

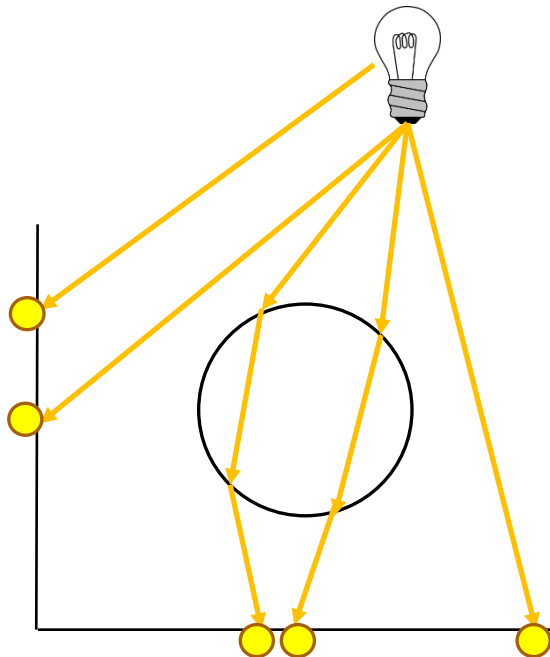
AI5505: Photorealistic Rendering

Global Illumination

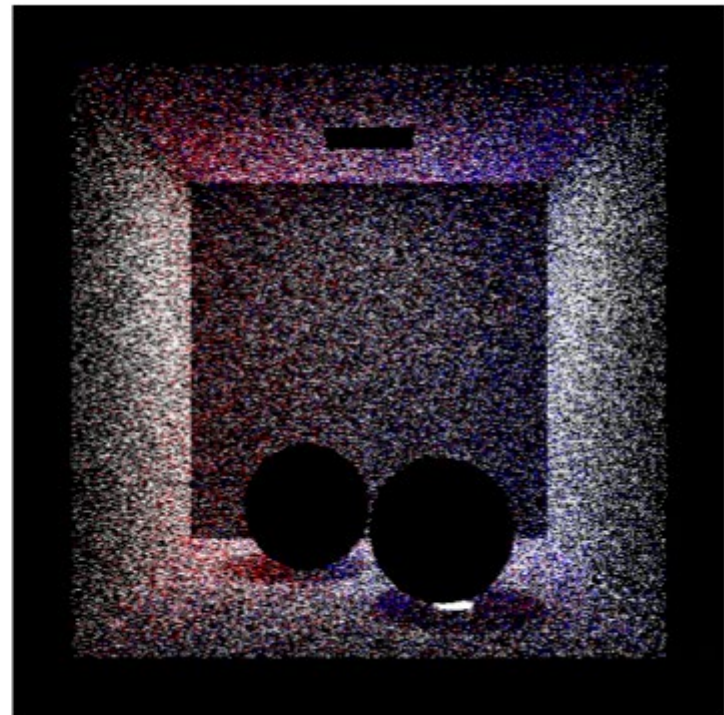
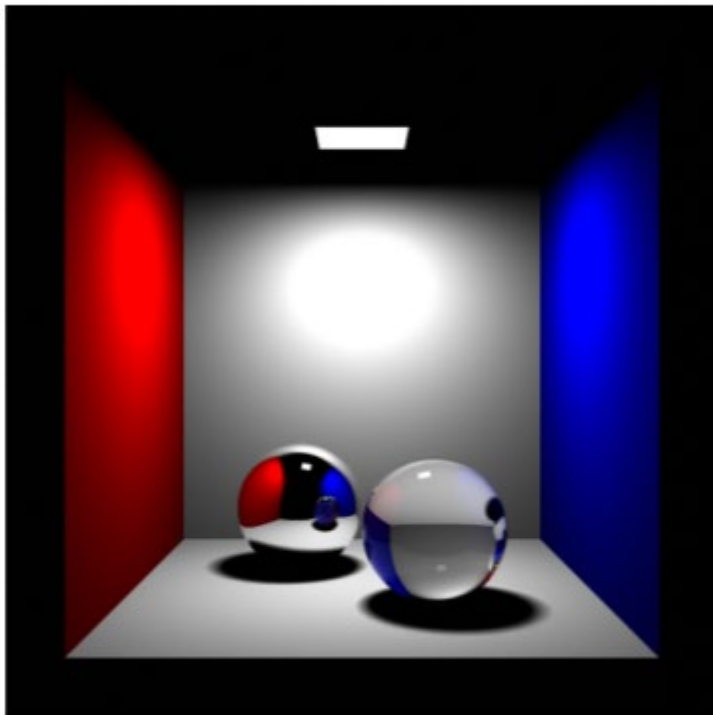
Lecturer: Bochang Moon

Photon Mapping

- [Jensen 1996]
- A two-pass rendering method
 - 1. build a photon map
 - 2. render an image using the map



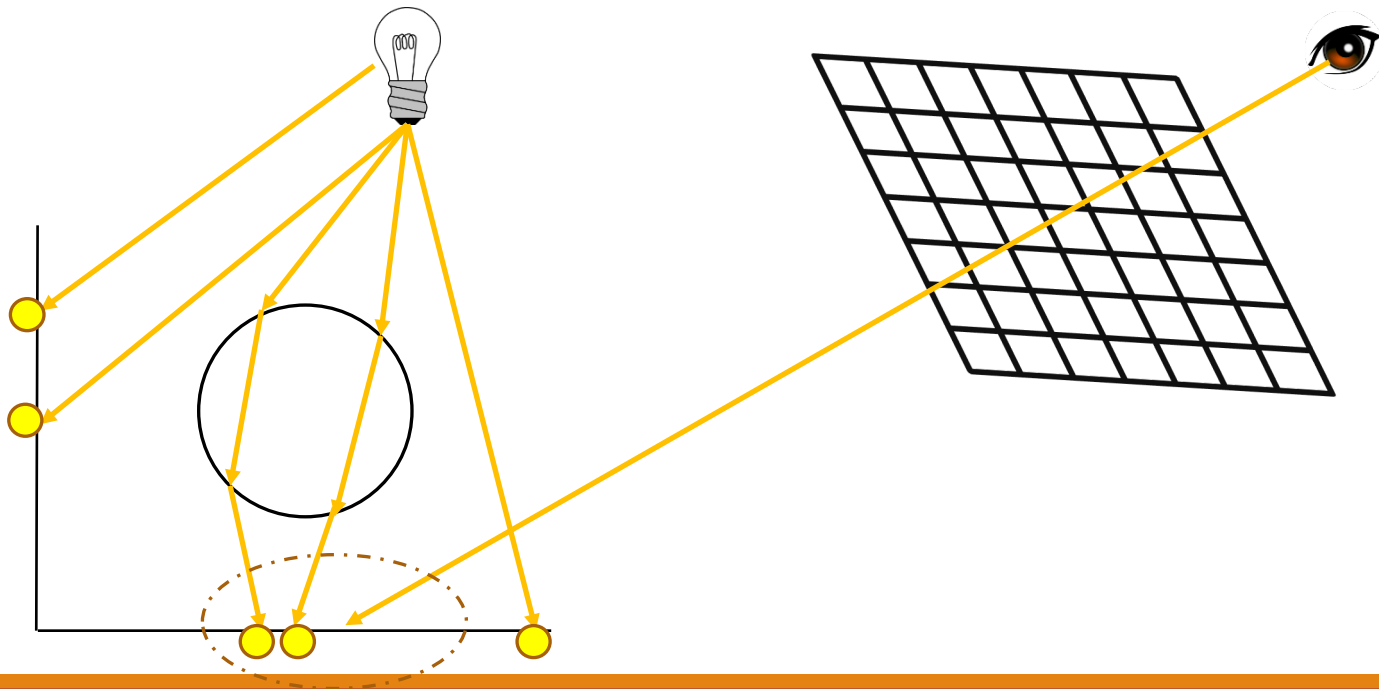
Photon Mapping



[Christensen and Jensen, SIGGRAPH 2000 course]

Photon Mapping

- [Jensen 1996]
- A two-pass rendering method
 - 1. (photon tracing) build a photon map
 - 2. (radiance estimation) render an image using the map



Photon Mapping

- Photon emission
 - Photons are generated from light sources
 - Each photon carries a fraction of the power of a light source
- Photon
 - Position (x, y, z)
 - Power $\Phi_{photon} = \frac{\Phi_{light}}{n_e}$
 - Incident direction

Photon Emission

- Photon emission
 - $n_e = 0$
 - *for* ($i = 0$ to N)
 - *select a random direction* d
 - *trace a photon from a light position* p *in direction* d
 - $n_e = n_e + 1$
 - *scale power of stored photons with* $\frac{1}{n_e}$
- Multiple light sources?
 - Each light source emits photons
 - Brighter light sources can emit more photons than from dim ones

Photon Scattering

- Photon tracing employs a ray tracing procedure:
 - If a photon hits a surface, it will be reflected or absorbed
- In practice, a Russian Roulette (RR) is used
 - RR is a stochastic technique to determine whether a photon is reflected or not
 - RR is widely used in Monte Carlo ray tracing methods
 - It improves efficiency by increasing likelihood that samples can have high contributions

Photon Scattering

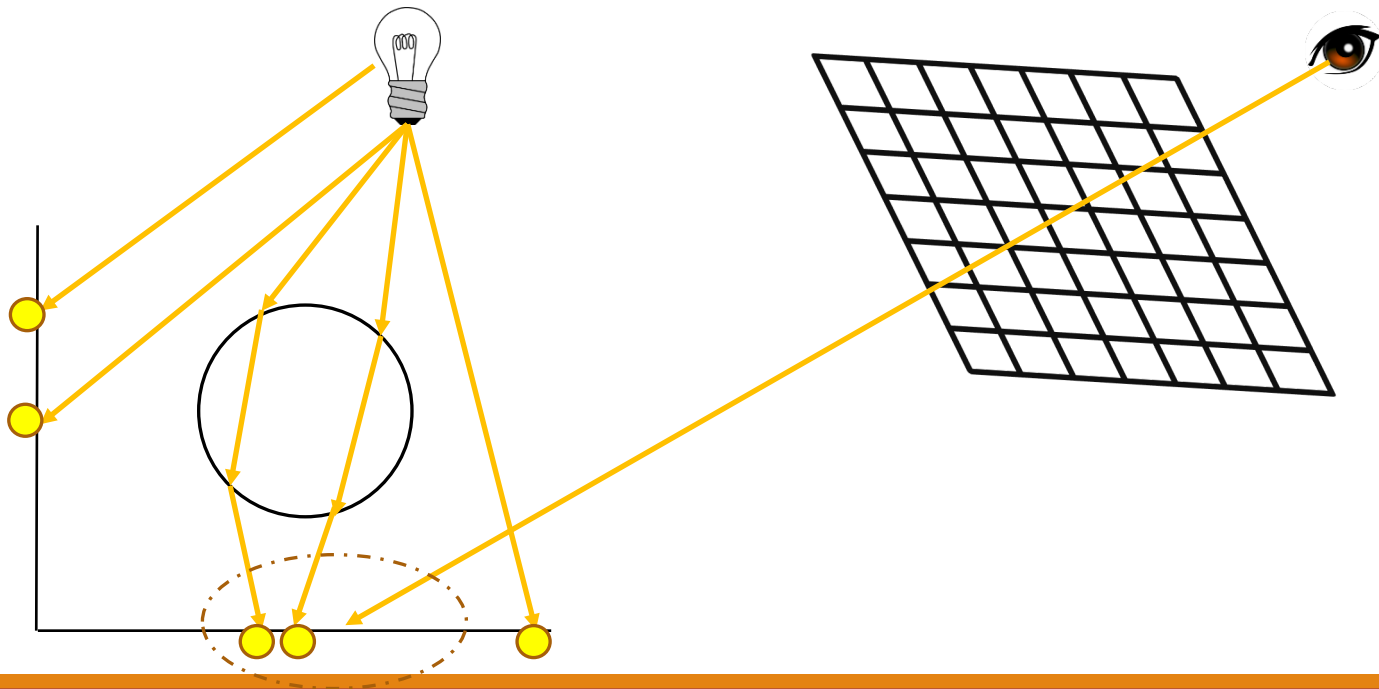
- Photon tracing employs a ray tracing procedure:
 - If a photon hits,
 - $p = d$ (*probability of reflection = reflectivity of the surface*)
 - $\xi \in [0,1]$ (*uniformly distributed random number*)
 - if ($\xi < p$)
 - *reflect photon with power Φ_p*
 - *else*
 - *photon is absorbed*
- Note
 - If N photons hit, we have two choices
 - Reflect N photons with half the power
 - Reflect N/2 photons with the full power (RR enables this efficient approach)

Photon Storing

- Store photons when they hit non-specular surfaces
 - Do not need to store them for specular reflection (e.g., reflection on mirrors)
- An emitted photon can be stored several times along its path
- A tree structure (kd-trees) is used to maintain the photons
 - This will be utilized for searching neighboring photons in the second step

Photon Mapping

- [Jensen 1996]
- A two-pass rendering method
 - 1. (photon tracing) build a photon map
 - 2. (radiance estimation) render an image using the map

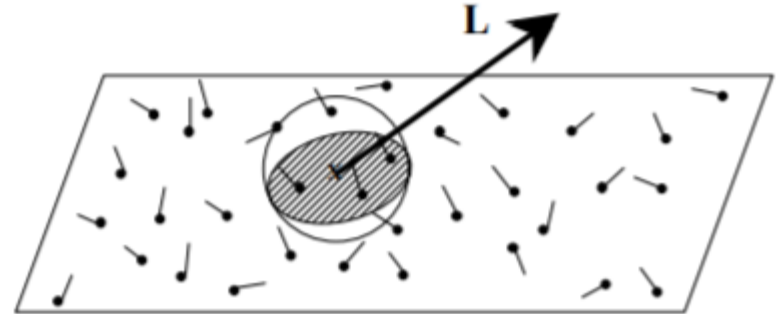


Radiance Estimation

- Need to estimate photon density $\frac{d\Phi}{dA}$ at query points (e.g., intersection points between primary rays and surfaces)
- $L_r(x, k_o) = \int_{\Omega_x} \rho(x, k_i, k_o) L_i(x, k_i) (n_x \cdot k_i) dk_i$
 - $L_i(x, k_i) = \frac{d^2\Phi_i(x, k_i)}{(n_x \cdot k_i) dk_i dA_i}$
- $L_r(x, k_o) = \int_{\Omega_x} \rho(x, k_i, k_o) \frac{d^2\Phi_i(x, k_i)}{(n_x \cdot k_i) dk_i dA_i} (n_x \cdot k_i) dk_i$
- $= \int_{\Omega_x} \rho(x, k_i, k_o) \frac{d^2\Phi_i(x, k_i)}{dk_i dA_i}$
- The incoming flux, $\Phi_i(x, k_i)$, is approximated with the photon map
 - Search k nearest photons from x

Radiance Estimation

- $L_r(x, k_o) = \int_{\Omega_x} \rho(x, k_i, k_o) \frac{d^2\Phi_i(x, k_i)}{dk_i dA_i}$
- Each photon p carries a fraction of a light power, $\Delta\Phi_p(k_p)$
- $L_r(x, k_o) \approx \sum_{p=1}^N \rho(x, k_p, k_o) \frac{\Delta\Phi_p(x, k_p)}{\Delta A}$
- $\Delta A = \pi r^2$
 - The radius r is set as the largest distance between x and positions of photons
 - Assume a locally flat surface around x
- $L_r(x, k_o) \approx \frac{1}{\pi r^2} \sum_{p=1}^N \rho(x, k_p, k_o) \Delta\Phi_p(x, k_p)$



[Christensen and Jensen, SIGGRAPH 2000 course]

Radiance Estimation

- $L_r(x, k_o) \approx \frac{1}{\pi r^2} \sum_{p=1}^N \rho(x, k_p, k_o) \Delta\Phi_p(x, k_p)$
- When assumptions (e.g., locally flat surfaces) are valid and the number of photons is infinite, the approximation error will be zero
- Q. can we store the infinite number of photons?
 - If not, is there any way to accomplish the consistency?
 - As an advanced topic in this direction, we will study Progressive Photon Mapping which addresses this issue