# A practical Microcylinder Appearance Model for Cloth Rendering

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# Overview

# Outline

# Introduction



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

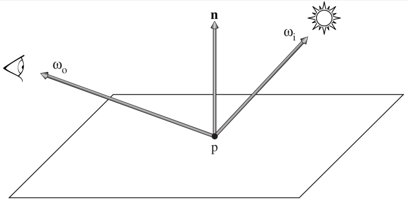


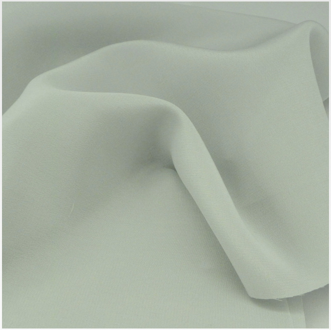

Diagram of light emitted from **p**, image taken from [PH10].

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, $\Omega$ hemisphere above $\mathbf{p}$, $\theta_i$ 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].

# Previous work



- Exampled-based
  - Data acquisition
  - BRDF fitting
  - Not flexible but fast
- Procedurally-based
  - Extending BRDF
  - Flexible but slow

Cloth rendered with a volumetric technique, image taken from [JAM*10].

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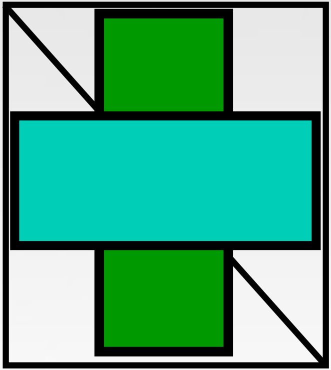
Proposed Model
- Appearance Model
- BRDF Model
- Shading Model

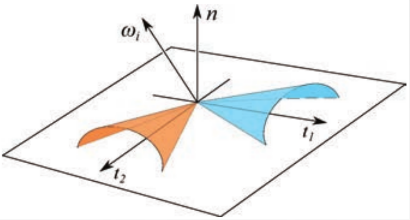
Results and Conclusion

# Appearance Model



- Two microcylinders [SBD*13]



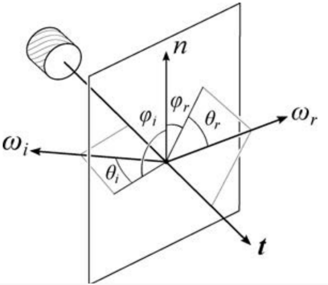



Left shows model in a triangle mesh, right shows scattering cones in a patch, images taken from [SBD*13].

# Appearance Model



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



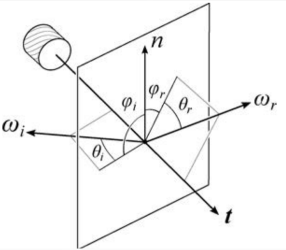

Angle definitions for a single thread, image taken from [SBD*13].

where $f$ is the BRDF function, $t$ is the thread direction, $\omega_i$ is the ray incoming direction, $\omega_r$ is the ray outgoing direction.

# BRDF Model



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



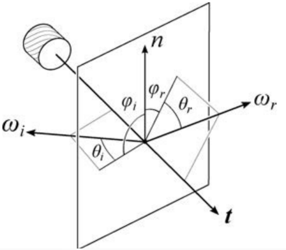

where $f$ is the BRDF function, $t$ is the thread direction, $\omega_i$ is the ray incoming direction, $\omega_r$ is the ray outgoing direction, $F$ are Fresnel terms, $\eta$ are Fresnel coefficients, $\theta$ and *phi* angles are shown in the figure, $g$ is a Gaussian lobe, $k_d$ is a scattering constant,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

# BRDF Model



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

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

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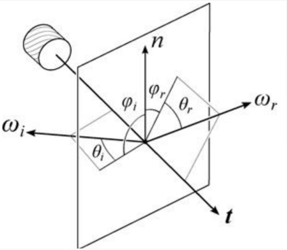
$$\text{BRDF: } f(t,\omega_i,\omega_r) = \Bigg( F_r(\eta,\omega_i)\cos(\phi_d/2) \overbrace{g(\gamma_s,\theta_h)}^{\text{Cylinder roughness}} + F_t(\eta,\omega_i)F_t(\eta',\omega_r')\frac{(1-k_d)g(\gamma_v,\theta_h)+k_d}{\cos\theta_i+\cos\theta_r}A\Bigg) / \cos^2(\theta_d),$$

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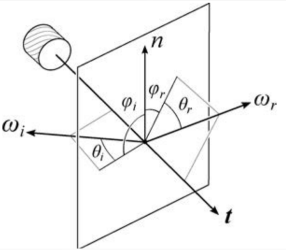
$$\text{BRDF: } f(t,\omega_i,\omega_r) = \left( \overbrace{F_r(\eta,\omega_i)}^{\text{Attenuation factor}} \cos(\phi_d/2) g(\gamma_s,\theta_h) + F_t(\eta,\omega_i) F_t(\eta',\omega_r') \frac{(1-k_d) g(\gamma_v,\theta_h) + k_d}{\cos\theta_i + \cos\theta_r} A \right) / \cos^2(\theta_d),$$

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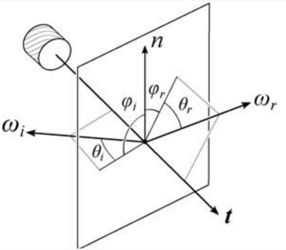


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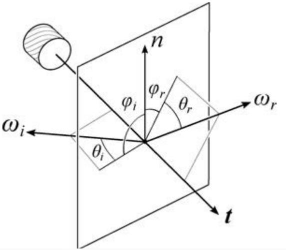


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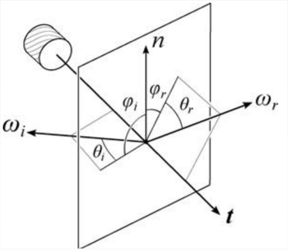


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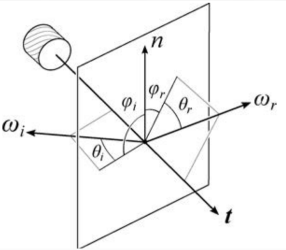


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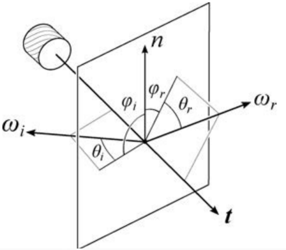


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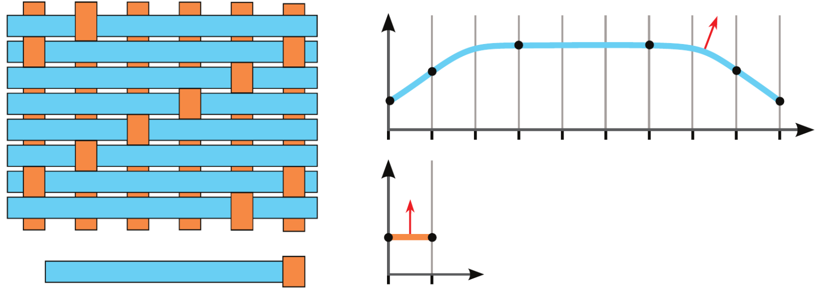
# Shading Model

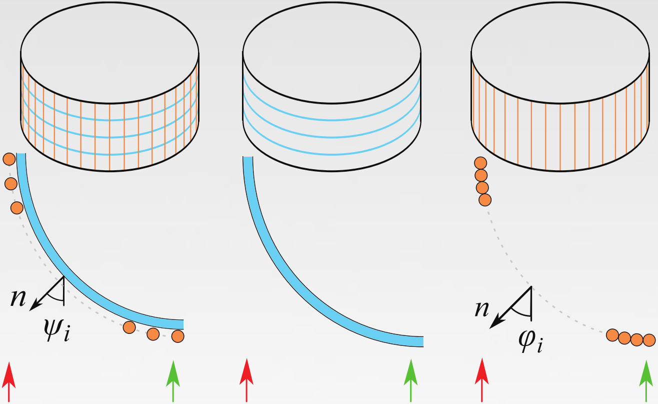




Normal sampling, (top-left) cloth patch, (bottom-left) smallest cloth patch, (top-right) blue thread tangent curve, (bottom-right) red thread tangent curve, image taken from [SBD*13].

# 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, $\omega_i$ is the ray incoming direction, $\omega_r$ is the ray outgoing direction, $\theta_i$ 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.

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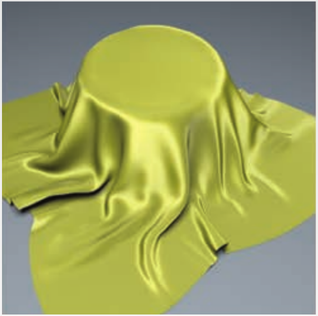
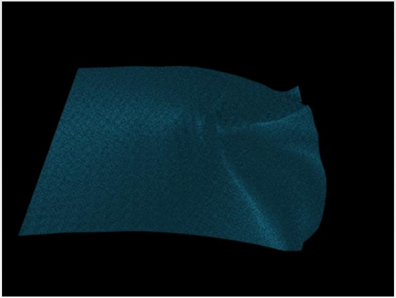
# Results





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

[JAM*10] Jackob W. et al. A radiative transfer framework for rendering materials with anisotropic structure. ACM 2010
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[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