Importance Sampling for a Microcylinder Based Cloth Bsdf

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We present an importance sampling method for a bidirectional scattering distribution function (*bsdf*) for cloth, based on the microcyliner based appearance model for cloth rendering presented in [Sadeghi et al. 2013]. Our algorithm is efficient, easy to implement and it has no significant memory overhead or need for precomputation. We have integrated our method into both a research raytracer and a micropolygon based production renderer. Figure 1 compares the rendering quality of our method to stratified uniform sampling for both direct (environment) lighting rendered with our production renderer and indirect lighting rendered with path tracing. In both cases, our method delivers significantly better image quality than uniform sampling using the same number of samples.

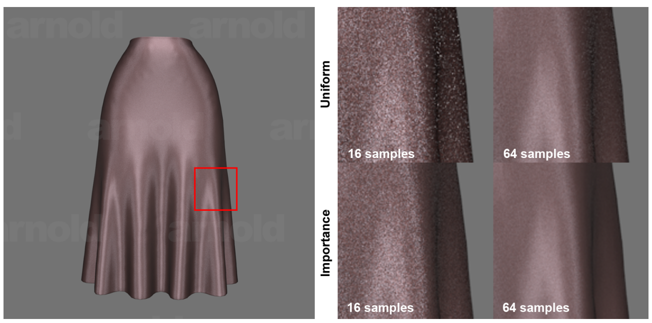

Figure 1: *Comparison of Poly Satin Skirt rendered using Importance Sampling vs Uniform Sampling*

Thread Importance Sampling

Sadeghi et al. [2013] proposed an microcylinder based cloth model. For each individual thread, the reflection model is separated into two lobes: surface reflection f_s and volume scattering f_v:

$$f(t, \omega_i, \omega_r) = f_s(t, \omega_i, \omega_r) + f_v(t, \omega_i, \omega_r)$$
$$f_s(t, \omega_i, \omega_r) = F_r \cos(\phi_d/2) g(\gamma_s, \theta_h) / \cos^2 \theta_d$$
$$f_v(t, \omega_i, \omega_r) = F_t \frac{(1 - k_d) g(\gamma_v, \theta_h) + k_d}{\cos\theta_i + \cos\theta_r} A / \cos^2 \theta_d$$

Each lobe can be sampled separately: the surface reflection f_s is very similar to the R lobe of the hair BSDF model propose in [Sadeghi et al. 2010] and importance sampled by [Ou et al. 2012], except the Fresnel reflectance factor F_r. For volume scattering f_v, the numerator $(1 - k_d)g(\gamma_v, \theta_h) + k_d$ is the dominant factor of the equation, and can be seen as a weighted sum of a diffuse lobe and a Gaussian lobe similar to the surface reflection f_s (albeit lacking the cosine factor). The detail of the sampling of each lobe is described below:

Sampling Surface Reflection f_s Similar to [Ou et al. 2012], we sample the Gaussian term using the Cauchy distribution. Given a random variable ξ uniformly drawn from range $[0, 1)$, we can sample θ_i as:

$$\theta_i = 2\gamma_s \tan(\xi(A - B) + B) - \theta_r$$

where $A = \tan^{-1}\left(\frac{\theta_r + \pi/2}{2\gamma_s}\right)$ and $B = \tan^{-1}\left(\frac{\theta_r - \pi/2}{2\gamma_s}\right)$. The *pdf* is $p(\theta_i) = \frac{1}{2(A-B)} \frac{\gamma_s}{\theta_h^2 + \gamma_s^2}$.

Sampling Azimuthal Term. To sample ϕ_i for the cosine term $\cos(\phi_d/2)$, let $\phi_i = \phi_r - 2\sin^{-1}(2\xi - 1)$. The pdf is $p(\phi_i) = \frac{1}{4}\cos(\frac{\phi_d}{2})$

Sampling the Volumetric Scattering f_v For f_v, we focus on sampling the numerators. These terms are sampled separately: the anisotropic term is chosen with probability $1 - k_d$, we then use the same method to sample ω_i as we did for surface reflection f_s. On the other hand, the isotropic term is chosen with probability k_d, we simply use a cosine-weighted distribution, so $\theta_i = \sin^{-1}(2\xi - 1)$, with pdf $p(\theta_i) = \frac{\cos(\theta_i)}{2}$. We combine both terms to compute the overall pdf $p(\theta_i) = (1 - k_d)\frac{1}{2(A-B)} \frac{\gamma_v}{\theta_h^2 + \gamma_v^2} + k_d \frac{\cos(\theta_i)}{2}$

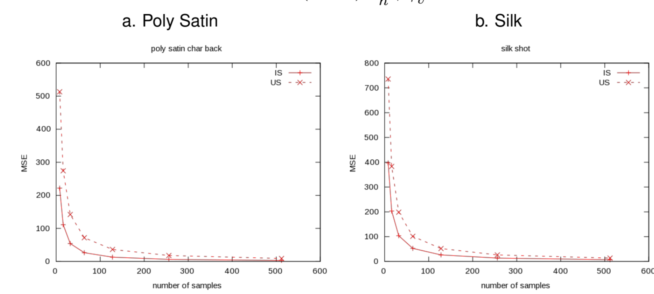

Figure 2: *Mean Square Error vs Number of Samples for importance and uniform sampling .*

Results

Figure 2 demonstrates our importance sampling algorithm is quite effective at noise/error reduction. For polyester satin and silk, the MSE of the image rendered using importance sampling is consistently 25% or lower compare to uniform sampling. This is also verified by the rendering comparisons of cloth *bsdf* with poly satin and silk settings using stratified uniform sampling versus our importance sampling algorithm, see Figure 3. In most of the directing lighting situations, our importance sampling algorithm yields better quality than uniform sampling with 4x number of samples. The improvement is even more significant in renders with multiple scattering and indirect lighting.

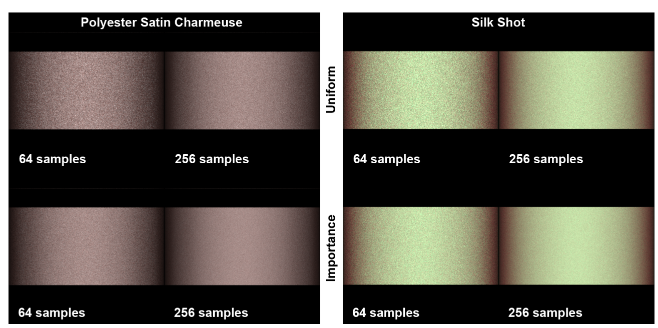

Figure 3: *Poly Satin and Silk Shot rendered using importance vs uniform sampling*

References

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SADEGHI, I., PRITCHETT, H., JENSEN, H. W., AND TAMSTORF, R. 2010. An artist friendly hair shading system. *ACM Transactions on Graphics 29*, 4 (July), 56:1–56:10.

SADEGHI, I., BISKER, O., DEKEN, J., AND JENSEN, H. 2013. A practical microcyliner appearance model for cloth rendering. *ACM Transactions on Graphics*.