VGP352 – Week 5

- Agenda:
  - Quiz #2!
  - Assigments:
    - Presentation of reading
    - Assignment #2, parts 1 and 2 due
  - Anisotropic reflection
    - What is it?
    - Anisotropic BRDFs
      - Ward
      - Ashikhmin
  - Implementing BRDFs in shaders

Isotropy

- From Wikipedia:

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- For lighting, this means that as long as the angle between N, L, and V remain constant, the lighting will remain constant.

Anisotropy

- From Wikipedia:

  “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.”

Anisotropic Reflection

- Some materials reflect light differently based on the orientation of the light and viewer with respect to the surface
  - None of our current lighting models support this
- Consider this fuzzy blanket
  - The angle of the light and the camera is constant, but the material has rotated within the plane

Anisotropic Reflection

- What additional information is needed to implement an anisotropic lighting model?
  - All our current models only use N, L, and V
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Anisotropic Reflection

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- The surface tangent!
  - If V' is the projection of V onto the plane containing T and B, $arccos(V' \bullet T)$ is the relative orientation angle

Banks Lighting Model

- Simple variation of Phong lighting that introduces anisotropy:

$$L_o = \left(K_d (L \cdot L_N) + K_s ((L_T \cdot V_T) - |L_N||V_N'|)^n \right) \times (L \cdot N)$$

  - L_N and V_N are the projections of L and V onto N
  - L_T and V_T are the projections of L and V onto T

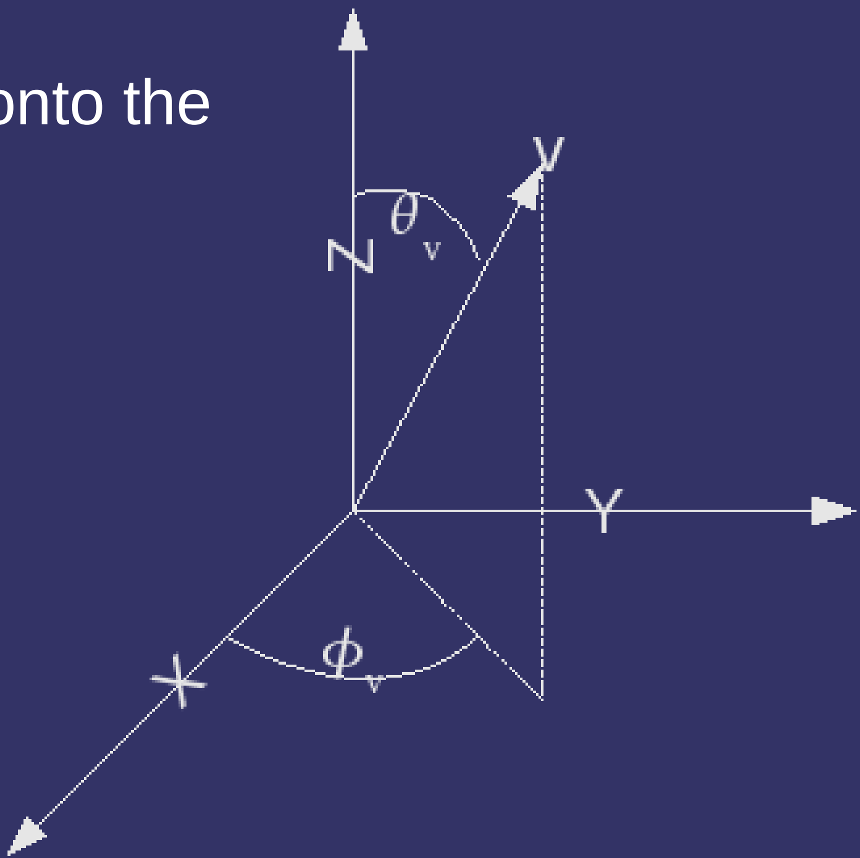
Ward's Anisotropic Model

- Ward defines a coordinate system with the surface normal as the positive Z-axis
  - The X-axis and Y-axis are mapped to the tangent and bitangent

θ_v is the angle between V and the Z-axis

ϕ_v is the angle between the projection of V onto the X/Y plane and the X-axis

The projection is easy: set $V_z = 0$



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Ward's Anisotropic Model

$$f(\omega_i, \omega_o) = \frac{K_d}{\pi} + \frac{K_s}{4\pi\alpha_x\alpha_y\sqrt{\cos\theta_i\cos\theta_o}} e^{-\tan^2\theta_H\left(\frac{\cos^2\phi_H}{\alpha_x^2}\frac{\sin^2\phi_H}{\alpha_y^2}\right)}$$

- α_x and α_y control the width of the highlight in the two principal directions
  - $\alpha_x = \alpha_y$ the reflection is isotropic
  - $\tan^2\theta = (1 - \cos^2\theta) / \cos^2\theta$
  - $\sin^2\theta = 1 - \cos^2\theta$

Ashikhmin Model

$$f_s(\omega_i,\omega_o)=\frac{\sqrt{(n_x+1)(n_y+1)}}{8\pi}\frac{(N\cdot H)^{n_x\cos^2\phi_H+n_y\sin^2\phi_H}}{(H\cdot\omega)\,max((N\cdot\omega_i),(N\cdot\omega_o))}F(\omega\cdot H)$$

- Most of the notation is the same as on the previous slides
  - This differs from the notation in Ashikhmin's paper
- n_x and n_y are Phong-like exponents that control the shape of the specular lobe
  - Roughly analogous to α_x and α_y in Ward's model
- $F(\theta)$ is the Fresnel term

Ashikhmin Model

$$f_d(\omega_i,\omega_o)=\frac{28K_d}{23\pi}(1-F(0))\left(1-\left(1-\frac{N\cdot\omega_i}{2}\right)^5\right)\left(1-\left(1-\frac{N\cdot\omega_o}{2}\right)^5\right)$$

- *F(0)* is the Fresnel term at an angle of 0°
- The strange constant factor is “designed to ensure energy conservation.”

References

Ashikhmin, M., Shirley, P. "An Anisotropic Phong BRDF Model" Journal of Graphics Tools, v.5, no. 2 (2000), pp.25-32. http://www.cs.utah.edu/~michael/brdfs/

Break

Implementing BRDFs in Shaders

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  - Environment map lighting
    - Prefiltering
    - Monte Carlo sampling

Point Light: Direct Implementation

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Point Light: Direct Implementation

- *Very* straightforward method.
- Use L for ω_i and V for ω_o and directly implement the math
  - We already do this for Phong lighting
  - More complex lighting equations can be prohibitively expensive
  - Since we're *not* integrating over the hemisphere, remove the $1/\pi$ from the equation!

Factorization

- Expensive equations can be broken down (factored) into sums or products of functions of fewer variables
  - Each input vector (i.e., V, L, H, N, etc.) becomes an input to one function
  - Each function is stored in an environment map
  - This technique works really well for sampled BRDFs
- Using two textures, the Poulin-Fournie anisotropic satin BRDF can be implemented as:

$$\alpha\, p(V)\, q(H)\, p(L)$$

  - $p()$ and $q()$ represent texture look-ups and α is a special scaling factor

References

University of Waterloo Factored BRDF Repository: http://www.cgl.uwaterloo.ca/Projects/rendering/Shading/database.html

Michael D. McCool, Jason Ang, Anis Ahmad, *Homomorphic Factorization of BRDFs for High-Performance Rendering*, SIGGAPH 2001, August 12-17, 2001. http://www.cgl.uwaterloo.ca/Projects/rendering/Papers/

Environment Maps

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- As with the Phong lighting model, env. maps can be prefiltered using complex BRDFs
  - Doesn't work well with dynamic env. maps
  - Doesn't work *at all* with aniostropic BRDFs
    - The ideal reflection vector isn't enough information!

Grid Sampling

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  - Might not sample the most important vectors for the environment map
    - If most of the environment map is dark with just a few bright spots, those bright spots are more important
    - This problem is especially difficult to solve

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Monte Carlo Integration

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  - The random locations are determined with a BRDF-dependent probability density function (PDF)
    - Several of the papers from this term, including the reading for next week, include a PDF for the BRDF
  - Still several problems:
    - Generating good random numbers on the GPU
    - Requires quite a few samples
      - Colbert and Křivánek found the around 40 looks good
    - Looks better on smaller polygons

References

Colbert, M. and Křivánek, J. 2007. *Real-time shading with filtered importance sampling.* In ACM SIGGRAPH 2007 Sketches (San Diego, California, August 05 - 09, 2007). SIGGRAPH '07. ACM, New York, NY, 71. http://graphics.cs.ucf.edu/gpusampling/

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

Next week...

- Fur rendering
  - Goldman's “Fake Fur Rendering”
    - *Please* read this paper for next week
  - Rendering larger hairs
  - More of the Banks model

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