CS 419: Production Rendering

Area Lights

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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.
- \textit{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 to points sampled on the light surface
  - Shoot shadow rays in the solid angle subtended at $p$ by the 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 \( s_i \) on the surface of the light
- Example: Imagine a hemispherical light surrounding \( p \)

- The light must be able to provide
  - Uniformly sampled points \( s_i \)
  - The normal at the point \( s_i \)
  - For what geometries would this be easy? Which would be hard?
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
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
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 surfaces

Using the area form of the rendering equation:

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

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

\[
\langle L_r(p, \omega_o) \rangle = \frac{1}{n} \sum_{j=1}^{n} \frac{f_r(p, \omega_i, \omega_o) L_e(p', -w_i) V(p, p') G(p, p')}{p(p'_j)}
\]
Estimating Direct Illumination

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

- 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 \( p(p'_j) = \frac{1}{A_j} \)
- Recall
  \[
  G(p, p') = \frac{\cos \theta_i \cos \theta'}{\|p' - p\|^2}
  \]
Penumbra can be noisy
- Why?
- So if a hit point is in a penumbra it will require 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

\[ G(p, p') = \frac{\cos \theta_i \cos \theta'}{\|p' - p\|^2} \]
Example

(a) 1 ray per pixel

(b) 100 rays per pixel
Example

(a) Disc Light

(b) Spherical Light
Why is the Spherical Light Noisy?

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

\[
\langle L_r(p, \omega_o) \rangle = \frac{1}{n} \sum_{j=1}^{n} \frac{f_r(p, \omega_{i,j}, \omega_o)L_i(p, -w_{i,j})\cos \theta_{i,j}}{p(\omega_{i,j})} \\
p = \cos \frac{\theta_i}{\pi}
\]
Example

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