CS 563 Advanced Topics in Computer Graphics

Area and Environment Lights

by Joe Miller

Goal of Area Lighting

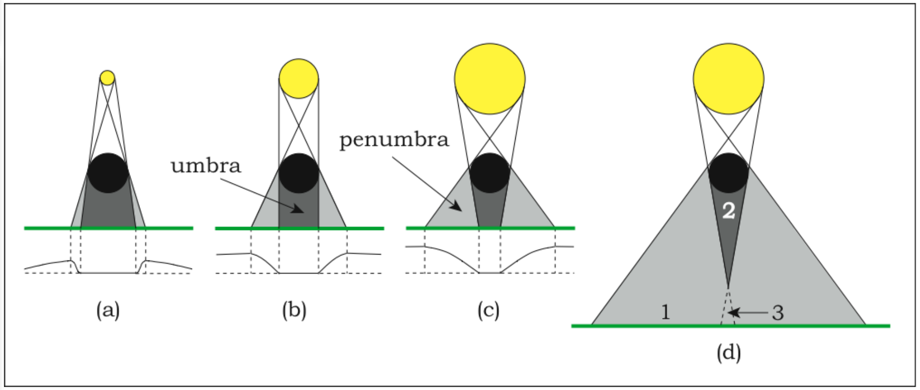
- The goal of area lighting is to provide more realistic lighting
  - Define an area for light emitted instead of single points
  - Produce soft shadows instead

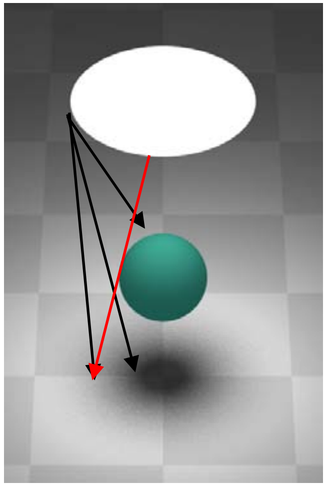
Point Light

Area Light

Overview / Review

- Using area lights we can simulate the penumbra which is lost with point lights and directional lights.
  - Umbra – the part of the shadow where no light is visible
  - Penumbra – the part of the shadow where a fraction of light is visible
- How much of a fraction is contributing to the penumbra is what needs to be computed.



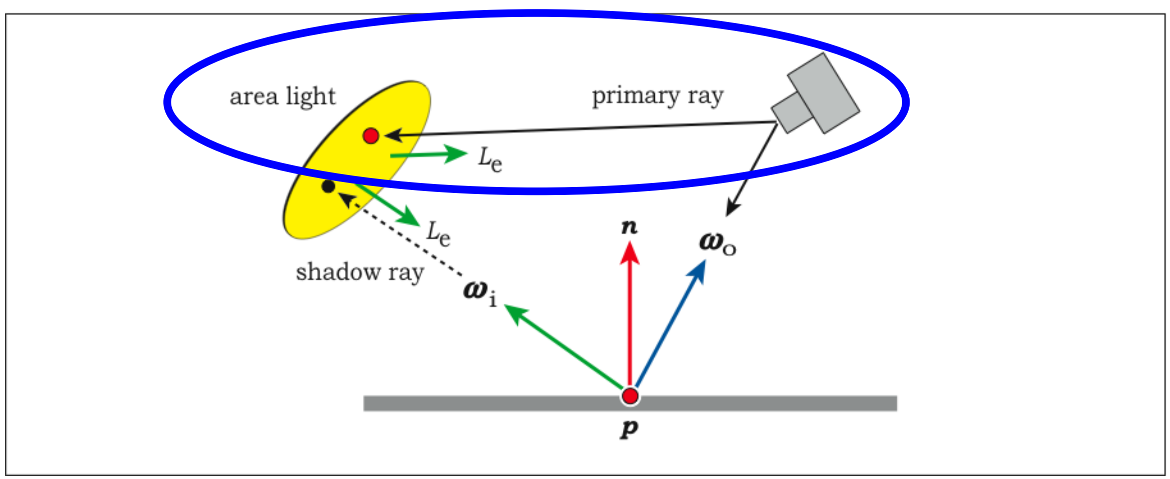


Area light details

- Two tasks need to be accomplished with area lights
  - Displaying the light
  - Computing the light's illumination on the scene

- Displaying the light involves setting the material of an object to be **emissive**

$$L_e(p, \omega_o)$$

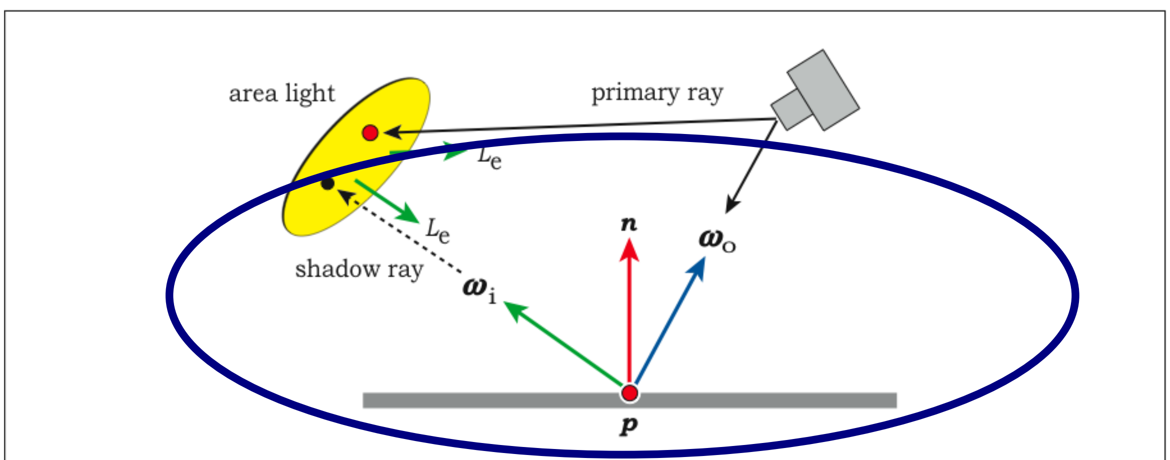


Area light details

- Need to estimate the direct illumination for a given point
- Recall *area form* rendering equation

$$L_o(p, \omega_o) = L_e(p, \omega_o) + \int_A f_r(p, \omega_i, \omega_o) L_o(p', -\omega_i) V(p, p') G(p, p') \, dA$$

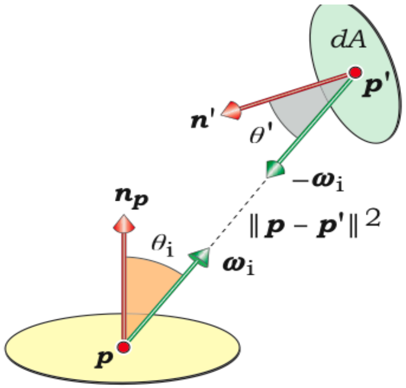
Exit Radiance   Visibility   Geometric Term



Estimating Direct Illumination

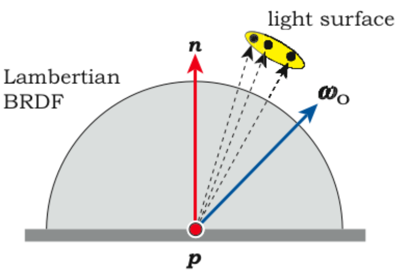
$$L_o(p,\omega_o) = L_e(p,\omega_o) + \int_A f_r(p,\omega_i,\omega_o) L_o(p',-\omega_i) V(p,p') G(p,p') dA$$

- $L_o(p',-\omega_i) = L_e(p',-\omega_i)$
- $G(p,p') = \cos\theta_i \cos\theta' / \|p'-p\|^2$



- Sum the illumination from all lights
  - $L_o(p,\omega_o) = \sum_{k=1}^{n_l} \int_{A,k} f_r(p,\omega_i,\omega_o) L_e(p',-\omega_i) V(p,p') G(p,p') dA'$
- Estimate the integral using Monte Carlo Integration

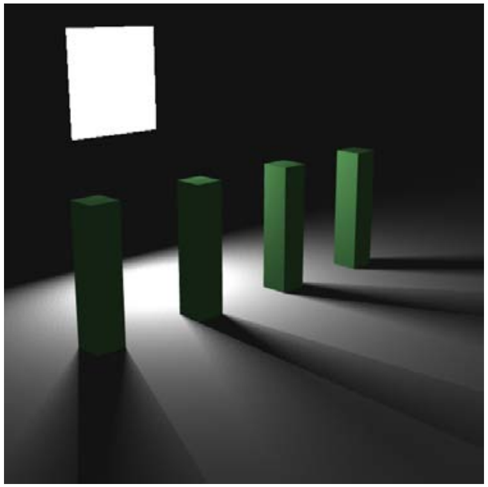
$$L_o(p,\omega_o) = \frac{1}{n_s} \sum_{k=1}^{n_l} \sum_{j=1}^{n_s} \frac{f_r(p,\omega_i,\omega_o) L_e(p',-\omega_i) V(p,p') G(p,p')}{p(p'_j)}$$



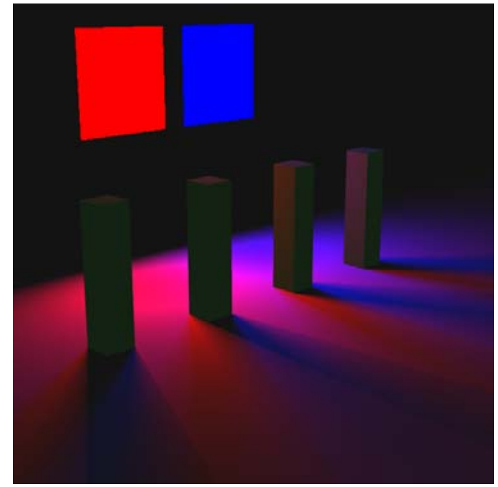
Choosing a pdf

- Defining the pdf can be difficult
- Ideally it represents the distribution of samples points over the light
- This may be difficult as the shape of the light becomes increasingly more complex
- For simple planar lights a uniform distribution over the light's surface area → $1 / A_l$
  - $p(x) = c$ → probability is constant
  - $\int_{A_l} p(x)\, dA = 1 \rightarrow c = 1/A_l$
- Surface area equations
  - Rectangle → $1/(w * h)$
  - Disk → $1/(\pi r^2)$
  - Sphere → $1/(4 \pi r^2)$???

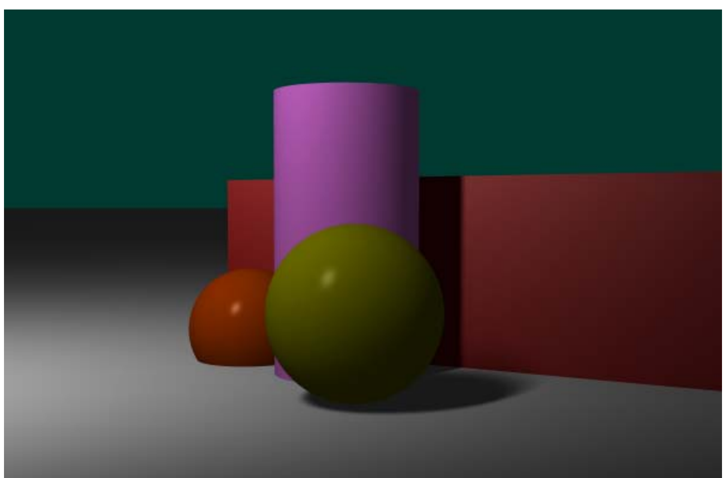
Examples

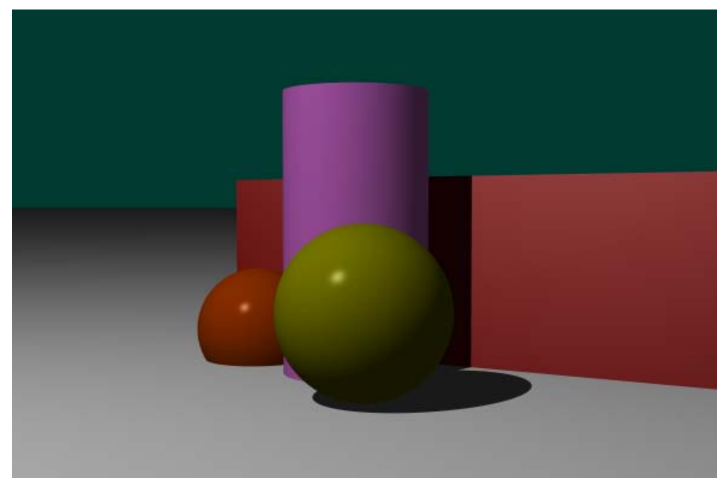


Single rectangular light



Multiple colored light

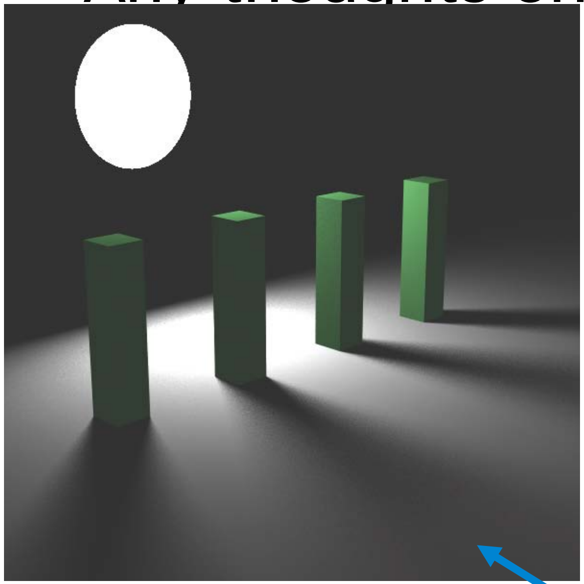


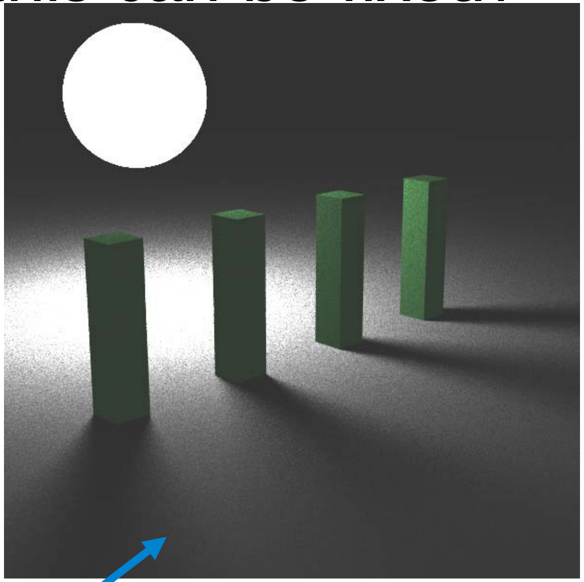


Phong Material

Potential Problems

- Rendering spherical lights can lead to more noise
  - Many of the sampled points on the sphere are useless since they represent the backside of the sphere
  - Any thoughts on how this can be fixed?

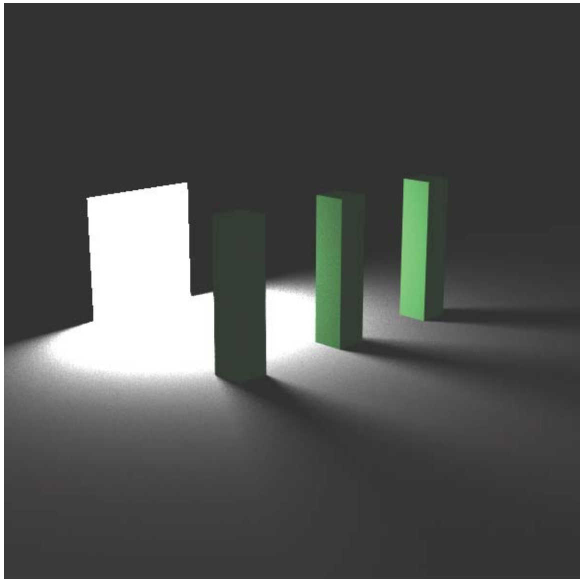


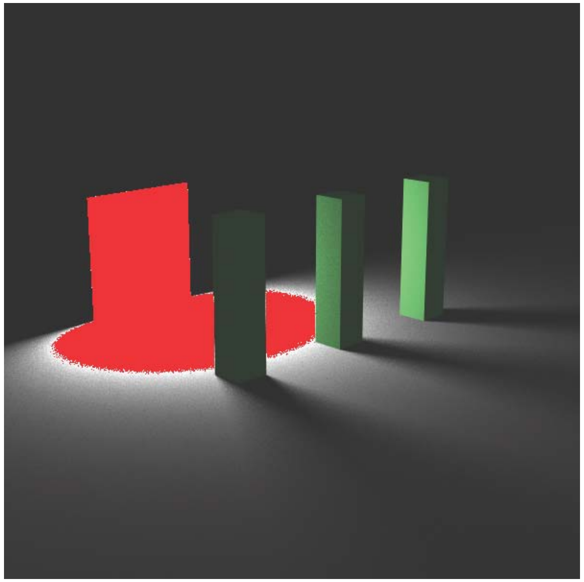


100 rays

More Potential Problems

- Another problem occurs when the light source is near an intersection point
  - The $1/d^2$ in the geometric term approaches infinity as d get larger





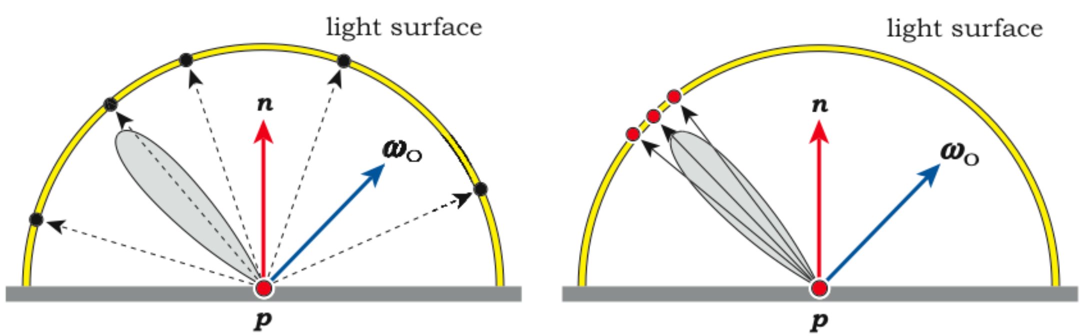
Environmental Lights

- Unlike area lights environmental lights surround the entire scene
- These lights often are intended to represent a global lighting effect.
- The general idea is to have a sphere surround the scene
- Similar to area lights, the sphere will have an emissive material which will cast light on other objects in the scene

Environment Light Details

- Once again we need to estimate the direct illumination at a hit point
- Shoot rays into the solid angle subtended at point p and test for intersection with the light
- Recall *hemisphere form* rendering equation

$$L_o(p,\omega_o) = L_e(p,\omega_o) + \int_{2\pi} f_r(p,\omega_i,\omega_o)\, L_i(p',\omega_i) \cos\theta_i \, d\omega_i$$



Environment Light Details

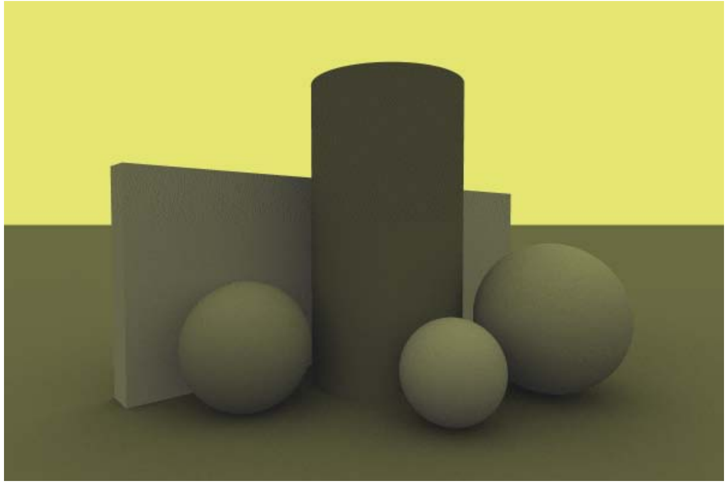
- Use Monte Carlo Integration to estimate hemisphere formula

$$L_o(p, \omega_o) = L_e(p, \omega_o) + \int_{2\pi} f_r(p, \omega_i, \omega_o) L_i(p', \omega_i) \cos\theta_i \, d\omega_i$$

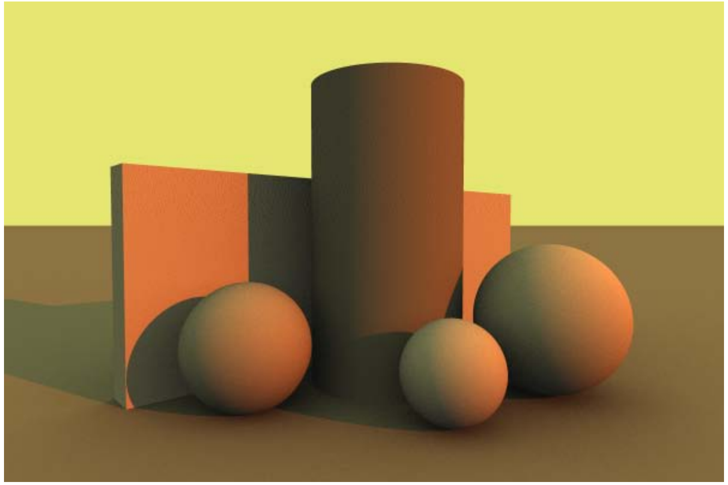
$$L_r(p, \omega_o) = (1/n_s) \sum_{j=1}^{n_s} \frac{f_r(p, \omega_{i,j}, \omega_o) L_i(p', \omega_{i,j}) \cos\theta_{i,j} \, d\omega_{i,j}}{p(\omega_{i,j})}$$

- Choosing a PDF
  - PDF is in terms of a solid angle – ω_i
  - Let p = c cos θ_i
  - $\int_{2\pi} p(\omega_i) \, d\omega_i = 1 \longrightarrow c \int_0^{2\pi} \int_0^{2\pi} \cos\theta_i \sin\theta_i \, d\theta_i \, d\phi_i = 1 \longrightarrow c = 1/\pi$
  - $p = \cos\theta_i / \pi$

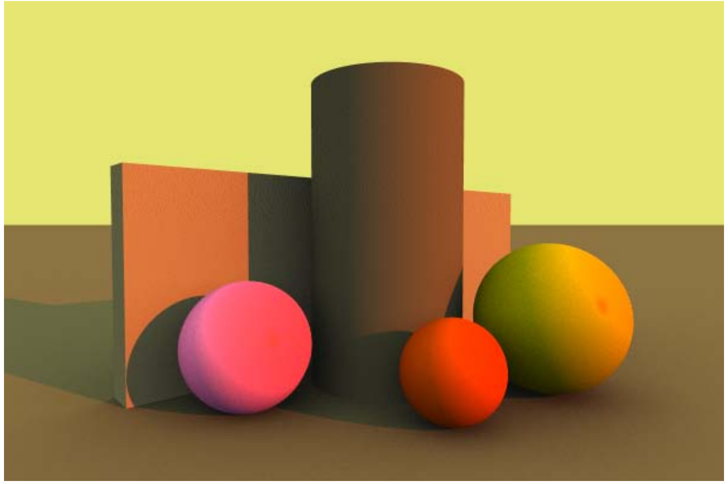
Hemisphere Light Examples



Environment Light



Add directional and ambient occlusion



Apply phong material

References

- Pharr, M., and G. Humphreys (2004). *Physically based rendering: From theory to implementation*. San Francisco: Morgan Kaufmann

- Suffern, Kevin (2007). *Ray Tracing from the Ground Up.* pp. 119-131 Wellesley, MA: A K Peters, Ltd.