ECE 595 / CS 491 / CS 591

Real-Time Rendering & Graphics Hardware

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Advanced Graphics Lab

Class 16
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Announcements

- GFX Café this Friday will be given by Christoph Salge on zooming into images arbitrarily

Last time

- Real-time soft shadow algorithms

Today

- Introduction to the theory of illumination

Real-time illumination

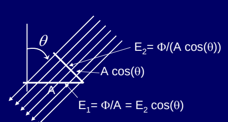
- In the last few classes, we've been studying how to compute what percentage of the light source is visible from different surfaces due to visibility occlusion (shadows)
- Today, we shall examine how that light interacts with the surface so that we can render it realistically

Basic radiometry

- Radiometry – the science of the physical measurement of electromagnetic energy
- Radiant flux (Φ) – amount of energy passing through a region of space per unit time (e.g. the power through a region of space). units: J/s or W
- Irradiance (E) – Flux per unit area. units: W/m^2
- Intensity (I) – Flux per unit solid angle. $I = d\Phi/d\omega$. Units: W/sr
- Radiance (L) – Flux density per unit solid angle per unit projected area. $L = d^2\Phi/d\omega dA^\perp$. units: W/sr m^2

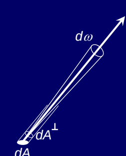
Irradiance

- Irradiance (E) – Flux per unit area. units: W/m^2
- E.g. power per unit area
- Inverse square law
- Lambert's law

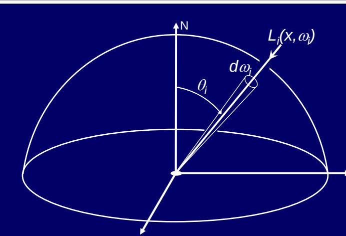


Radiance

- Radiance (L) – Flux density per unit solid angle per unit projected area. $L = d^2\Phi/d\omega dA^\perp$
- Also defined as intensity per unit projected area

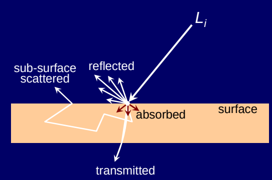


Converting incident radiance to irradiance



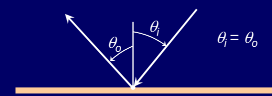
$$E(x) = \int_\Omega L_i(x,\omega_i)\cos\theta_i d\omega_i$$

Light-surface interaction



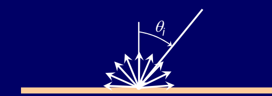
Reflection functions

- Ideal specular (e.g. mirror reflection)



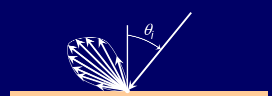
Reflection functions

- Ideal specular reflection (e.g. mirror)
- Diffuse reflection (e.g. matte surface)



Reflection functions

- Ideal specular reflection (e.g. mirror)
- Diffuse reflection (e.g. matte surface)
- Glossy reflection



BRDF

- Bidirectional reflectance distribution function
- First described by F. Nicodemus (1970)
- Ratio of reflected radiance in direction ω_o to incident irradiance in direction ω_i (units sr^{-1})

heterogeneous $f_r(x, \omega_i \rightarrow \omega_o)$

homogeneous $f_r(\omega_i \rightarrow \omega_o)$

$$f_r(\theta_i, \phi_i; \theta_o, \phi_o)$$

Properties of the BRDF

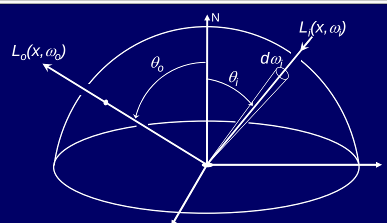
- Reciprocity (Helmholtz)

$$f_r(\omega_i \rightarrow \omega_o) = f_r(\omega_o \rightarrow \omega_i)$$

- Linearity
- Isotropic

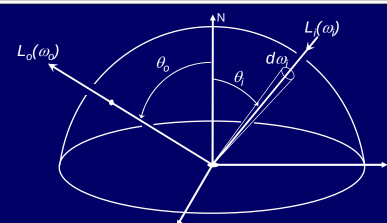
$$f_r(\theta_i, \phi_i; \theta_o, \phi_o) = f_r(\theta_i, \theta_o, \phi_o - \phi_i)$$

Reflection equation



$$L_o(x, \omega_o) = \int_\Omega f_r(x, \omega_i \rightarrow \omega_o) L_i(x, \omega_i) \cos\theta_i d\omega_i$$

Reflection equation (homogeneous material)



$$L_o(\omega_o) = \int_\Omega f_r(\omega_i \rightarrow \omega_o) L_i(\omega_i) \cos\theta_i d\omega_i$$

Specular surface illumination

- BRDF becomes a delta function

$f_r(\omega_i \rightarrow \omega_o) = 1$ when w_o is the specular reflection angle of w_i

$f_r(\omega_i \rightarrow \omega_o) = 0$ otherwise

- Can represent it on the hardware with an environment map

Environment map courtesy Paul Debevec

Diffuse surface illumination

- Follows Lambert's Law
- Assumes light is equally likely to be reflected in any direction

$$f_r(\omega_i \rightarrow \omega_o) = c$$

$$L_o(\omega_o) = \int_{\Omega} f_r(\omega_i \rightarrow \omega_o) L_i(\omega_i) \cos\theta_i d\omega_i$$

$$L_o(\omega_o) = c \int_{\Omega} L_i(\omega_i) \cos\theta_i d\omega_i$$

From mirror to diffuse

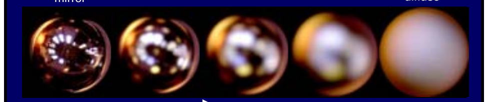


Figure courtesy Ravi Rammamoorthi

BRDF and incident illumination

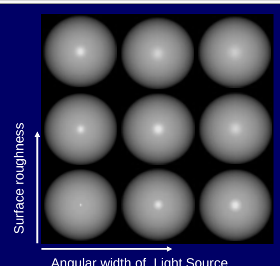


Figure courtesy Ravi Rammamoorthi

Reflection as convolution