Diffuse Reflection and Lambertian BRDF - Recap

- Surface appears equally bright from ALL directions! (independent of $\mathbf{v}$)

- Lambertian BRDF is simply a constant: $f(\theta_i, \phi_i; \theta_r, \phi_r) = \frac{\rho_d}{\pi}$

- Surface Radiance: $L = \frac{\rho_d}{\pi} I \cos \theta_i = \frac{\rho_d}{\pi} I \mathbf{n} \cdot \mathbf{s}$

- Commonly used in Vision and Graphics!
Diffuse Reflection and Lambertian BRDF - Recap

Radiance decreases with increase in angle between surface normal and source

**Lambert's Cosine Law**
Rendered Sphere with Lambertian BRDF

- Edges are dark (N.S = 0) when lit head-on
- See shading effects clearly.
Why does the Full Moon have a flat appearance?

- The moon appears matte (or diffuse)
- But still, edges of the moon look bright (not close to zero) when illuminated by earth’s radiance.
Why does the Full Moon have a flat appearance?

Lambertian Spheres and Moon Photos illuminated similarly
Surface Roughness Causes Flat Appearance

Actual Vase

Lambertian Vase
Surface Roughness Causes Flat Appearance – More Examples
Surface Roughness Causes Flat Appearance

Lambertian model

Valid for only SMOOTH MATTE surfaces.

Bad for ROUGH MATTE surfaces.
Blurred Highlights and Surface Roughness - RECAP
Oren-Nayar Model – Main Points

• Physically Based Model for Diffuse Reflection.

• Based on Geometric Optics.

• Explains view dependent appearance in Matte Surfaces.

• Take into account partial interreflections.

• Roughness represented like in Torrance-Sparrow Model.

• Lambertian model is simply an extreme case with roughness equal to zero.
Modeling Rough Surfaces - Microfacets

• Roughness simulated by Symmetric V-groves at Microscopic level.

• Distribution on the slopes of the V-grove faces are modeled.

• Each microfacet assumed to behave like a **perfect lambertian surface**.
View Dependence of Matte Surfaces - Key Observation

- Overall brightness increases as the angle between the source and viewing direction decreases. WHY?

- Pixels have finite areas. As the viewing direction changes, different mixes between dark and bright are added up to give pixel brightness.
Torrance-Sparrow BRDF – Different Factors (RECAP)

\[ f = \frac{F(\theta_i)G(\omega_i, \omega_r)D(\theta_h)}{4 \cos(\theta_i) \cos(\theta_r)} \]

- **Fresnel term:** allows for wavelength dependency
- **Geometric Attenuation:** reduces the output based on the amount of shadowing or masking that occurs.
- **Distribution:** distribution function determines what percentage of microfacets are oriented to reflect in the viewer direction.
- How much of the macroscopic surface is visible to the light source
- How much of the macroscopic surface is visible to the viewer
Slope Distribution Model

- Model the distribution of slopes as Gaussian.
- Mean is Zero, Variance represents ROUGHNESS.

\[ \rho_\alpha(\alpha) = \frac{1}{\sqrt{2\pi}\sigma_\alpha} e^{-\frac{\alpha^2}{2\sigma_\alpha^2}}. \]
Geometric Attenuation Factor

- No interreflections taken into account in above function.
- Derivation found in 1967 JOSA paper (read if interested).

\[ G(\theta_i, \theta_r, \phi_r) = \min\left(1, \frac{2 \cos \alpha \cos \theta_r}{\cos \theta'_i}, \frac{2 \cos \alpha \cos \theta'_i}{\cos \theta'_i} \right). \]
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Oren-Nayar Model – Different Factors

Fresnel term: allows for wavelength dependency

Geometric Attenuation: reduces the output based on the amount of shadowing or masking that occurs.

Distribution: distribution function determines what fraction of the surface area do the facets of the same orientation cover?

\[
f = \frac{F(\theta_i)G(\omega_i, \omega_r)D(\theta_h)}{4 \cos(\theta_i) \cos(\theta_r)}
\]

How much of the macroscopic surface is visible to the light source

How much of the macroscopic surface is visible to the viewer
Oren-Nayar Model – Different Factors (contd.)

- Take into account two light bounces (reflections).
- Hard to solve analytically, so they find a functional approximation.
Lambertian model is simply an extreme case with roughness equal to zero.
Fig. 7. (a-c) Real image of a cylindrical clay vase compared with images rendered using the Lambertian and proposed models. Illumination is from the direction $\theta_i = 0^\circ$. (d) Comparison between image brightness along the cross-sections of the three vases.
Comparison to Ground Truth

Real Objects

Renderings
Many surfaces may be rough and show both diffuse and surface reflection.
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Why bother modeling BRDFs?

Why not directly measure BRDFs?

• True knowledge of surface properties

• Accurate models for graphics