A practical Microcylinder Appearance Model for Cloth Rendering

Presented by Garoe Dorta Perez

University of Bath
Centre For Digital Entertainment

May 27, 2015

Overview

Outline

Introduction

$$L_o(\mathbf{p}, \boldsymbol{\omega_o}) = L_e(\mathbf{p}, \boldsymbol{\omega_o}) + \int_\Omega f(\mathbf{p}, \boldsymbol{\omega_o}, \boldsymbol{\omega_i}) L_i(\mathbf{p}, \boldsymbol{\omega_i}) |\cos\theta_i| d\boldsymbol{\omega_i}$$

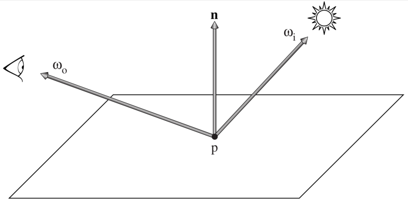
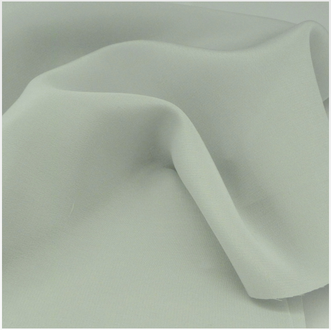


Diagram of light emitted from **p**, image taken from [PH10].

where L_o is the outgoing radiance, L_i incoming radiance, L_e emitted radiance, f BRDF function, $\mathbf{p}$ surface point, $\boldsymbol{\omega_i}$ incident light, $\boldsymbol{\omega_o}$ outgoing light, Ω hemisphere above $\mathbf{p}$, θ_i angle of incidence.

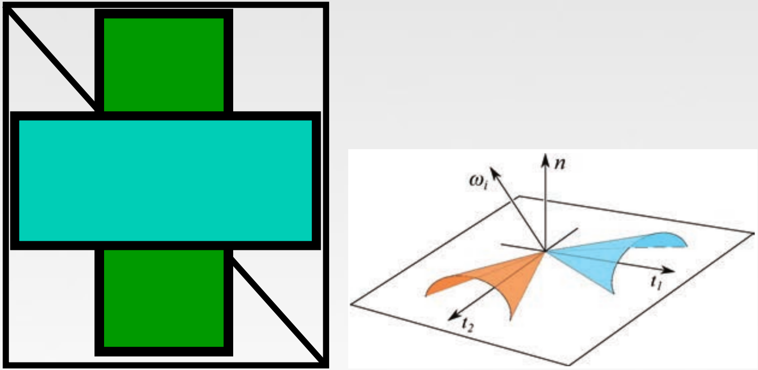
The problem

- Render cloth fast and realistically
  - Small threads
  - Weaving patterns



Left shows a close up view of fabric, right shows a picture of cloth, images taken from [SBD*13].

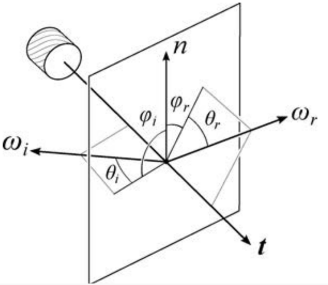
- Two microcylinders [SBD*13]



Left shows model in a triangle mesh, right shows scattering cones in a patch, images taken from [SBD*13].

Appearance model

$$\text{BRDF: } f(t,\omega_i,\omega_r) = \frac{\text{Reflection term} + \text{Volume scattering term}}{\text{Normalization factor}},$$



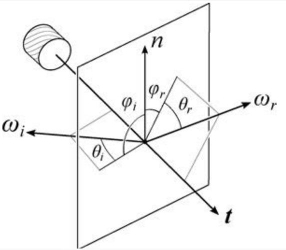
Angle definitions for a single thread, image taken from [SBD*13].

where f is the BRDF function, t is the thread direction, ω_i is the ray incoming direction, ω_r is the ray outgoing direction.

Outline

BRDF

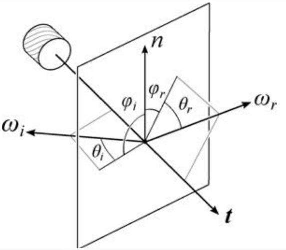
$$\text{BRDF: } f(t,\omega_i,\omega_r) = \left(\overbrace{F_r(\eta,\omega_i)\cos(\phi_d/2)g(\gamma_s,\theta_h)}^{\text{Reflection term}} + F_t(\eta,\omega_i)F_t(\eta',\omega_r')\frac{(1-k_d)g(\gamma_v,\theta_h)+k_d}{\cos\theta_i+\cos\theta_r}A \right) / \cos^2(\theta_d),$$



where f is the BRDF function, t is the thread direction, ω_i is the ray incoming direction, ω_r is the ray outgoing direction, F are Fresnel terms, η are Fresnel coefficients, θ and *phi* angles are shown in the figure, g is a Gaussian lobe, k_d is a scattering constant, A is an albedo constant, γ are Gaussian widths, $\theta_h = (\theta_i + \theta_r)/2$ and $\phi_d = \phi_i - \phi_r$.

$$\text{BRDF: } f(t,\omega_i,\omega_r) = \left(F_r(\eta,\omega_i) \overbrace{\cos(\phi_d/2)}^{\text{Cylinder reflection}} g(\gamma_s,\theta_h) + \right.$$

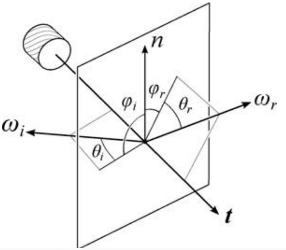
$$\left. F_t(\eta,\omega_i)F_t(\eta',\omega_r')\frac{(1-k_d)g(\gamma_v,\theta_h)+k_d}{\cos\theta_i+\cos\theta_r}A \right) / \cos^2(\theta_d),$$



where f is the BRDF function, t is the thread direction, ω_i is the ray incoming direction, ω_r is the ray outgoing direction, F are Fresnel terms, η are Fresnel coefficients, θ and *phi* angles are shown in the figure, g is a Gaussian lobe, k_d is a scattering constant, A is an albedo constant, γ are Gaussian widths, $\theta_h = (\theta_i + \theta_r)/2$ and $\phi_d = \phi_i - \phi_r$.

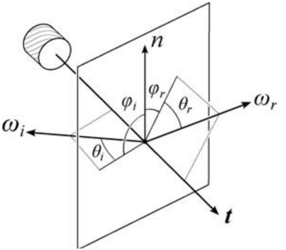
BRDF

$$\text{BRDF: } f(t,\omega_i,\omega_r) = \Bigg(F_r(\eta,\omega_i)\cos(\phi_d/2) \overbrace{g(\gamma_s,\theta_h)}^{\text{Cylinder roughness}} + F_t(\eta,\omega_i)F_t(\eta',\omega_r')\frac{(1-k_d)g(\gamma_v,\theta_h)+k_d}{\cos\theta_i+\cos\theta_r}A\Bigg) \Big/ \cos^2(\theta_d),$$



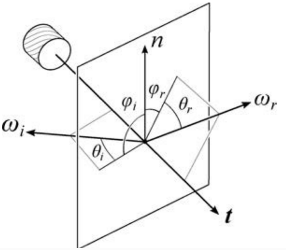
where f is the BRDF function, t is the thread direction, ω_i is the ray incoming direction, ω_r is the ray outgoing direction, F are Fresnel terms, η are Fresnel coefficients, θ and *phi* angles are shown in the figure, g is a Gaussian lobe, k_d is a scattering constant, A is an albedo constant, γ are Gaussian widths, $\theta_h = (\theta_i + \theta_r)/2$ and $\phi_d = \phi_i - \phi_r$.

$$\text{BRDF: } f(t,\omega_i,\omega_r) = \left(\overbrace{F_r(\eta,\omega_i)}^{\text{Attenuation factor}} \cos(\phi_d/2)g(\gamma_s,\theta_h) + F_t(\eta,\omega_i)F_t(\eta',\omega_r')\frac{(1-k_d)g(\gamma_v,\theta_h)+k_d}{\cos\theta_i+\cos\theta_r}A \right) / \cos^2(\theta_d),$$



where f is the BRDF function, t is the thread direction, ω_i is the ray incoming direction, ω_r is the ray outgoing direction, F are Fresnel terms, η are Fresnel coefficients, θ and *phi* angles are shown in the figure, g is a Gaussian lobe, k_d is a scattering constant, A is an albedo constant, γ are Gaussian widths, $\theta_h = (\theta_i + \theta_r)/2$ and $\phi_d = \phi_i - \phi_r$.

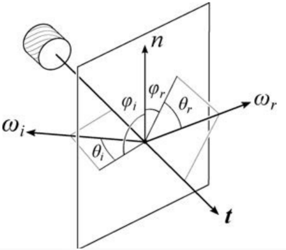
$$\text{BRDF: } f(t,\omega_i,\omega_r) = \Bigg(F_r(\eta,\omega_i)\cos(\phi_d/2)g(\gamma_s,\theta_h) + \overbrace{F_t(\eta,\omega_i)F_t(\eta',\omega_r')\frac{(1-k_d)g(\gamma_v,\theta_h)+k_d}{\cos\theta_i+\cos\theta_r}A}^{\text{Volume scattering term}} \Bigg) / \cos^2(\theta_d),$$



where f is the BRDF function, t is the thread direction, ω_i is the ray incoming direction, ω_r is the ray outgoing direction, F are Fresnel terms, η are Fresnel coefficients, θ and *phi* angles are shown in the figure, g is a Gaussian lobe, k_d is a scattering constant, A is an albedo constant, γ are Gaussian widths, $\theta_h = (\theta_i+\theta_r)/2$ and $\phi_d = \phi_i - \phi_r$.

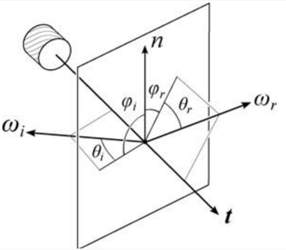
BRDF

$$\text{BRDF: } f(t,\omega_i,\omega_r) = \Bigg(F_r(\eta,\omega_i)\cos(\phi_d/2)g(\gamma_s,\theta_h) + \overbrace{F_t(\eta,\omega_i)F_t(\eta',\omega_r')}^{\text{Attenuation factor}} \frac{(1-k_d)g(\gamma_v,\theta_h)+k_d}{\cos\theta_i+\cos\theta_r} A \Bigg) / \cos^2(\theta_d),$$



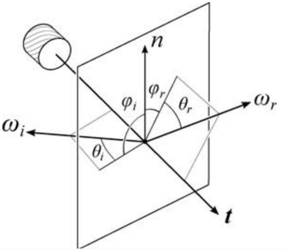
where f is the BRDF function, t is the thread direction, ω_i is the ray incoming direction, ω_r is the ray outgoing direction, F are Fresnel terms, η are Fresnel coefficients, θ and *phi* angles are shown in the figure, g is a Gaussian lobe, k_d is a scattering constant, A is an albedo constant, γ are Gaussian widths, $\theta_h = (\theta_i + \theta_r)/2$ and $\phi_d = \phi_i - \phi_r$.

$$\text{BRDF: } f(t,\omega_i,\omega_r) = \Bigg(F_r(\eta,\omega_i)\cos(\phi_d/2)g(\gamma_s,\theta_h) + F_t(\eta,\omega_i)F_t(\eta',\omega_r')\frac{(1-k_d)\overbrace{g(\gamma_v,\theta_h)}^{\text{Scattering cone}}+k_d}{\cos\theta_i+\cos\theta_r}A\Bigg) / \cos^2(\theta_d),$$



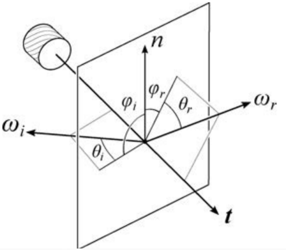
where f is the BRDF function, t is the thread direction, ω_i is the ray incoming direction, ω_r is the ray outgoing direction, F are Fresnel terms, η are Fresnel coefficients, θ and *phi* angles are shown in the figure, g is a Gaussian lobe, k_d is a scattering constant, A is an albedo constant, γ are Gaussian widths, $\theta_h = (\theta_i+\theta_r)/2$ and $\phi_d = \phi_i - \phi_r$.

$$\text{BRDF: } f(t,\omega_i,\omega_r) = \Bigg(F_r(\eta,\omega_i)\cos(\phi_d/2)g(\gamma_s,\theta_h) + F_t(\eta,\omega_i)F_t(\eta',\omega_r')\frac{(1-k_d)g(\gamma_v,\theta_h)+k_d}{\underbrace{\cos\theta_i+\cos\theta_r}_{\text{Normalization factor}}}A \Bigg) / \cos^2(\theta_d),$$



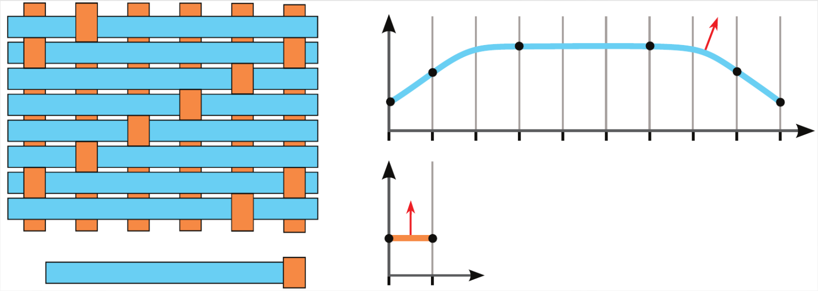
where f is the BRDF function, t is the thread direction, ω_i is the ray incoming direction, ω_r is the ray outgoing direction, F are Fresnel terms, η are Fresnel coefficients, θ and *phi* angles are shown in the figure, g is a Gaussian lobe, k_d is a scattering constant, A is an albedo constant, γ are Gaussian widths, $\theta_h = (\theta_i + \theta_r)/2$ and $\phi_d = \phi_i - \phi_r$.

$$\text{BRDF: } f(t,\omega_i,\omega_r) = \Bigg(F_r(\eta,\omega_i)\cos(\phi_d/2)g(\gamma_s,\theta_h) + F_t(\eta,\omega_i)F_t(\eta',\omega_r')\frac{(1-k_d)g(\gamma_v,\theta_h)+k_d}{\cos\theta_i+\cos\theta_r}A\Bigg) \Big/ \overbrace{\cos^2(\theta_d)}^{\text{Normalization factor}},$$



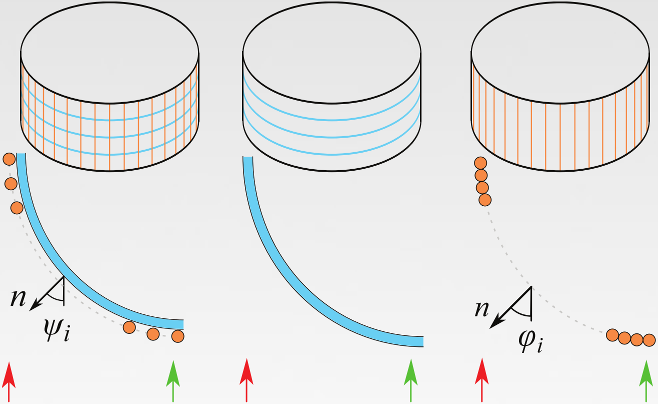
where f is the BRDF function, t is the thread direction, ω_i is the ray incoming direction, ω_r is the ray outgoing direction, F are Fresnel terms, η are Fresnel coefficients, θ and *phi* angles are shown in the figure, g is a Gaussian lobe, k_d is a scattering constant, A is an albedo constant, γ are Gaussian widths, $\theta_h = (\theta_i + \theta_r)/2$ and $\phi_d = \phi_i - \phi_r$.

Shading Model



Normal sampling, (top-left) cloth patch, (bottom-left) smallest cloth patch, (top-right) blue thread tangent curve, (bottom-right) red thread tangent curve, image taken from [SBD*13].

Shading Model



Masking examples, Green arrow points view from above, red arrow points view at grazing angle, image taken from [SBD*13].

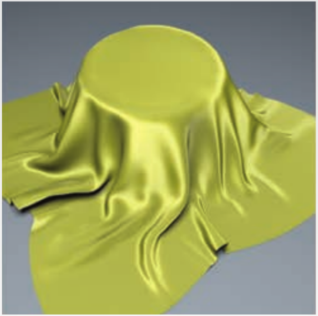
Shading Model

$$L_r(\omega_r) = Q(t) \sum \int L_i(\omega_i) f(t, \omega_i, \omega_r) M(t) P(t) \cos\theta_i d\omega_i,$$

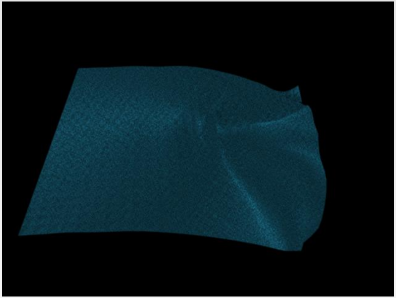
where f is the BRDF function, t is the thread direction, ω_i is the ray incoming direction, ω_r is the ray outgoing direction, θ_i is the incoming ray angle, $Q(t)$ is a normalization factor for samples and non watertight patches, $M(t)$ is the masking term and $P(t)$ is a view-projection normalization factor.

Outline

Results



Cloth render result from [SBD*13].



Our cloth implementation in Maya®using MentalRay®.

Conclusions and Future Work

- Limitations
    - Requires captured data
    - Difficult parametrization
- Future work
    - Implement full model
    - Importance sampling extensions by [MI] and [WXK]

Thank you

Questions?

References

[SBD*13] Sadeghi, I. et al. A practical microcylinder appearance model for cloth rendering. ACM 2013
[PH10] Pharr, M. et al. Physically based rendering: From theory to implementation, Morgan Kaufmann, 2010
[MI] Mizutani K. et al. Importance Sampling for Cloth Rendering under Environment Light, Mathematical Progress in Expressive Image Synthesis I, 2014
[WXK] Wang J. et al. Importance Sampling for a Microcylinder Based Cloth Bsdf, SIGGRAPH Talks, 2014