

CG Programming II (VGP 352)

Agenda:

- ♦ Discuss & hand in assignment #3.
- ♦ Datasets for Lafortune BRDF
- ♦ Anisotropic BRDFs
 - ♦ How can we add anisotropy to BRDFs that we already know.
 - ♦ Can these models be improved?

Lafortune Refresher

- ♦ The Lafortune BRDF extends Phong's lighting model by adding transformed “specular” lobes.
 - ♦ Typically 2 or 3 lobes.
 - ♦ Transformations are *per component* diagonal matrices where $M_{1,1} = M_{2,2}$.
 - ♦ Typical Lafortune notation calls these C_x , C_y , and C_z .
 - ♦ Each lobe also has a specular exponent.
- ♦ Result is $3 \times 3 \times (2 + 1) = 27$ material properties to pass into the shader.

Lafortune Data

- ◆ Matte finished steel:

Lobe 1, red: $C_{xy} = -1.11854$, $C_z = 1.01272$, $n = 15.8708$

Lobe 1, green: $C_{xy} = -1.11845$, $C_z = 1.01469$, $n = 15.6489$

Lobe 1, blue: $C_{xy} = -1.11999$, $C_z = 1.01942$, $n = 15.4571$

Lobe 2, red: $C_{xy} = -1.05334$, $C_z = 0.69541$, $n = 111.267$

Lobe 2, green: $C_{xy} = -1.06409$, $C_z = 0.662178$, $n = 88.9222$

Lobe 2, blue: $C_{xy} = -1.08378$, $C_z = 0.626672$, $n = 65.2179$

Lobe 3, red: $C_{xy} = -1.01684$, $C_z = 1.00132$, $n = 180.181$

Lobe 3, green: $C_{xy} = -1.01635$, $C_z = 1.00112$, $n = 184.152$

Lobe 3, blue: $C_{xy} = -1.01529$, $C_z = 1.00108$, $n = 195.773$

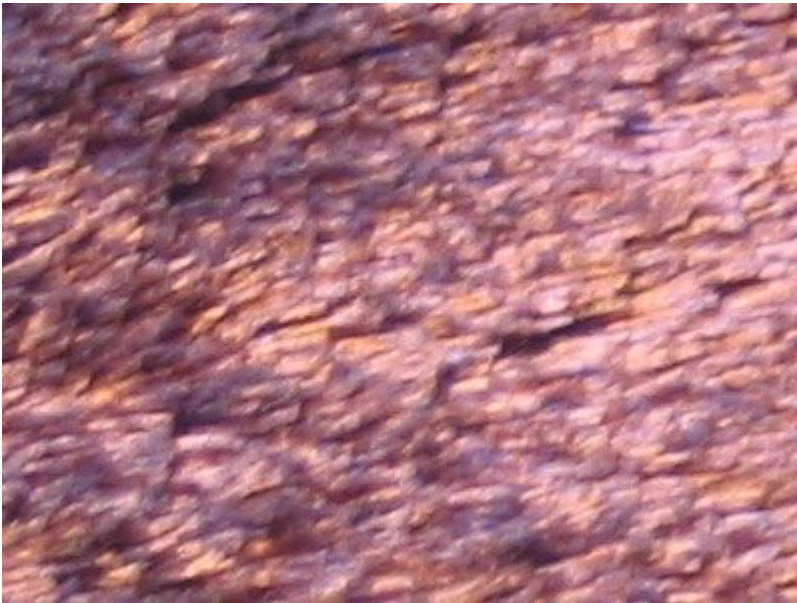
- ◆ From http://www.rendermanacademy.com/docs/lafortune_model.htm

Isotropic vs. Anisotropic

- ♦ From wikipedia:
 - ♦ “Isotropy is ... property of being independent of direction. Isotropic radiation has the same intensity regardless of the direction of measurement, and an isotropic field exerts the same action regardless of how the test particle is oriented.”
 - ♦ “Anisotropy ... is the property of being directionally dependent. Something which is anisotropic may appear different or have different characteristics in different directions. An example is the light coming through a polarising (sic) lens.”

How does this apply to BRDFs?

- ◆ Some materials reflect light differently based on the orientation of the light and viewer with respect to the surface.
 - ◆ None of our current BRDFs can model this!



What is needed for an *anisotropic* model?

- ♦ All previous models are based on N, V, and L.
 - ♦ Gives no way to know the relative orientation of the surface w.r.t. the light or the viewer.
 - ♦ What can we use to calculate this?

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- ♦ **The surface tangent!!!**

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- ♦ **The surface tangent!!!**
- ♦ If V' is the projection of V onto the surface defined by T and B , $\arccos(V' \cdot T)$ is the relative orientation angle.

Banks Model

- ♦ Simple variation of Phong lighting that introduces anisotropy:

$$L_o = K_d(L' \cdot L) + K_s(L' \cdot H)^{\frac{1}{r}}$$

- ♦ L' is the projection of L onto the plane formed by N and T.
- ♦ r is the surface roughness.

Cook-Torrance

- ♦ By changing the D calculation, we can add anisotropy.
- ♦ Instead of the Beckmann model, we can use the Ward model:

$$D = \frac{1}{\sqrt{(N \cdot L)(N \cdot V)}} \frac{N \cdot L}{4 \alpha_x \alpha_y} e^{\left[-2 \frac{\left(\frac{H \cdot B}{\alpha_x} \right)^2 + \left(\frac{H \cdot T}{\alpha_y} \right)^2}{1 + (H \cdot N)} \right]}$$

Ashikhmin Model

- ♦ Linear interpolation of the diffuse component and the specular component:

$$K_d(1 - K_s) f_d(\omega_o, \omega_i) + K_s f_s(\omega_o, \omega_i)$$

- ♦ $(K_d + K_s) \leq 1$
- ♦ Light energy that is specularly reflected cannot be diffusely reflected.
 - ♦ Simulates materials with a reflective coating.
- ♦ For metals, $f_d = 0$.

Ashikhmin Model (cont.)

- ◆ Specular defined by:

$$f_s(\omega_o, \omega_i) = \frac{\sqrt{(q_T + 1)(q_B + 1)} (N \cdot H)^{(q_T(H \cdot T)^2 + q_B(H \cdot B)^2) / (1 - (N \cdot H)^2)}}{8 (\omega \cdot H) \max(N \cdot \omega_i, N \cdot \omega_o)} F$$

- ◆ q_T and q_B are settable parameters that control the shape of the specular highlight.

Ashikhmin Model (cont.)

- ♦ Diffuse is defined by:

$$f_d(\omega_o, \omega_i) = \frac{28}{23} \left(1 - \left(1 - (N \cdot \omega_o) \right)^5 \right) \left(1 - \left(1 - (N \cdot \omega_i) \right)^5 \right)$$

References for later

http://en.wikipedia.org/wiki/Specular_highlight

<http://en.wikipedia.org/wiki/Anisotropy>

<http://en.wikipedia.org/wiki/Isotropy>

http://www.rendermanacademy.com/docs/lafortune_model.htm

<http://www.cs.utah.edu/~shirley/papers/jgtbrdf.pdf>

What about fur?!?!

- ♦ Many fur models exist.
- ♦ We'll discuss one developed by Dan Goldman at ILM.
- ♦ Several assumptions:
 - ♦ Individual hairs cannot be resolved.
 - ♦ Hairs are truncated cones with a length much greater than the radius of either end.
 - ♦ Radius of the base is greater than the radius of the end.

fakefur

- ♦ “fakefur” is made up of several parts:
 - ♦ Diffuse reflection of the hairs.
 - ♦ Specular reflection of the hairs.
 - ♦ Opacity of the hair.

fakefur Diffuse and Specular

- ◆ Since each hair is an infinitesimal cylinder, it doesn't have a surface normal to speak of.
 - ◆ Instead we use the hair's tangent, which points along the length of the strand.

$$f_d = K_d \sin(T, L)$$

$$f_s = K_s \left((T \cdot \omega_i)(T \cdot \omega_o) + \sin(T, \omega_i) \sin(T, \omega_o) \right)^p$$

fakefur Attenuation

- ◆ Since there is no normal, hairs are lit the same whether using back-lighting or front-lighting.
- ◆ This is fixed by adding two parameters and an attenuation factor:

$$\kappa = \frac{(T \times \omega_i) \cdot (T \times \omega_o)}{|T \times \omega_i| |T \times \omega_o|}$$

$$f_{dir} = \frac{1 + \kappa}{2} \rho_{reflect} + \frac{1 - \kappa}{2} \rho_{transmit}$$

fakefur Self-Shadowing

- ♦ Self-shadowing is controlled by a second attenuation factor and 3 additional parameter:

$$f_{surface} = 1 + \rho_{surface} (\text{smoothstep}(N \cdot \omega_i, \cos \theta_{min}, \cos \theta_{max}) - 1)$$

- ♦ $\rho_{surface}$ is on the range $[0,1]$ and controls the amount of self-shadowing.
- ♦ θ_{min} and θ_{max} control the range of fur angles where shadowing occurs. These can be tuned to match reference images.

Smoothstep

- ♦ Smoothstep is a Hermite interpolator.

$$0, \forall x < a$$

$$1, \forall x > b$$

$$\mathit{smoothstep}(x, a, b) = \begin{cases} 0, & \forall x < a \\ 1, & \forall x > b \\ -2 \left(\frac{x-a}{b-a} \right)^3 + 3 \left(\frac{x-a}{b-a} \right)^2, & \forall a < x < b \end{cases}$$

fakefur Opacity Factor

- ◆ Determines how much of the surface below the hair can be seen:

$$\alpha_f(\omega) = 1 - \frac{1}{e^{DA_h g(\omega, T, N)}}$$

$$g(\omega, T, N) = \frac{\sin(\omega, T)}{\omega \cdot N}$$

$$A_h = l_{hair} (r_{base} + r_{top}) / 2$$

- ◆ D is the local hair density.

Putting It All Together

- ♦ Put all the attenuation factors together with the opacity and the skin color to get:

$$f_{hair} = f_{dir} f_{surface} (f_{diffuse} + f_{specular})$$

$$\lambda_{skin} = K_L \left(1 - \alpha_f(\omega_i) \right) f_{skin}$$

$$\lambda_{hair} = K_L \left(1 - \frac{\alpha_f(\omega_i)}{2} \right) f_{hair}$$

$$f = \alpha_f(\omega_o) \lambda_{hair} + (1 - \alpha_f(\omega_o)) \lambda_{skin}$$

- ♦ f_{skin} is calculated by some other means. Lafortune, perhaps.

References for later

<http://www.cs.washington.edu/homes/dgoldman/fakefur/>

- This was one of the readings. Did you read it? ;)

<http://www.intel.com/cd/ids/developer/asmo-na/eng/216547.htm?page=1>

For next time...

- ♦ Environmental lighting with BRDFs.
- ♦ Discuss & assign final project.
 - ♦ It will be due on the day of the final, 3/19.

Questions?

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