CS 563 Advanced Topics in Computer Graphics
Rendering Hair and Fur

by Emmanuel Agu

Introduction

- Humans used to seeing faces, hair
- Hair
  - tough to render right
  - Takes over ¼ of rendering time of many characters

Rendering Hair and Fur

- Two books describe Hair and Fur structure:
  - James Robertson, *Forensic Examination of Human Hair,* CRC Press
  - Blaze et al, *Atlas of Microscopic Structure of Fur Skins,* Elsevier, 1989

    (Website: http://www.furskin.cz/)
- We focus on rendering fur and hair
- Brute force strand by strand rendering, is slow
- Faster to consider a volume of hair or fur

Hair Rendering Background

- Jim Blinn, SIGGRAPH 1982
  - Render volume densities
  - **Homogeneous** volume of microscopic spheres
- Kajiya and Von Herzen, SIGGRAPH 1984
  - Generalized Blinn model to non-homogeneous media

Kajiya and Von Herzen: Volume Densities

- For each ray through the volume...
  - Find the transparency of the surface

$$e^{-r\int_{tnear}^{tfar}\rho(x(s),y(s),z(s))ds}$$

  - Find the brightness of the surface

$$\int_{tnear}^{tfar} e^{-r\int_{tnear}^{t}\rho(x(u),y(u),z(u))du}$$

$$\times[\sum_i I_i(x(t),y(t),z(t))p(cos(\theta)]$$

$$\times\rho(x(t),y(t),z(t))dt$$

Volume densities

Three parts of the brightness integral

Visibility of the current position in the volume

$$\int_{tnear}^{tfar} e^{-r\int_{tnear}^{t}\rho(x(u),y(u),z(u))du}$$

Sum of the light contribution from each light source

$$\times[\sum_i I_i(x(t),y(t),z(t))p(cos(\theta)]$$

$$\times\rho(x(t),y(t),z(t))dt$$

Density of the surface at the point

Kajiya and Kay (1989): Texels

- Replace volume densities with *texels*
  - 3D array containing microsurface data
- Texels: replace all integrals with sums
  - Transparency equation becomes

$$e^{-r\sum_{t=tnear}^{tfar}\rho(x(s),y(s),z(s))}$$

  - Brightness equation becomes

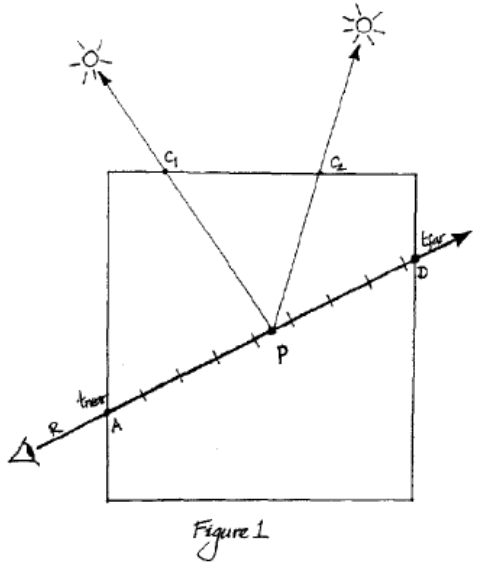


Figure 1

$$\sum_{t=tnear}^{tfar} e^{-r\sum_{t=tnear}^{t}\rho(x(u),y(u),z(u))}$$

$$\times[\sum_i I_i(x(t),y(t),z(t))\psi(x(u),y(u),z(u),\theta,\phi,\rho)]$$

$$\times\rho(x(t),y(t),z(t))$$

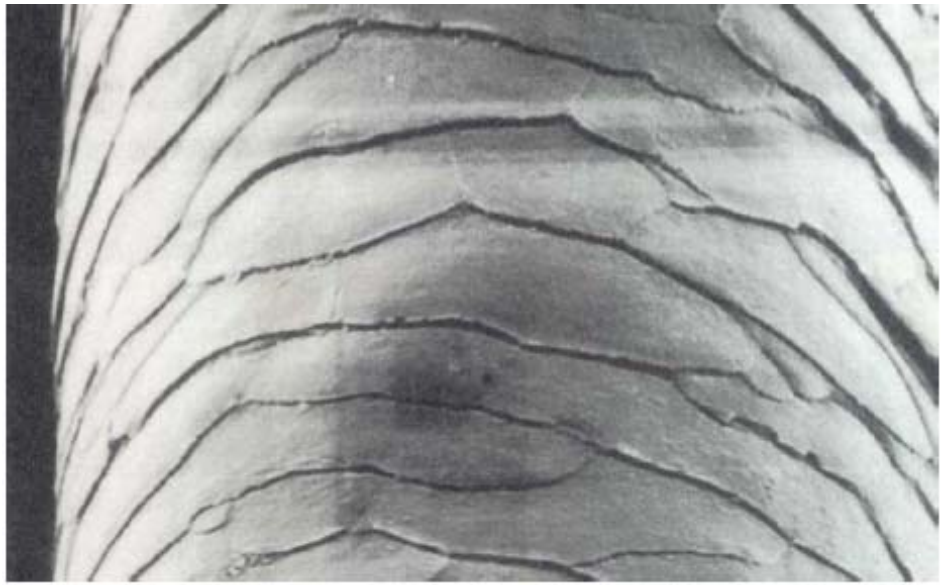
Kajiy and Kay: Fur Rendering

- Four steps to rendering fur:
  - Create fur texel
  - Map texels to world space
  - Shoot rays into texel
  - Calculate lighting

Rendering time: 2 hours

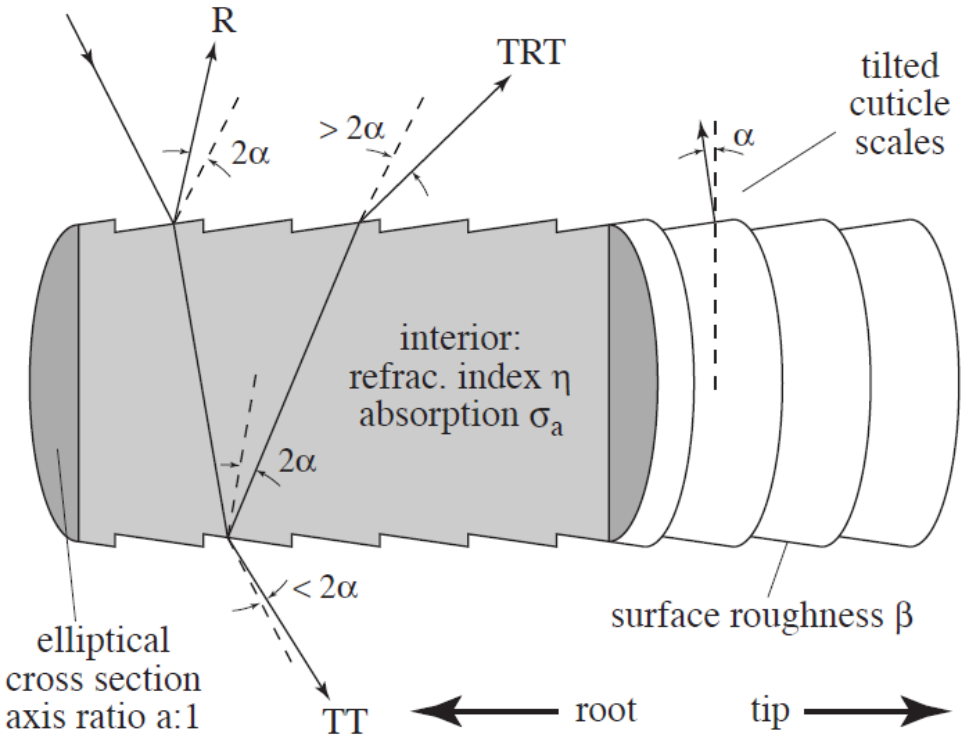
Marschner et al, SIGGRAPH 2003

- Kajiya and Kay model okay for short hair
- Hair exhibits volumetric scattering, anisotropic
- Robbins (1994) observed Hair was made up of tiny overlapping scales



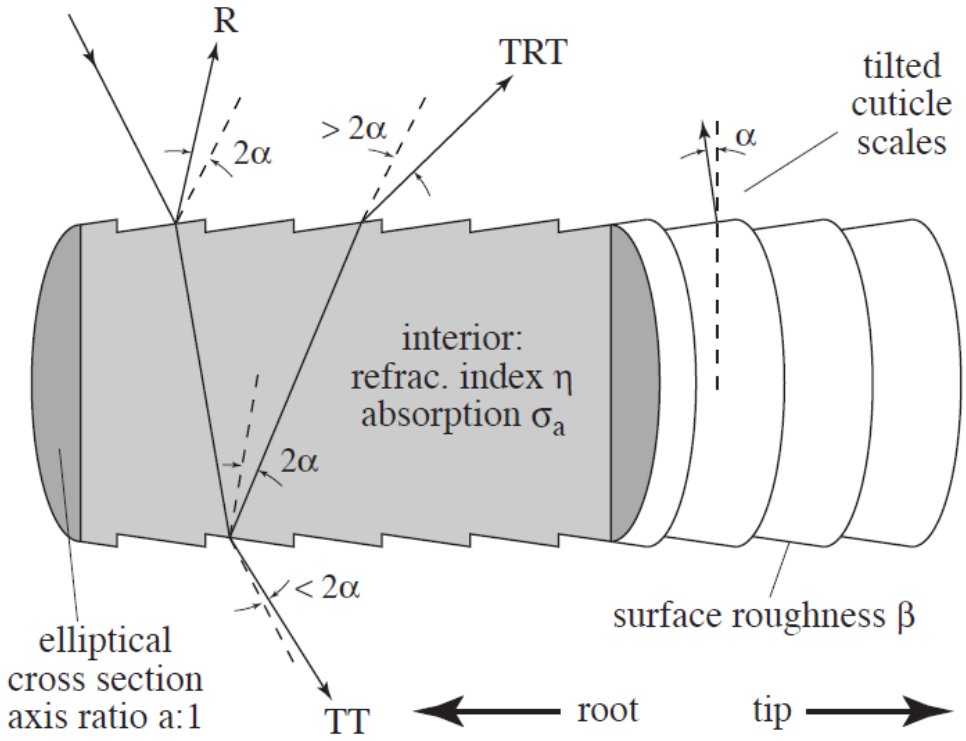
Marschner et al, SIGGRAPH 2003

- Model as elliptical scales which form cylinder
- Model sub-surface scattering as before
- R, TRT (highlights) successively less bright



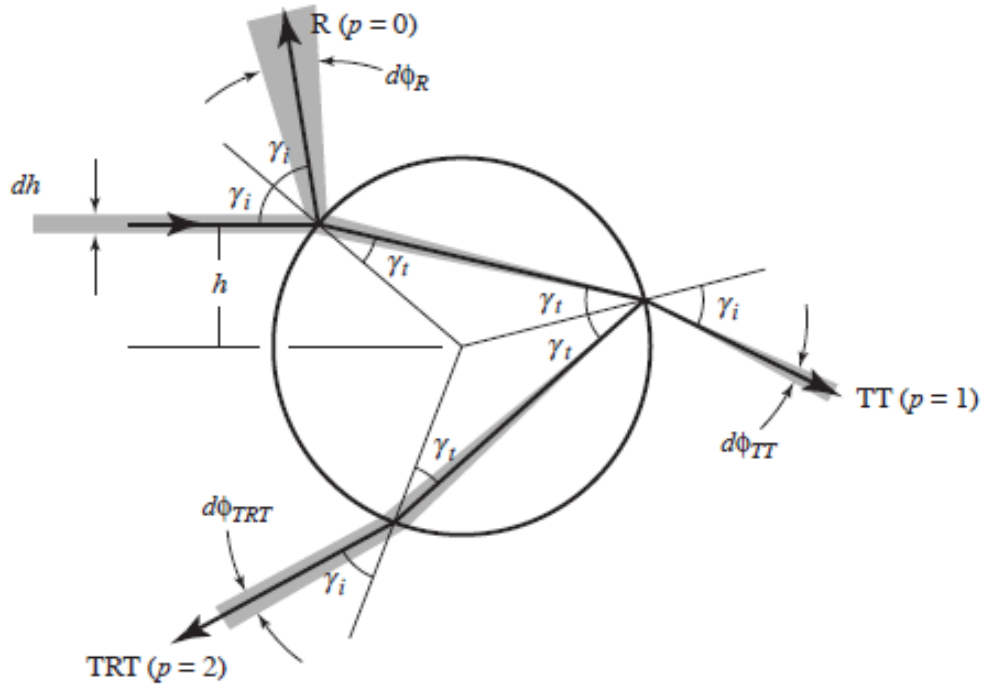
Marschner et al, SIGGRAPH 2003

- Tilted scales: R direction and TRT direction means different shape of secondary highlights
- Elliptical cross-section: simply rotating hair about axis changes distance between R, TRT



Marschner et al, Hair, 2003

- Hair is dielectric: absorption across cross-section
- Part of ray absorbed = Secondary less bright
- Hair is colored = Secondary highlight shows color
- Blond hair absorbs less light = Secondary highlight less noticeable



Compare Kajiya, Marschner and Real

- Marschner model shows more secondary, tertiary highlights, etc

Kajiya

Marschner

Real Hair

Final Words

- Moon and Marschner, SIGGRAPH 2006
  - Interreflections from hair is highly directional
  - Irradiance caching approach for interreflections
  - Sped up light calculations
- Marschner 2008
  - Used spherical harmonics to speed up rendering

References

- Dorsey, Rushmeier and Sillion, Digital Modeling of Material Appearance, Morgan Kaufmann, 2007
- Marc Olano, Slides on Hair Rendering, UMBC CMSC 635, 2005
- Kajiya and Kay, Rendering Fur with Three Dimensional Textures, SIGGRAPH 1989
- Stephen R. Marschner, Henrik Wann Jensen, Mike Cammarano, Steve Worley, and Pat Hanrahan. “Light Scattering from Human Hair Fibers.” In proceedings of *SIGGRAPH 2003*. San Diego, July 2003
- C. R. Robbins, *Chemical and Physical Behavior of Human Hair, 3rd ed.*Springer-Verlag, New York, 1994.
- Ward et al, A Survey on Hair Modeling: Styling, Simulation, and Rendering, IEEE Trans Viz and graphics, 2007