply a single non-physical modification to comply with artistic expectations regarding the light terminator.

2 Microfacet Distribution

The main specular response from a velvet-like material comes from micro-fibers mainly oriented in the normal direction. There will be some random deviation from this direction, so the distribution of normals will not be a singular peak in the grazing direction. Instead of using a reversed gaussian-like distribution [Ashikmin et al. 2000] we propose an exponentiated sinusoidal:

$$D(m) = \frac{(2 + 1/r)\sin^{1/r}\theta}{2\pi}, \tag{2}$$

where r is a roughness parameter in $(0, 1]$ to modulate how much the microfibers diverge from the normal direction.

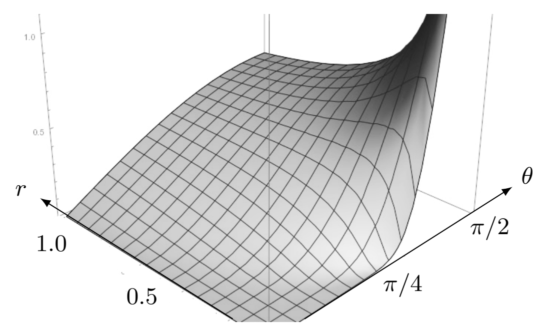

Figure 2: *Our density function plot over* θ *and the roughness* r. *It becomes sharper and more concentrated at the grazing angle as* r *approaches* 0

While sampling micronormals is straightforward using the inverted CDF, this can be problematic for grazing distributions because the weights will be divided by $\cos\theta_m$, which can become very small. Additionally, the reflected vector often gets scattered below the surface. We found plain uniform sampling of the upper hemisphere to be more effective.

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Figure 3: *Ashikhmin-Shirley Velvet model on the left and ours on the right. Upper and lower rows show two different lighting conditions. The dark spot on the light's direction is a common issue with their distribution. Our sine based alternative offers a softer look.*

r	a	b	c	d	e
0.0	25.3245	3.32435	0.16801	−1.27393	−4.85967
1.0	21.5473	3.82987	0.19823	−1.97760	−4.32054

Table 1: *Values for our Λ curve fitting. We interpolate parameters* $P = (1-r)^2 P_{0.0} + (1-(1-r)^2) P_{1.0}$

3 Shadowing Term

Following the projected-area normalization procedure [Heitz 2014] we find G numerically, since there is no easy analytical solution to $\int_\Omega \langle \omega \cdot m \rangle D(m) dm$. Instead of using a look-up table we found a good fit for Λ:

$$\Lambda(\theta) = \begin{cases} e^{L(\cos\theta)} & \text{if } \cos\theta < 0.5 \\ e^{2\,L(0.5) - L(1-\cos\theta)} & \text{otherwise,} \end{cases} \tag{3}$$

where $L(x) = a/(1 + bx^c) + dx + e$, and the a, b, c, d, e values were found by curve fitting. We obtained fits for $r = 0$ and $r = 1$, as shown in Table 1. For intermediate roughness values, we interpolate using $(1-r)^2$. The final shadowing function is computed using the correlated form $1/(1 + \Lambda(\omega_o) + \Lambda(\omega_i))$

4 Terminator Softening

Terminator issues often emerge in back-scattering BRDFs, even in a volume interpretation of velvet [Koenderink and Pont 2003]. While our model softens the terminator by means of the shadowing term, artists felt that the transition was still too abrupt and visually distracting. We softened the transition further by modifying our light-side Λ-function as follows:

$$\Lambda'(\theta_i) = \Lambda(\theta_i)^{1+2(1-\cos\theta_i)^8}. \tag{4}$$

This is the only point where we break the physical model and make the BRDF non-reciprocal. The effect can be seen in Figure 4.

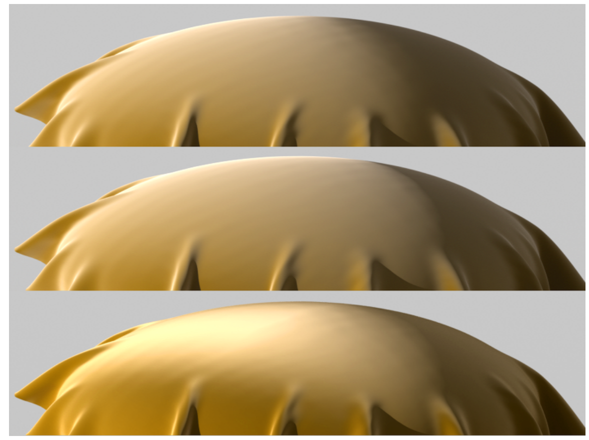

Figure 4: *Top row shows our model with the terminator softening in-place. Middle row shows the raw model without the fix. Even though the shading is plausible, artists preferred the softer look of the modified shadowing. Bottom row is the Ashikhmin-Shirley model.*

5 Layering

We use an albedo-scaling technique [Kelemen and Szirmay-Kalos 2001] to layer this BRDF as a specular response on top of any other arbitrary BSDF. However, we ignore the substrate BSDF renormalization. We obtain the albedos for incoming and outgoing directions α_i, α_o and scale the nested lobe by $\min(\alpha_i, \alpha_o)$. While this incurs some energy loss, the artists have not found it objectionable.

```
Ci = base_color * diffuse(N) + Kt * translucent(N);
Ci = sheen(Ci, N, spec_tint, roughness);
```

The OSL API demonstrated above allows a very practical nesting. Note, we pass `Ci` to `sheen()` so that the renderer can handle the scaling instead of creating a linear combination of the components in OSL. Our closure guarantees there is no energy gain by applying the albedo scaling to the nested closure, which can be any energy-preserving combination. This building block is, therefore, transparently integrated with the rest of our shading system.

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