rendering

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WE NEED TO GO DEEPER
I went that deep
Realistic approach

Hybrid fur rendering: combining volumetric fur with explicit hair strands

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Fig. 1 Most animal furs consist of both guard hairs and undercoat (left, as an example). These two fur layers are very different and hard to model and render believably with explicit hairs only (middle) or volumetric fur only. We present a pipeline for hybrid fur rendering that enables efficient combination of explicit hair strands with volumetric fur (right).

http://people.compute.dtu.dk/jerf/papers/hybrid_fur.pdf
Fig. 2 Close-up photos of a brown mink fur. The fur skin is bent to better illustrate the visual differences of the undercoat hairs and the guard hairs. Both fur layers should be modeled to qualitatively match the appearance of real fur.
Fig. 3 Overview of our shader pipeline. In steps 1–3, we generate explicit hair strand and shell geometry. In steps 4–6, the generated geometry is rasterized and shaded (see also Fig. 4 and Section 3.1.3.2). In step 7, the shaded fragments are depth sorted and blended in accordance with our blending algorithm (see also Fig. 5 and Section 3.3).
Fig. 9 Renderings of a brown mink fur hat illuminated by the HDR environment map shown in Fig. 10: a implicitly rendered fur, b explicitly rendered fur, c hybrid rendered fur.

Fig. 11 Comparison of explicit fur and hybrid fur. Magnified nose and back of the furry Stanford bunny seen in full in the leftmost column: a, b explicitly rendered fur; c, d hybrid rendered fur.
Physical approach

HOLD MY BEER

I GOT THIS
Physical approach

Physically-Accurate Fur Reflectance: Modeling, Measurement and Rendering

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\textbf{Figure 1:} A rendering of the Wolf scene under environment lighting using (left) our physically-based double cylinder fur reflectance model with parameters from our database of animal fur samples, and (right) energy conserving Marschner model \cite{Marschner:2003:Marschner} \cite{d'Eon:2011:dEon} with best-fit parameters. Insets showing detailed comparisons from top to bottom using our model, Marschner model and Kajiya-Kay model. Since the Marschner model consists of only specular lobes, it often produces dark regions (limbs and tail). Furthermore, since the TT lobe is extremely strong in the Marschner model, especially for light colored fur fibers, it completely fails in heterogeneous regions (head) where dark colored fur is covered by light colored fur. The Kajiya-Kay model produces empirically plausible but hard-and-solid appearance, and it doesn’t fit the measured reflectence data in Sec. 6.

https://cseweb.ucsd.edu/~ravir/paper_fur.pdf
**Figure 3:** Structure of human hair and animal fur fibers. From left to right: section of a human hair fiber, cuticle of a human hair fiber, section of a cougar fur fiber, cuticle of a corsac fox fur fiber. Note major differences in the size of the medulla and complexity of the cuticle. Images authorized by [Wei 2006; Galatk et al. 2011].

**Figure 4:** (Left) A microscope photograph of a sample of polar bear fur. Note the obvious coating formed by the cuticle scales. (Right) A slice of cuticle scales on human hair shaft. Images authorized by [Carrlee and Horelick 2011; Hashimoto 1988].

**Figure 6:** (Left) A photograph of a real fur fiber under bright field microscopy with medulla filled half with air and half with a mounting medium. (Right) Our Monte Carlo simulated back-lit microscopic appearance of fur fiber samples with unmounted and mounted medulla (two images stitched). Photograph publicly licensed by [Deedrick and Koch 2004a].
Figure 7: (Left) The spherical gantry we use to measure individual fibers’ reflectance profiles. (Right) Illustration of setup for two-dimensional far-field reflectance measurements.

Figure 8: 2D reflectance profiles measured from different animals’ fur fibers (left), synthesized from full 3D volumetric path tracing of a double cylinder (middle), and from our factored rendering model from Sec. 7 (right). The signals are in arbitrary units and displayed in logarithmic space to visualize perceptual brightness.
Figure 2: (Left) Longitudinal-azimuthal parameterization for hair/fur fibers. $\theta$ is angle to plane orthogonal to cylinder axis; $\phi$ is angle within plane. (Middle & Right) Illustration of Marschner model with factored representation longitudinally and azimuthally.

Figure 5: Schematic of our double cylinder model in longitudinal section (left) and azimuthal section (right). Our model considers the medulla and cuticle effects as introduced in Sec. 4. We mark new types of paths $TrT$, $TrRrT$, $TtT$, $TtTrT$, $TtTrRtT$ that our model introduces. For clarity we hide TT and TRT paths that were previously considered by [Marschner et al. 2003] in Fig. 2. These TT, TRT paths enter the cortex, but miss the medulla entirely.

Figure 14: Precomputing medulla scattering. We enumerate $\sigma_m, s, g$ and vary azimuthal offset $h'$ and longitudinal incident angle $\theta'_i$, respectively. We store the yellow-marked scattered lobe in every outgoing azimuth $\phi'$ and longitudinal outgoing angle $\theta'_r$.

Figure 15: Illustration for computing longitudinal scattered lobe $M^s$. Refractions are considered here at $P$, $Q$, $P'$ and $Q'$. 
Figure 10: Renderings of a fur ball with 9 different sets of fit parameters. All the images are rendered using 1024 samples per pixel with top-front area lighting.

Figure 18: Renderings of the Fur pelt scene under area lighting. (Top left) Our rendering model. (Top right) Marschner model. (Bottom left) Kajiya-Kay model. (Bottom right) Marschner model blended with diffuse lobe.
RENDERING FUR WITH THREE DIMENSIONAL TEXTURES

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Abstract. We present a method for rendering scenes with fine detail via an object called a texel, a rendering primitive inspired by volume densities mixed with anisotropic lighting models. This technique solves a long outstanding problem in image synthesis: the rendering of furry surfaces.

However, for very fine detail, a significant problem has so far prevented the inclusion of furry surfaces into synthetic images. The conventional approach gives rise to a severe, intractable aliasing problem. We feel that this aliasing problem arises because geometry is used to define surfaces at an inappropriate scale. An alternative approach is to treat fine geometry as texture rather than geometry. We explore that approach here.
The attenuation between point \( P \) and \( A \) due to the medium is given by an integral of the density along the ray. The equations are:

\[
T = e^{-r} \int_{t_{\text{source}}}^{t_{\text{target}}} \rho(x(t), y(t), z(t)) \, dt
\]

and

\[
B = \int_{t_{\text{source}}}^{t_{\text{target}}} e^{-r} \int_{\text{source}}^{\text{target}} \rho(x(u), y(u), z(u)) \, du
\]

\[
\times \left[ \sum_i I_i(x(t), y(t), z(t)) \Psi(x(t), y(t), z(t), \theta, \phi, \rho) \right]
\]

\[
\times \rho(x(t), y(t), z(t)) \, dt
\]

The equations for a texel illumination are

\[
T = e^{-r} \sum_{t_{\text{source}}}^{t_{\text{target}}} \rho(x(t), y(t), z(t))
\]

and

\[
B = \sum_{t_{\text{source}}}^{t_{\text{target}}} e^{-r} \sum_{x_{\text{source}}}^{x_{\text{target}}} \rho(x(u), y(u), z(u))
\]

\[
\times \left[ \sum_i I_i(x(t), y(t), z(t)) \Psi(x(t), y(t), z(t), \theta, \phi, \rho) \right]
\]

\[
\times \rho(x(t), y(t), z(t))
\]
Disney’s Dinosaur, 2000
Probabilistic approach

Fake Fur Rendering

Dan B Goldman*

Industrial Light and Magic

http://danbgoldman.com/misc/fakefur/fakefur.pdf
“This render took 1 minute, previous one took 30s”
Procedural approach

A Simple and Fast Technique for Fur Rendering
Technical Report - Tutorial

Georgios Papaioannou

Department of Informatics, University of Athens

Figure 2. The fur opacity layers generation.

Figure 1. Procedure overview. The fur model is approximated by a set of surface layers. Opacity maps are used to control the transparency of the fur coating with respect to the distance from the skin.

https://pdfs.semanticscholar.org/a9c9/367ead85b58c0a152b5427db0eea808465d4.pdf
Shells and fins

Real-Time Fur over Arbitrary Surfaces

Jerome Lengyel
Microsoft Research
http://research.microsoft.com/~jedl

Emil Praun
Princeton University
http://www.cs.princeton.edu/~emilp

Adam Finkelstein
Princeton University
http://www.cs.princeton.edu/~af

Hugues Hoppe
Microsoft Research
http://research.microsoft.com/~hoppe

http://hhoppe.com/fur.pdf

https://www.youtube.com/watch?v=pskGb-IP1qE
(a) Input: mesh and vector field; (b) Output: lapped patches
Figure 1. Geometry preprocessing: creation of lapped patches.
nvidia

A. Model rendered using only shells

B. Silhouettes of the model rendered using fins

C. Shells and fins combined in the final rendering

nvidia demos

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Release Date: April 11, 2019
Originally released for: GeForce RTX 20-Series Graphics Cards

Experience advanced ray-traced reflections in a photo-realistic environment, and accelerate performance with Deep Learning Super Sampling

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ATOMIC HEART RTX TECH DEMO

Release Date: April 11, 2019
Originally released for: GeForce RTX 20-Series Graphics Cards

An early look at Mundfish’s graphically-advanced Atomic Heart, which is enhanced by the addition of advanced ray-traced reflections and shadows, and accelerated by the inclusion of Deep Learning Super Sampling.

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wolfman

WOLFMAN

Released February 1, 2001

Originally released for: GeForce 4-Series Graphics Cards

Wolfman was the first demo to use real-time volumetric fur rendering on a fully-animated character model.

Download > [29.6MB]

https://www.youtube.com/watch?v=tfrmvNjeR9A
Workshop time!

Rendering Realistic Animal Fur
https://graphics.stanford.edu/courses/cs348b-competition/cs348b-03/fur/

Fur Rendering
http://www.catalinzima.com/xna/tutorials/fur-rendering/

Fur Effects - Teddies, Cats, Hair...
http://www.xbdev.net/directx3dx/specialX/Fur/index.php
There is a shadertoy for that

https://www.shadertoy.com/view/XsfGWN
“That's all Folks!”