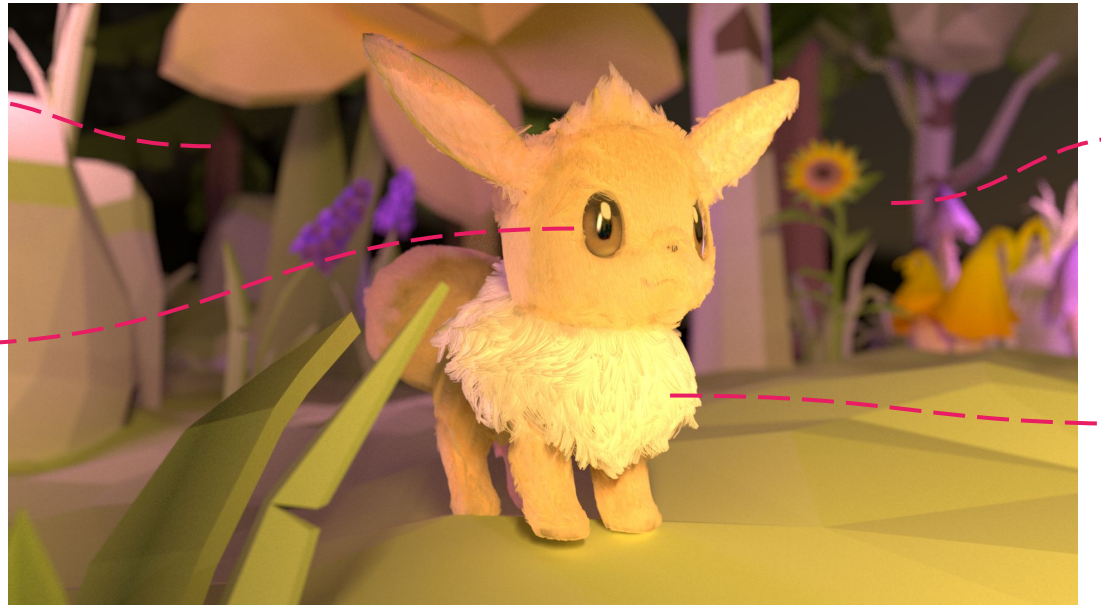
Whimsical Night: Artistic Control of a Physically Based Rendering Model



1920x1080, 4096 spp, 9 hrs

How do we make worlds that are magical, but familiar?

Frozen 2 (2019)

Monsters University (2013)

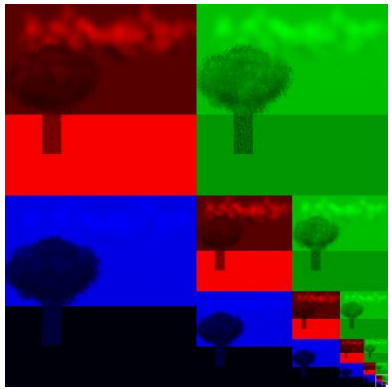
Texture Mapping

Nori Starter

Nori with Textures

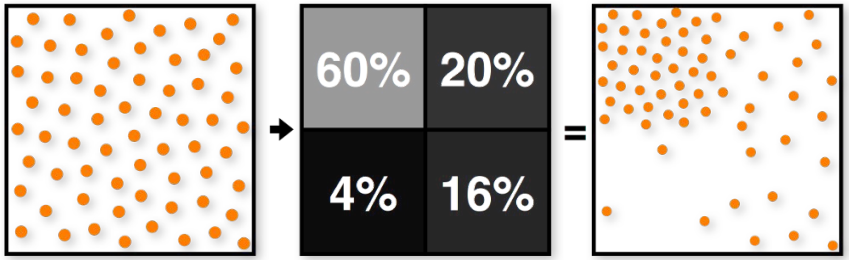
Texture Mapping

- Texture Mapping is done using a MIP map
- Textures were exported from Blender



Environment Mapping and Hierarchical Warping

- The environment map can be thought of as an infinite area light



- The mipmap allows for fast hierarchical importance sampling

Day

Night

Thin Lens Camera Model

0.00

0.02

0.20

Rendering Hair

Hair Anatomy

Cuticle

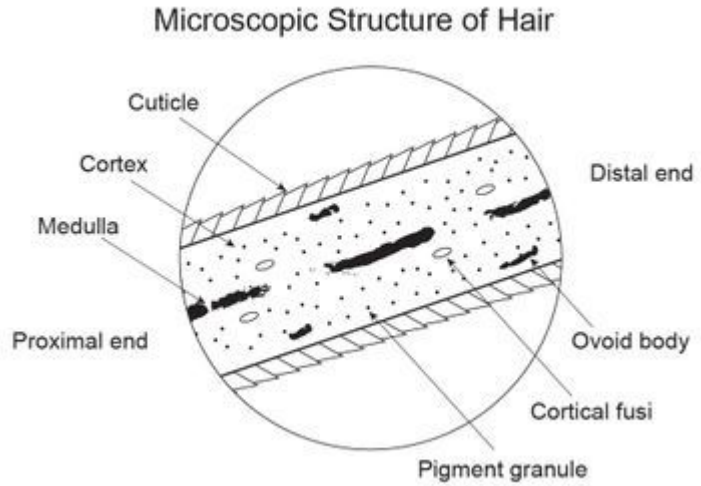
- Outer layer
- Angled at ~2°
- Rough dielectric

Cortex

- 90% of hair volume
- Absorbs most light

Medulla

- An extremely thick core.
- Causes scattering



A Physically Based Hair Model

Three Phenomena

- Absorption
- Azimuthal scattering
- Longitudinal scattering

Figure 12: A comparison of Kajiya and Kay's model (left) under a single point source, our proposed model (center) with the same lighting, and the hair from the photograph in Figure 11 (removed from context to simplify the comparison). The Kajiya model's diffuse term results in a flat appearance, while the secondary highlight in our model correctly captures the colored shading of the real hair.

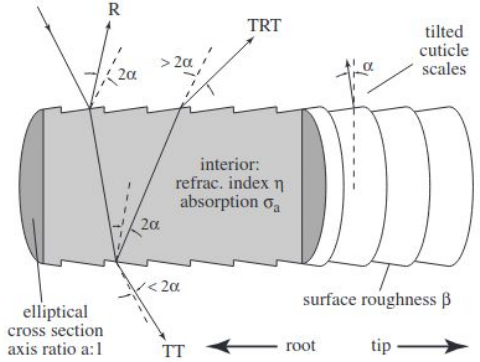
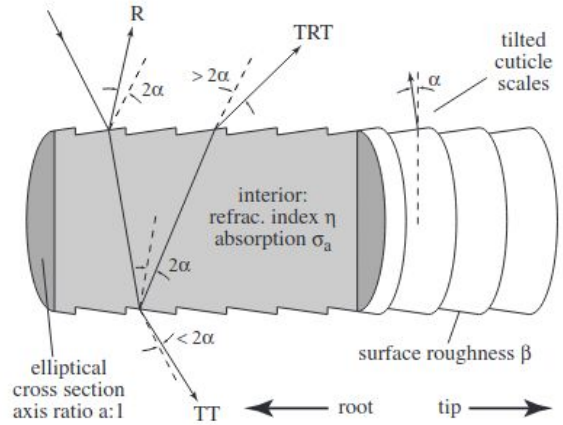


Figure 1: A schematic of our model for a hair fiber. The dashed lines indicate the scattering angles for a cylinder without tilted surface scales.

Light Scattering from Human Hair Fibers (SIGGRAPH 2003)

The First Three Lobes



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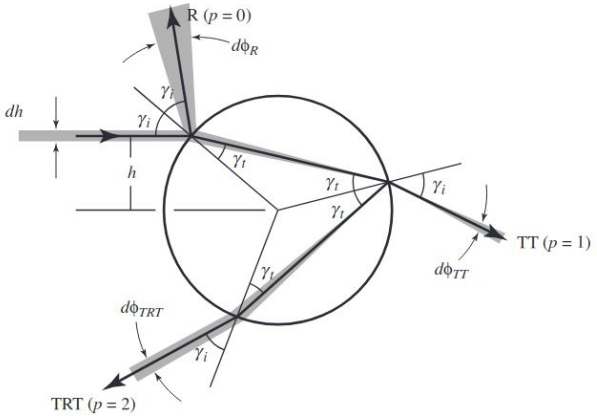
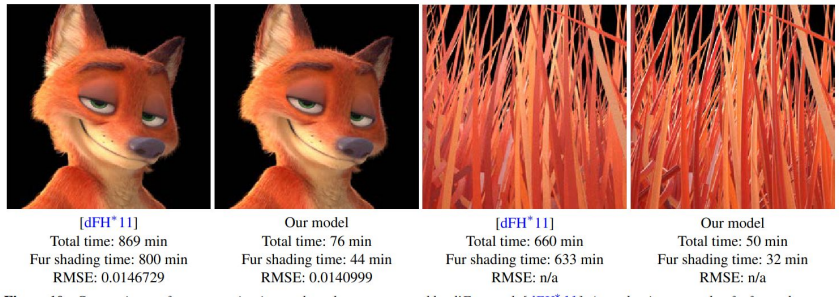


Figure 9: Geometry for scattering from a circular cross section.

A Controllable Hair Model

- With prior hair models, the parameters are a bit unintuitive
- This paper describes a way to map reflectance, and linearly scaled roughness to hair parameters.

Figure 2: *Species differentiation through azimuthal roughness. Photo reference of three different species (top) and fur renderings with varying azimuthal roughness (bottom) artistically matching the overall softness.*

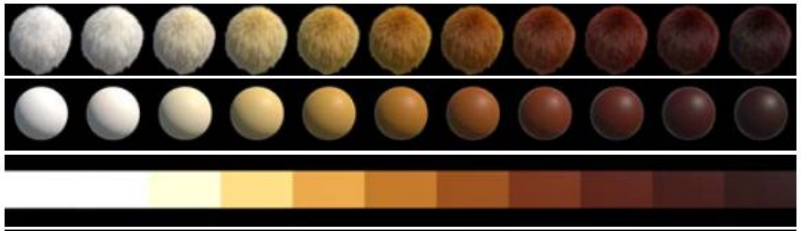


A Practical and Controllable Hair and Fur Model for Production Path Tracing (Eurographics 2016)

User Control of Hair Parameters

Color is mapped to absorption using a special scale

$$\sigma_a = (\ln C/(5.969 - 0.215\beta_N + 2.532\beta_N^2 - 10.73\beta_N^3 + 5.574\beta_N^4 + 0.245\beta_N^5))^2$$

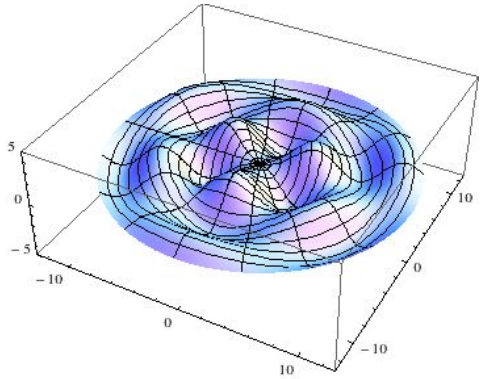


Scattering coefficients are also scaled

$$\nu = (0.726\beta_M + 0.812\beta_M^2 + 3.7\beta_M^{20})^2.$$

$$s = 0.265\beta_N + 1.194\beta_N^2 + 5.372\beta_N^{22}.$$

Sampling the Hair BSDF



Longitudinal Scattering

- Uses Bessel function [dFH*11]

$$M_p(\theta_o, \theta_i) = \frac{1}{2v \sinh(1/v)} e^{-\frac{\sin\theta_i \sin\theta_o}{v}} I_0\left(\frac{\cos\theta_o \cos\theta_i}{v}\right)$$

Azimuthal Scattering

- Sample from logistic distribution [CBTB16]

Absorption

- Depends on the offset between the incident ray and center of the hair

Diffuse vs Hair BSDF

Diffuse

Hair

Much better energy conservation!

Limitations

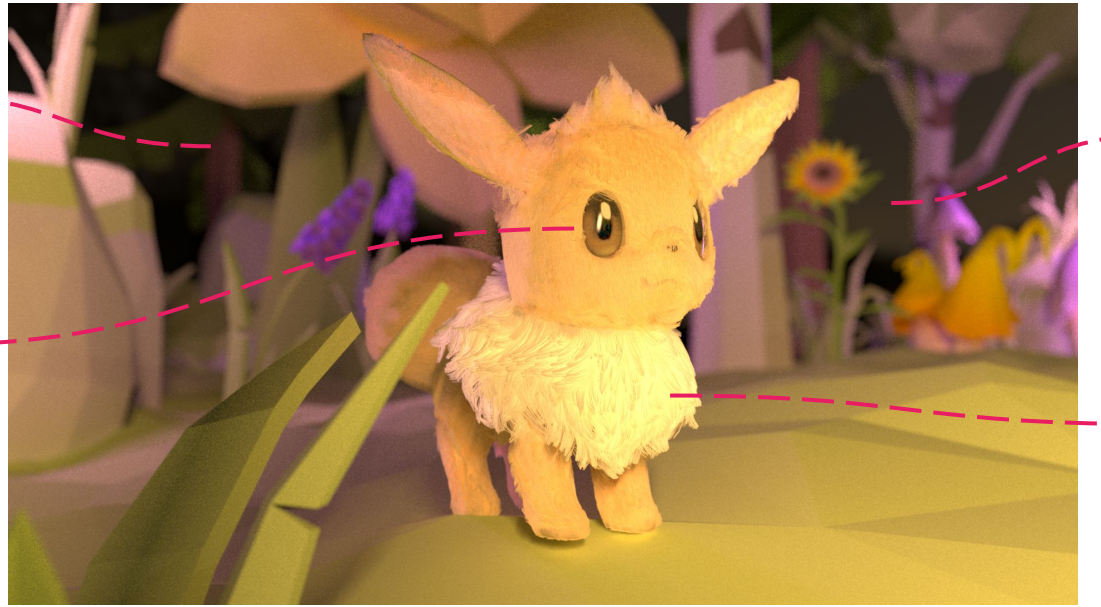
Scattering is not accurate!

Hair is being approximated by a triangle mesh.

An important direction for future work would be to add geometry primitives, and to improve the Blender plugin.

Recap
How do we make worlds that are magical, but familiar?

Whimsical Night



Texture Mapping

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Nori with Textures

Challenge: Energy Conservation

- The 3 lobe approach results in high energy loss, especially when there is low absorption.
- [CBTB16] proposes a factored lobe approach to model scattering efficiently

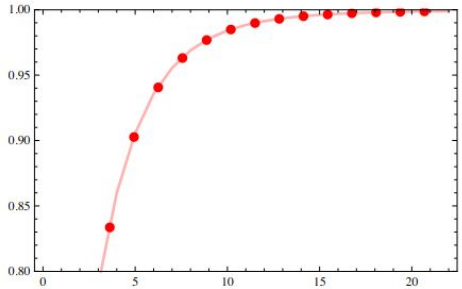

Figure 4: *Total spherical—directional reflectance of a non-absorbing (white) fiber at inclination angle 85° as a function of the number of lobes considered. High-order lobes have diminishing contributions to the total energy yet still substantial as a whole.*

10 lobes are needed for 99% energy conservation! [CBTB16]

$$A_{\text{fourth}} = \sum_{p=TRRT}^{\infty} A_p = \frac{(1-f)^2 f^2 T^3}{1-fT},$$

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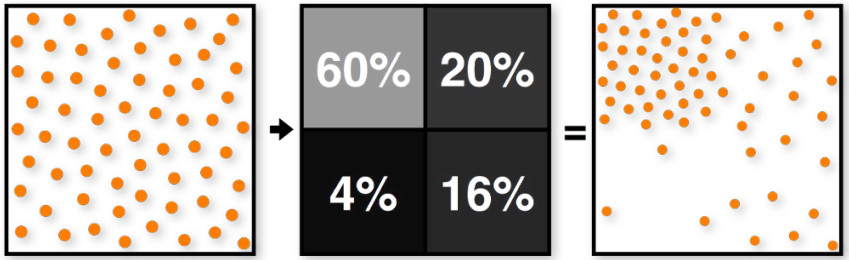

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Diffuse vs Hair BSDF

Diffuse

Hair

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Grading Notes from Steve

- Centered on fur but has several other components
- Added textures
- Env map sampling using hierarchical warping
- Thin lens camera model
- Hair is the most extensive part
- Discussion of hair anatomy and optics
- Implementation is somehow applied to triangle mesh fibers
- gets a nice volumetric look but unclear whether benefits of hair BSDF are there
- Overall a very nice and finished looking image

Echoes the thorough and well-prepared presentation. You spend a lot of time talking about the Chiang et al. hair model, but don't show any results from your implementation that would indicate whether or not the implementation works. The hair does end up looking soft, which is good, though I'm quite confused by the comparison showing diffuse with an odd glow behind the fibers and hair looking quite emissive (possible normalization issue?), but also maybe with an overall blurrier image.

The contest image is impressive and nicely refined/tuned; it shows off the various new features effectively.

4.0/4.0