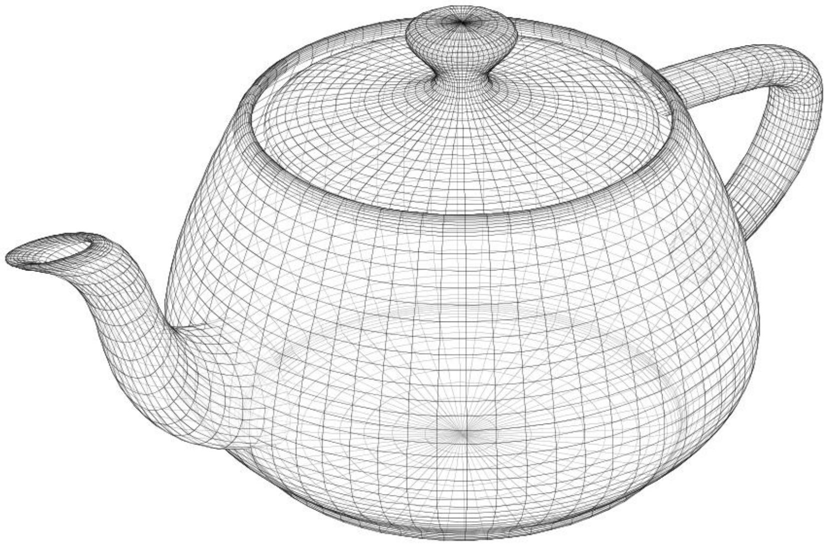

Area Lights

Production Computer Graphics

Eric Shaffer

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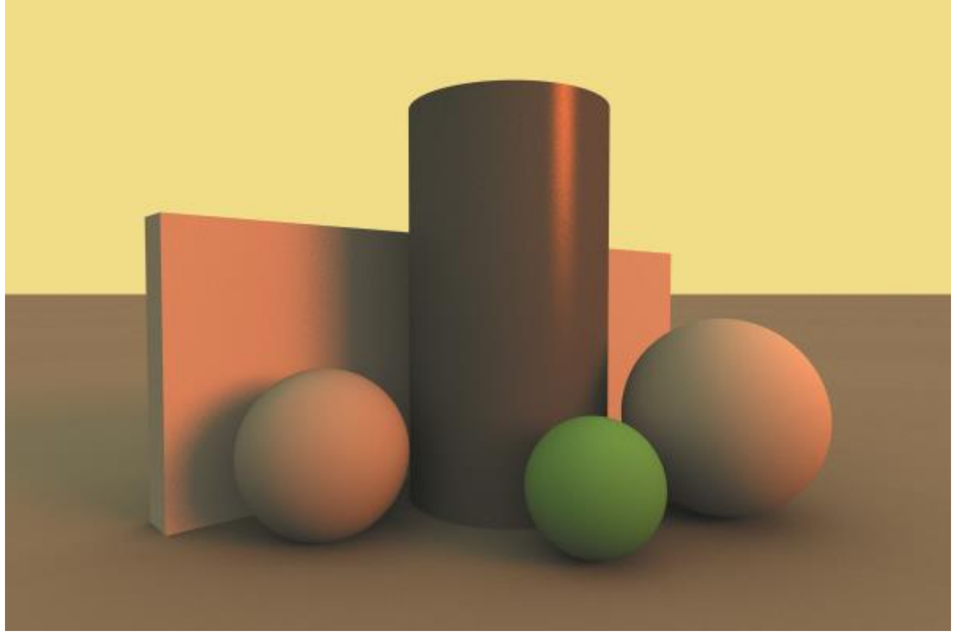
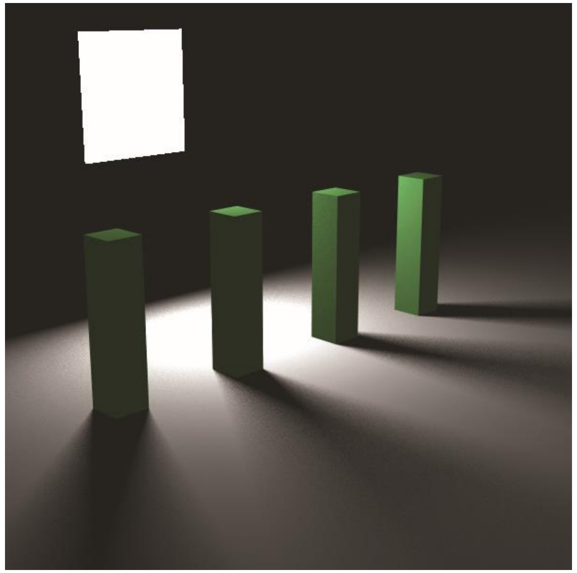
Objectives

- Understand how area lights are modeled and rendered
- Understand the idea of an environmental light
- Be able to implement both



What is an area light?

- An area light has a finite area
  - In addition to position, orientation, color, and luminance
- Adding area lights greatly increases the realism in a lit scene
  - You get soft shadows as opposed to just hard-edged shadows
- Area lights require more sampling per pixel
  - Longer render times

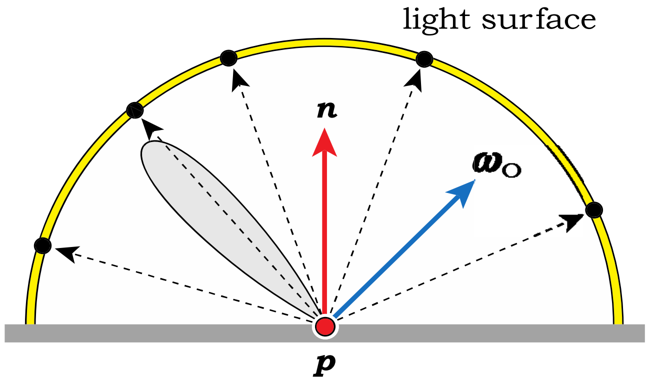


Implementing Area Lights

- Area lights can have different geometries
  - Circle, rectangle, sphere, etc.
- *RTftGU* implements an emissive material class
  - Any geometric object can then be made into a light
- Need to estimate the incident radiance from the light on a point ***p***
- Three possible techniques
  - Shoot shadow rays to points sampled on the light surface
  - Shoot shadow rays in the solid angle subtended at ***p*** by the light object
  - Shoot rays by sampling the BRDF at the point ***p***

Sampling the Light Surface

- To determine incident radiance at a hit point ***p***
  - Generate shadow rays
    - Originating p
    - Directed to a sample point $\boldsymbol{s}_i$ on the surface of the light
- Example: a hemispherical light surrounding ***p***



- The light must be able to provide
  - Uniformly sampled points $\boldsymbol{s}_i$
  - The normal at the point $\boldsymbol{s}_i$
  - For what geometries would this be easy? Which would be hard?

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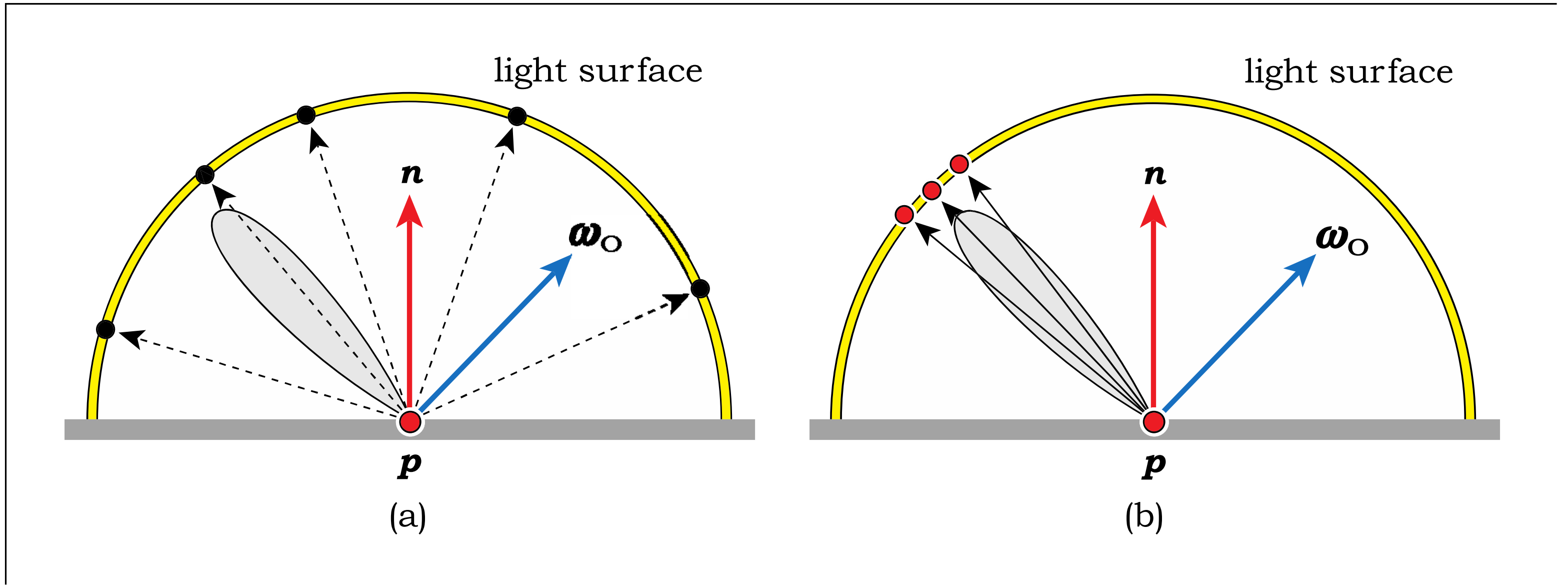
Sampling the BRDF

- To determine incident radiance at a hit point ***p***
  - Generate rays
    - Originating p
    - Directions distributed according to the BRDF
      - i.e. sample hemisphere around ***p*** possibly non-uniformly
- Example: (a) is uniform and undersamples, (b) samples BRDF



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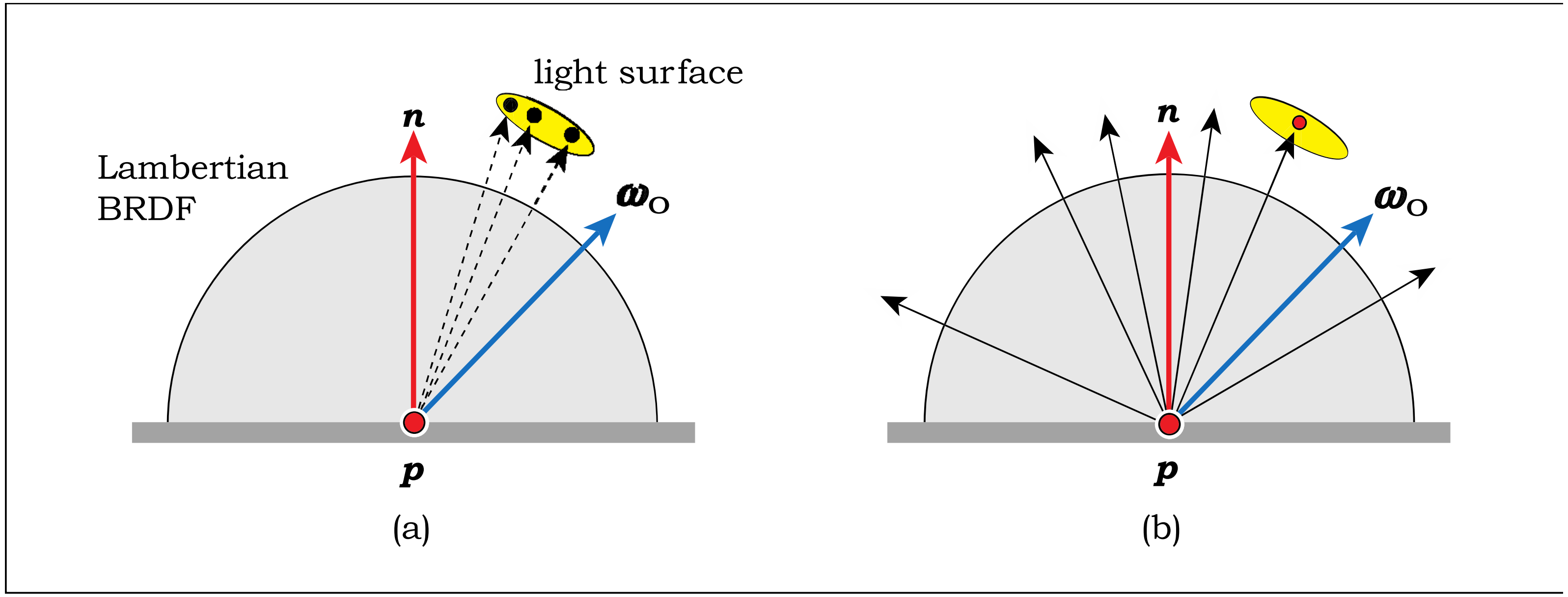
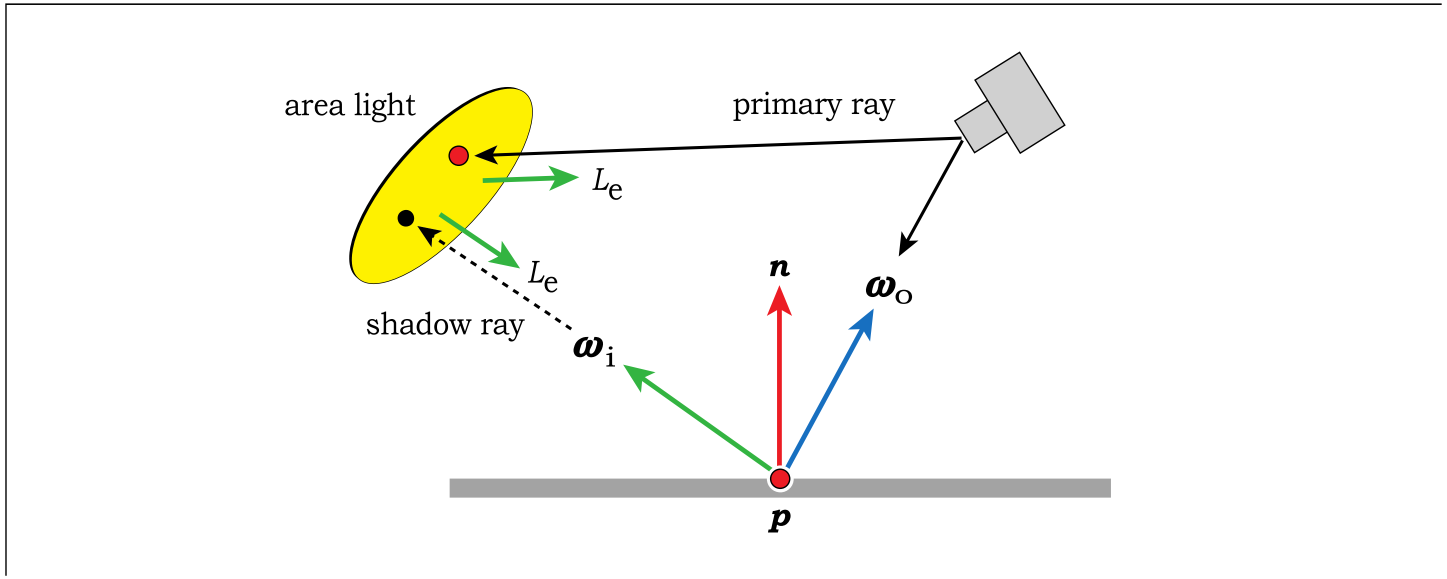
Importance Sampling Revisited

- There are situations in which sampling the BRDF is less efficient
  - Choosing the most efficient sampling method for a situation is an application of importance sampling



What to do?

- *RTftGU* chooses to
  - Sample the light for rectangular, circular, and spherical lights
  - Sample the entire hemisphere for environment light
- We also need to be able to render the light itself



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Estimating Direct Illumination

- We need to compute exitant radiance at point ***p'***
- For direct illumination, we gather only illumination from lights
  - We neglect indirect light reflected off other surfces
- Using the area form of the rendering equation:

$$L_r(p,\omega_o) = \int_{A_{lights}} f_r(p,\omega_i,\omega_o) L_e(p',-\omega_i) V(p,p') G(p,p')\, dA'$$

- For a single area light the Monte Carlo estimator for the integral is

$$\langle L_r(p,\omega_o)\rangle = \frac{1}{n}\sum_{j=1}^{n} \frac{f_r(p,\omega_i,\omega_o) L_e(p',-\omega_i) V(p,p') G(p,p')}{p(p'_j)}$$

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Estimating Direct Illumination

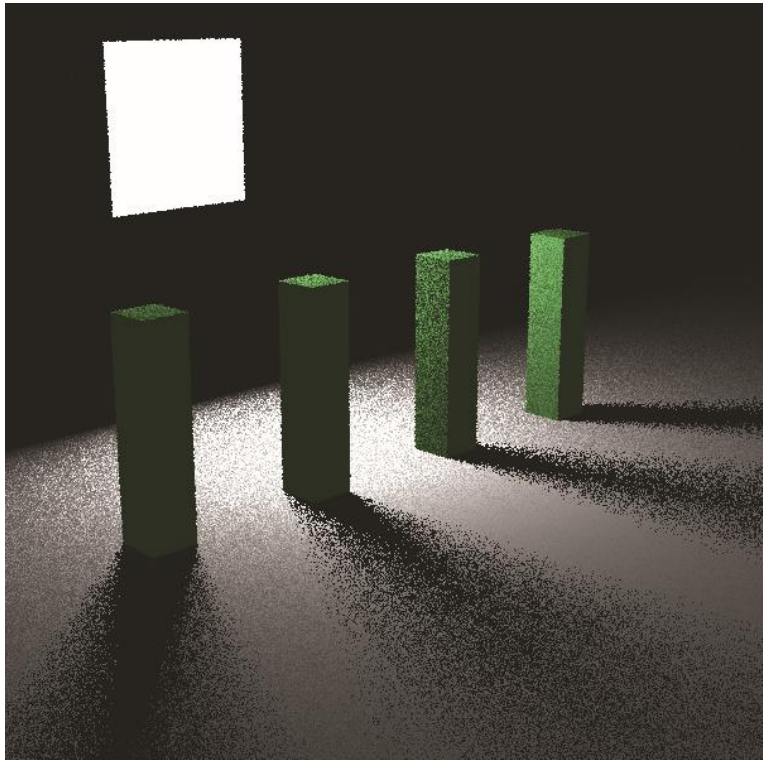
$$\langle L_r(p,\omega_o)\rangle = \frac{1}{n}\sum_{j=1}^{n} \frac{f_r(p,\omega_i,\omega_o)L_e(p',-\omega_i)V(p,p')G(p,p')}{p(p'_j)}$$

- We have n sample points
- p() is the probability distribution function over the light surface
- p() can be hard to determine in general
- In practice use uniform distribution $p(p'_j) = \dfrac{1}{A_j}$
- Recall $G(p,p') = \dfrac{\cos\theta_i \cos\theta'}{\left\| p' - p \right\|^2}$

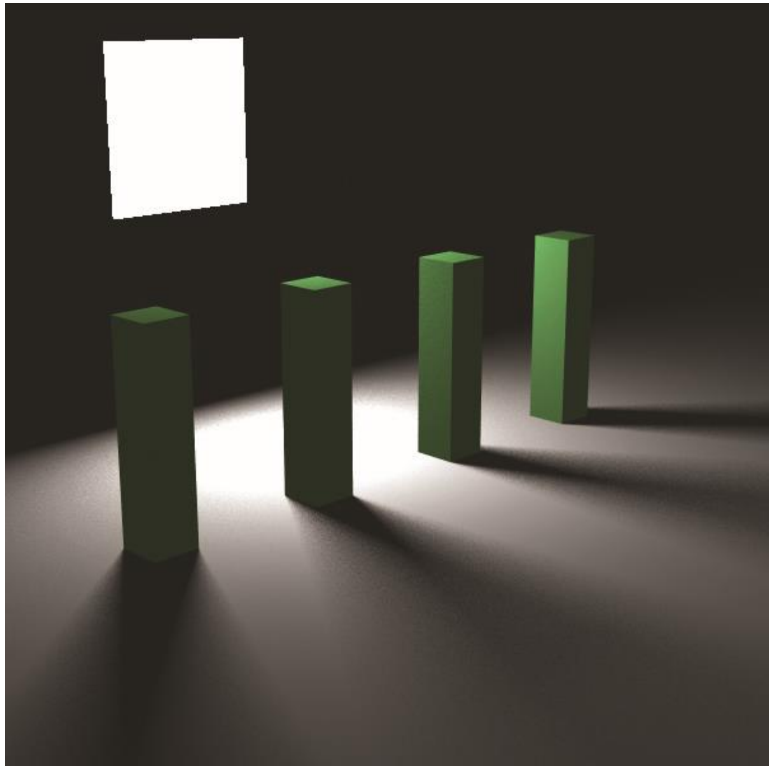
Sources of Noise with Area Lights

- Penumbra can be noisy
  - Why?
  - If a hit point is in a penumbra, requires a large number of samples to resolve correctly
- If the area light is large, the estimator can exhibit a lot of variation
  - So it will take a lot of samples to converge
  - Why? It has to do with $G(p, p') = \dfrac{\cos\theta_i \cos\theta'}{\|p' - p\|^2}$

Example

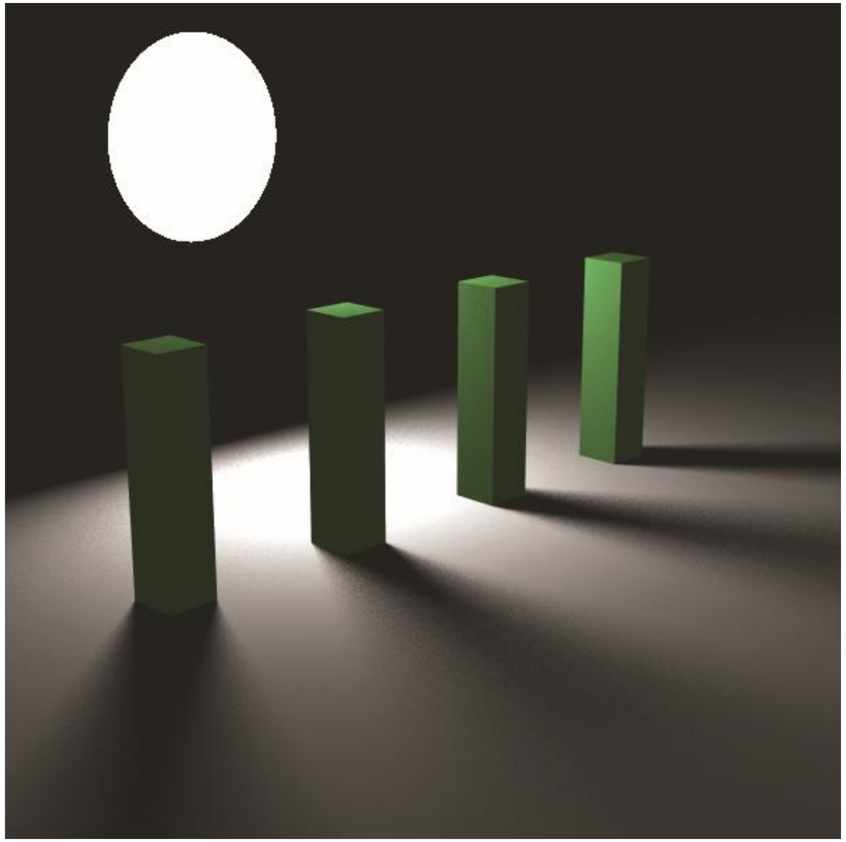


(a) 1 ray per pixel

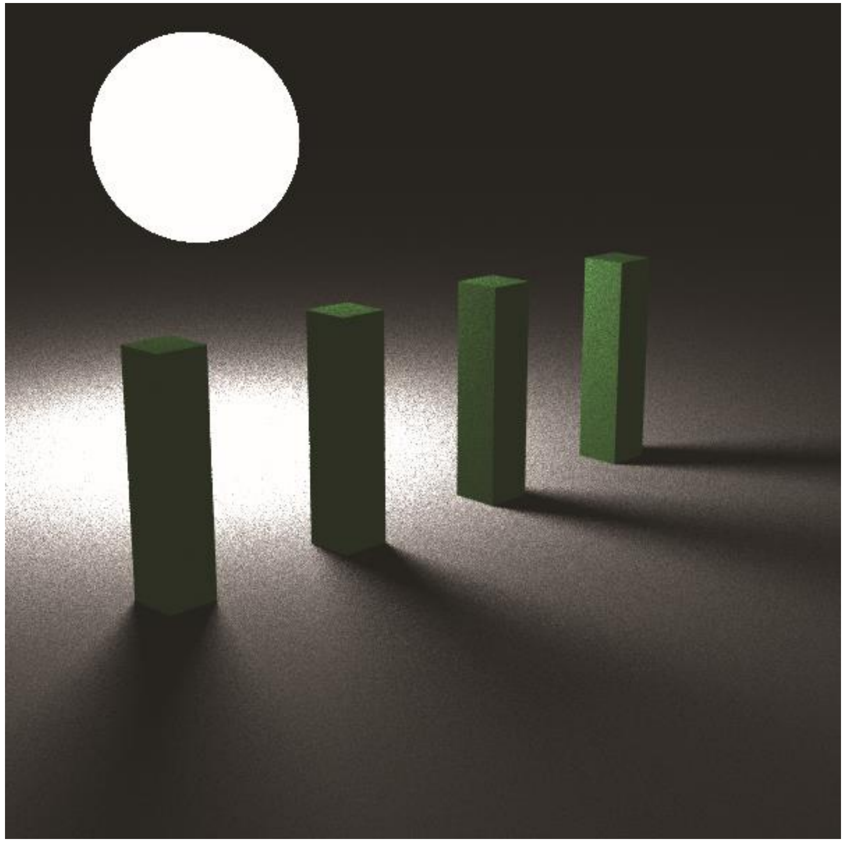


(b) 100 rays per pixel

Example



(a) Disc Light



(b) Spherical Light

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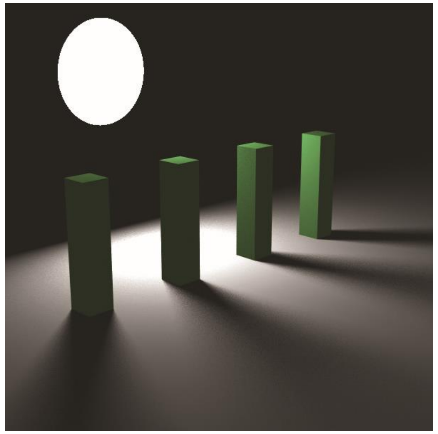
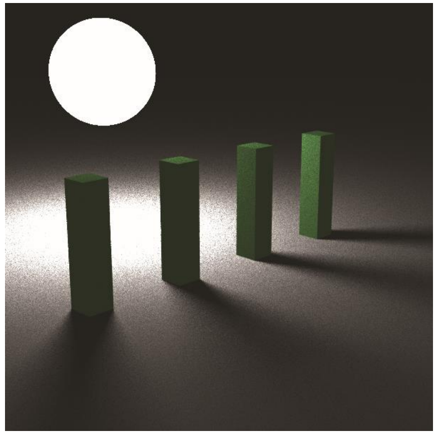
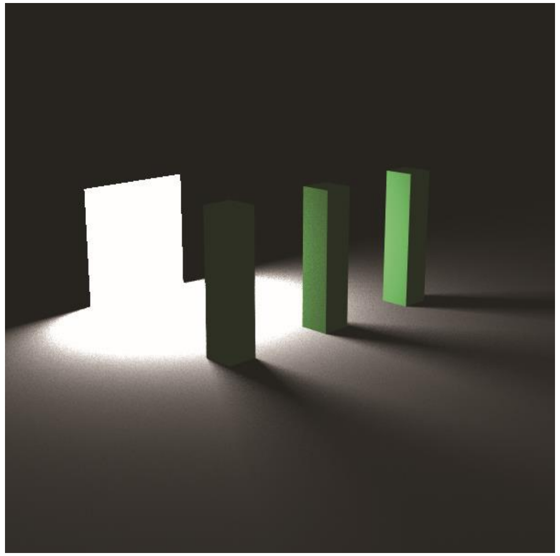
Why is the Spherical Light Noisy?

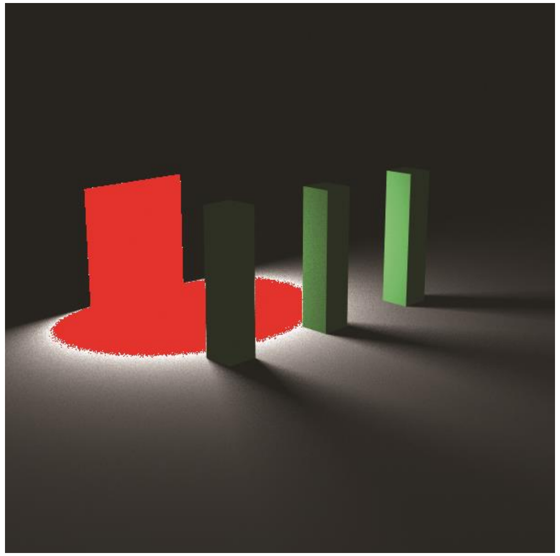




- Both lights use 100 rays per pixel
- The spherical light uniformly samples the surface
  - $p = \frac{1}{4pr^2}$
  - The cos term in G() varies significantly
- Note that the shadow shapes are relatively insensitive to light geometry

Overflow





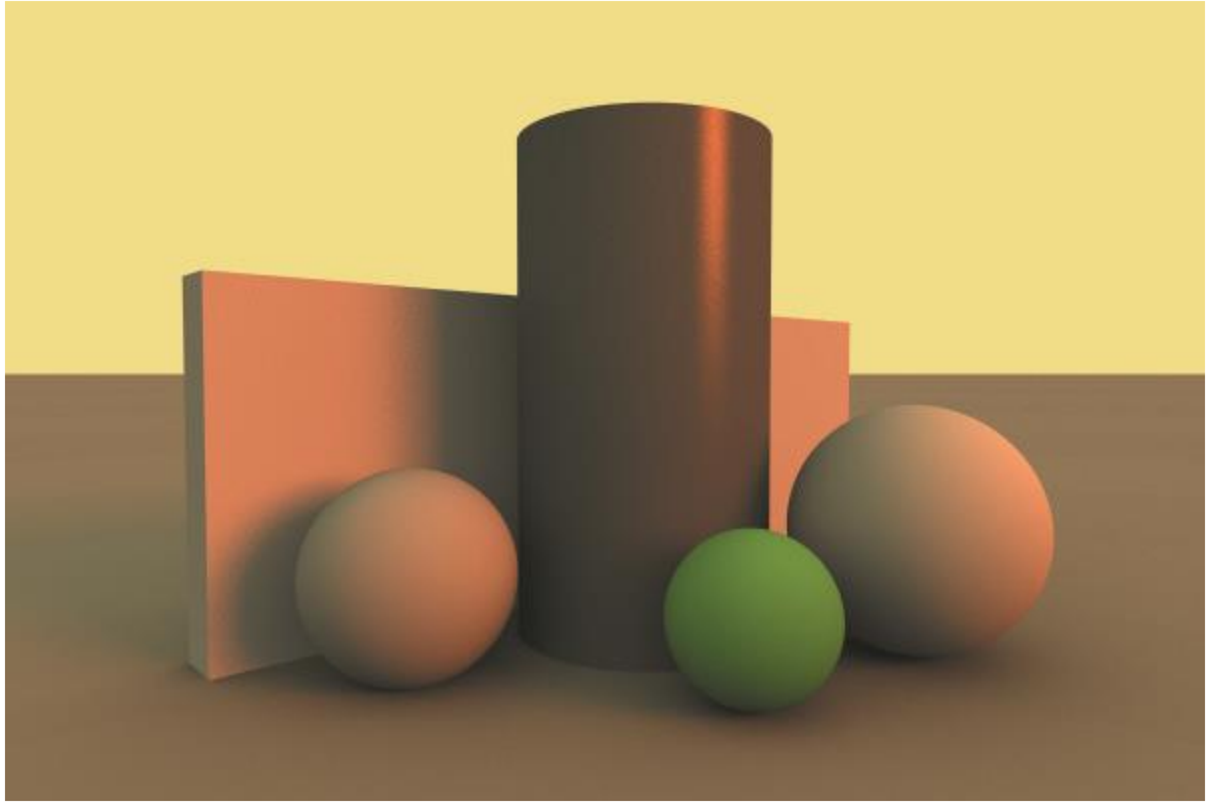
- The area light touches the plane
- Note that overflow occurs around the light….
  - Why?
- Can fix this in several ways
  - Keep lights away from objects
  - Use a PDF that includes a $1/d^2$ term
  - Use the hemisphere rather than area form of the rendering equation

Environment Light

- An Environment Light
  - Is an infinitely large spherical (or hemispherical) light
  - Surrounds the scene
  - Emissive material with possibly spatially varying color
- Shoot shadow rays using cosine distribution
  - Use hemisphere form of the rendering equation
- Monte Carlo Estimator is $\langle L_r(p,\omega_o)\rangle = \frac{1}{n}\sum_{j=1}^{n}\frac{f_r(p,\omega_{i,j},\omega_o)L_i(p,-\omega_{i,j})\cos\theta_{i,j}}{p(\omega_{i,j})}$

$$p = \cos\frac{\theta_i}{\pi}$$

Example



- Environment lights simulate outdoor lighting conditions
- Here we have
  - yellow environment light
  - orange directional light
  - ambient occlusion