CS482: Acceleration Methods for MC Ray Tracing:

Sung-Eui Yoon
(윤성의)

http://sglab.kaist.ac.kr/~sungeui/ICG

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Questions

- **Why is the increase of variance not a problem in russian roulette?**
- **If many object have high reflectance in scene, will the performance of Russian Roulette decrease? For example, If room have many mirrors, can an infinity loop appear in recursion?**

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Student Presentation Guidelines

- **Good summary, not full detail, of the paper**
  - **Talk about motivations of the work**
  - **Give a broad background on the related work**
  - **Explain main idea and results of the paper**
  - **Discuss strengths and weaknesses of the method**

- **Prepare an overview slide**
  - **Talk about most important things and connect them well**

High-Level Ideas

- **Deliver most important ideas and results**
  - **Do not talk about minor details**
  - **Give enough background instead**
- **Deeper understanding on a paper is required**
  - **Go over at least two related papers and explain them in a few slides**
- **Spend most time to figure out the most important things and prepare good slides for them**

Deliver Main Ideas of the Paper

- **Identify main ideas/contributions of the paper and deliver them**

- **If there are prior techniques that you need to understand, study those prior techniques and explain them**
  - **For example, A paper utilizes B's technique in its main idea. In this case, you need to explain B to explain A well.**

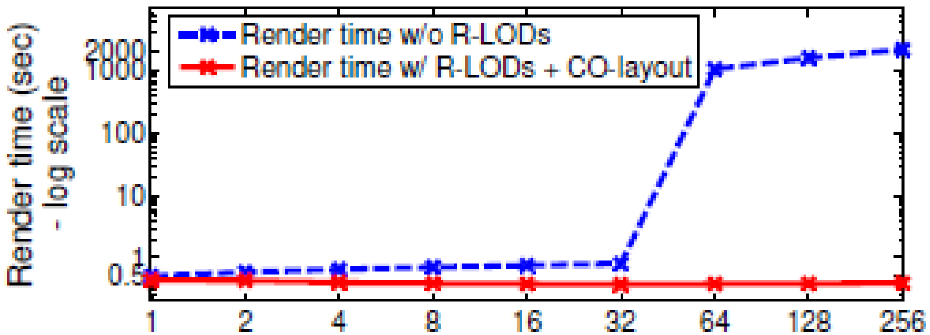
Be Honest

- **Do not skip important ideas that you don't know**
  - **Explain as much as you know and mention that you don't understand some parts**

- **If you get questions you don't know good answers, just say it**
  - **You need to explain them at KLMS board**

Result Presentation

- **Give full experiment settings and present data with the related information**
  - **What does the x-axis mean in the below image?**



- **After showing the data, give a message that we can pull of the data**
- **Show images/videos, if there are**

Utilizing Existing Resources

- **Use author's slides, codes, and video, if they exist**
- **Give proper credits or citations**
  - **Without them, you are cheating!**

Audience feedback form

Date:
Talk title:
Speaker:

1. Was the talk well organized and well prepared?
5: Excellent 4: good 3: okay 2: less than average 1: poor

2. Was the talk comprehensible? How well were important concepts covered?
5: Excellent 4: good 3: okay 2: less than average 1: poor

Any comments to the speaker

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As an Evaluator

- **Evaluate in an objective manner**
- **Do not rank talks; just focus on each talk**

Prepare Quiz

- **Review most important concepts of your talk**
  - **Prepare two multiple-choices questions**

- **Example: What is the biased algorithm?**
  - **A: Given N samples, the expected mean of the estimator is I**
  - **B: Given N samples, the exp. Mean of the estimator is I + e**
  - **C: Given N samples, the exp. Mean of the estimator is I + e, where e goes to zero, as N goes to infinite**

- **Grade them in the scale of 0 to 10 and send it to TA**

Class Objectives

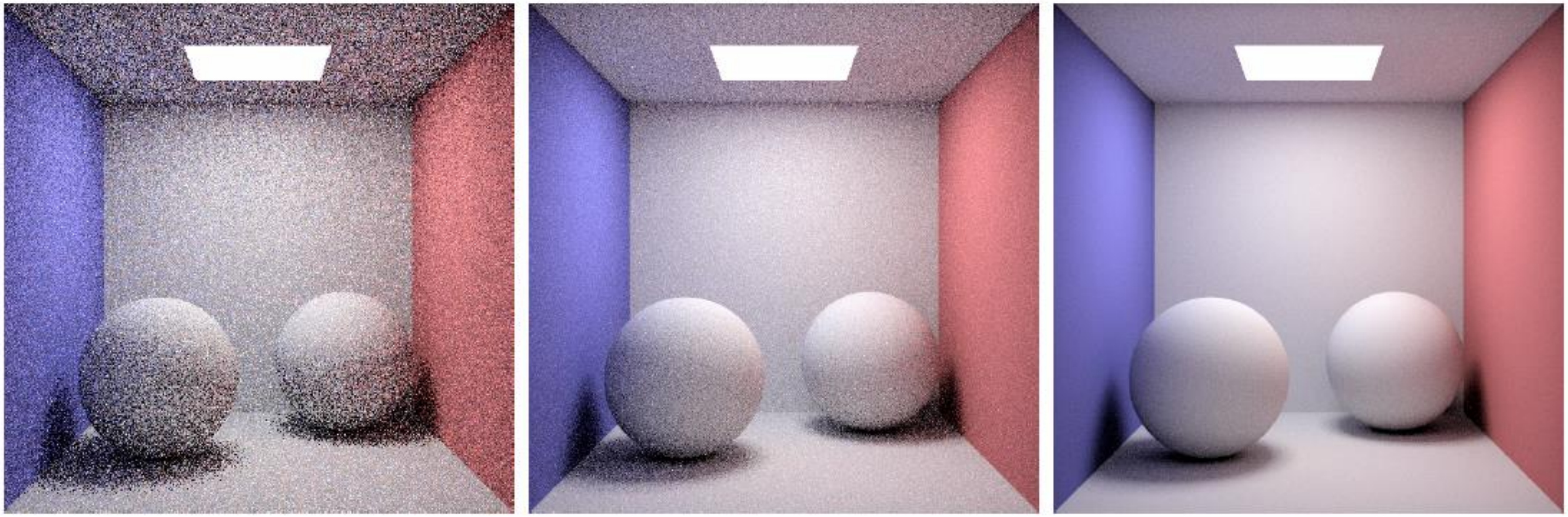
- Discuss acceleration methods for GI
  - Importance sampling, bidirectional path tracing, and Metropolis
- Study biased techniques
  - Irradiance caching and photon mapping

- Last time:
  - Path tracing, a basic structure of Monte Carlo ray tracing including Russian roulette

Algorithm so far: Path tracing

- **Shoot primary rays through each pixel**
- **Shoot indirect rays, sampled over hemisphere**
  - **Path tracing shoots only 1 indirect ray**
- **Terminate recursion using Russian Roulette**

Path Tracing



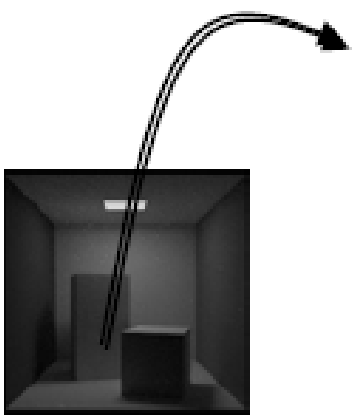
1 spp (samples per pixel) | 4 spp | 16 spp

- **Pixel sampling + light source sampling folded into one method**

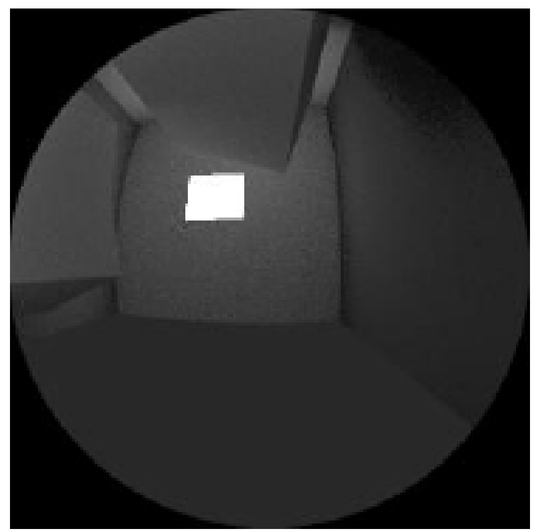
Importance Sampling

$$L(x \rightarrow \Theta) = L_e(x \rightarrow \Theta) + \int_{\Omega_x} f_r(\Psi \leftrightarrow \Theta) \cdot L(x \leftarrow \Psi) \cdot \cos(\Psi, n_x) \cdot d\omega_\Psi$$

Radiance from light sources + radiance from other surfaces



$$= L_e + \int_{\Omega_x}$$

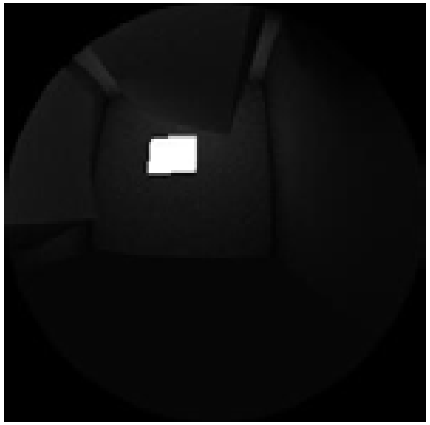


$$\cdot f_r \cdot \cos$$

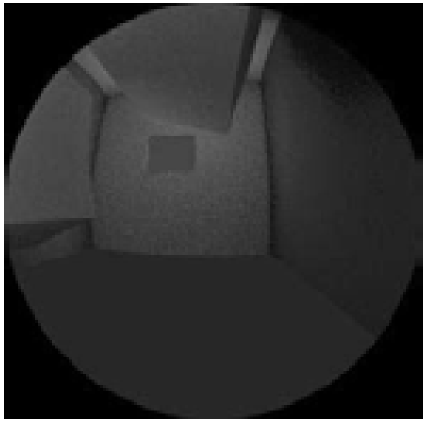
Importance Sampling

$$L(x \rightarrow \Theta) = L_e + L_{direct} + L_{indirect}$$

$$= L_e + \int_{\Omega_x}$$



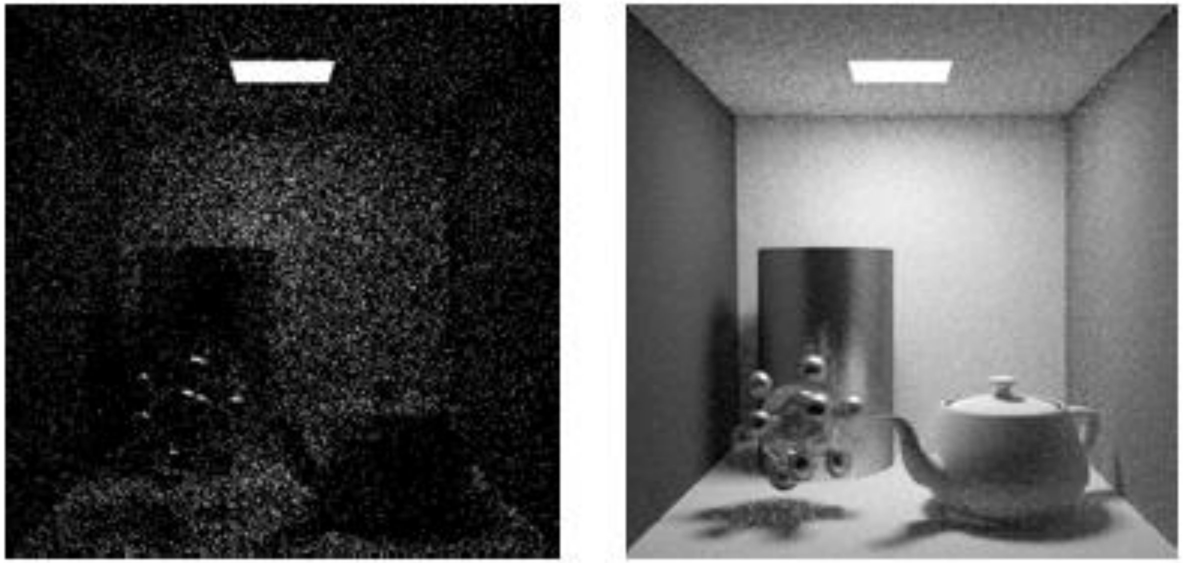
$$\cdot f_r \cdot \cos + \int_{\Omega_x}$$



$$\cdot f_r \cdot \cos$$

- So … sample direct and indirect with separate MC integration

Comparison



From kavita's slides

- **With and without considering direct illumination**
  - **16 samples / pixel**

Rays per pixel

1 sample/ pixel

4 samples/ pixel

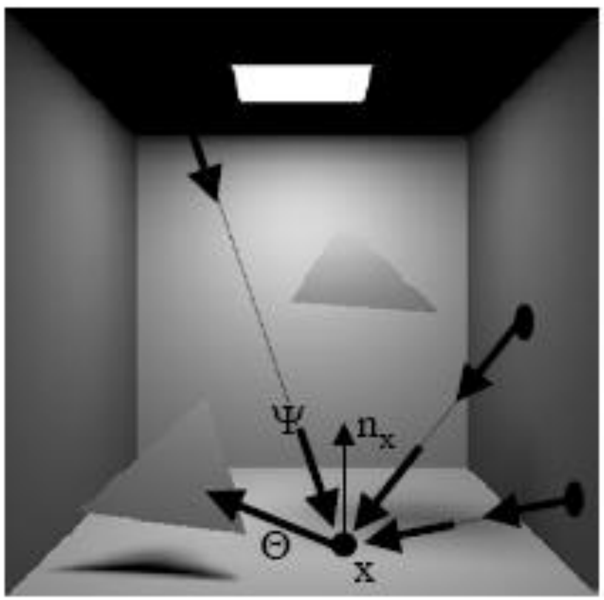
16 samples/ pixel

256 samples/ pixel

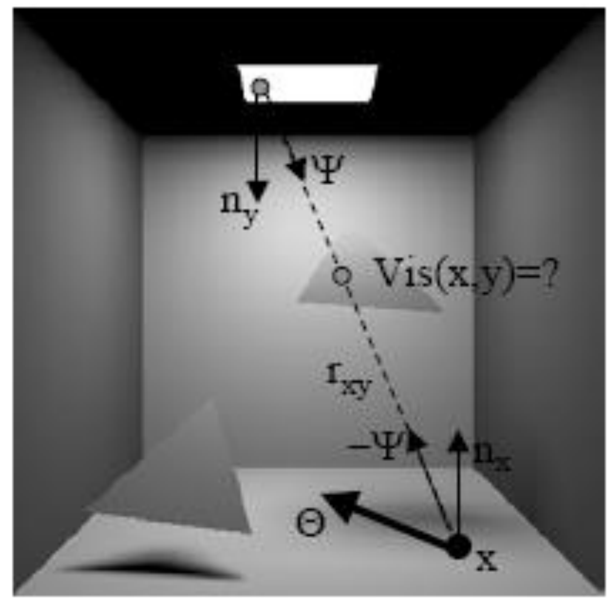
Direct Illumination

$$L(x \to \Theta) = \int_{A_{source}} f_r(x, -\Psi \leftrightarrow \Theta) \cdot L(y \to \Psi) \cdot G(x,y) \cdot dA_y$$

$$G(x,y) = \frac{\cos(n_x, \Theta)\cos(n_y, \Psi) Vis(x,y)}{r_{xy}^2}$$



hemisphere integration



area integration

Estimator for direct lighting

- Pick a point on the light's surface with pdf

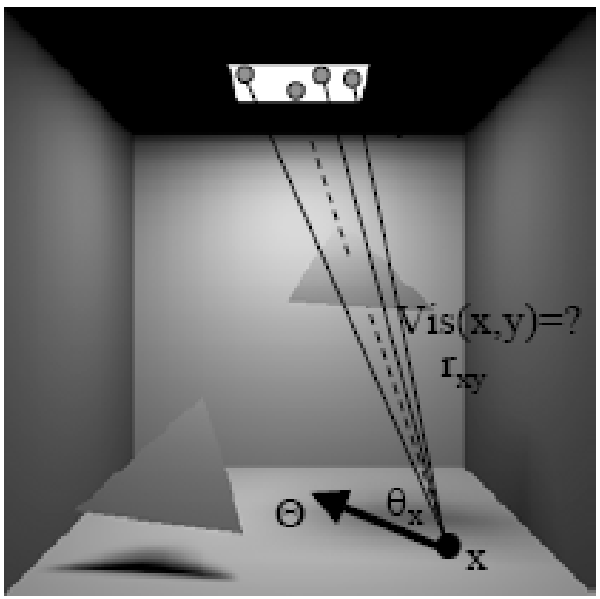
$$p(y)$$

- For N samples, direct light at point x is:

$$E(x) = \frac{1}{N}\sum_{i=1}^{N} \frac{f_r L_{source} \dfrac{\cos\theta_x \cos\theta_{\bar{y}_i}}{r^2_{x\bar{y}_i}} Vis(x, \bar{y}_i)}{p(\bar{y}_i)}$$

Generating direct paths

- Pick surface points y_i on light source
- Evaluate direct illumination integral



$$\langle L(x \to \Theta) \rangle = \frac{1}{N} \sum_{i=1}^{N} \frac{f_r(\ldots)L(\ldots)G(x,y_i)}{p(y_i)}$$

PDF for sampling light

- Uniform

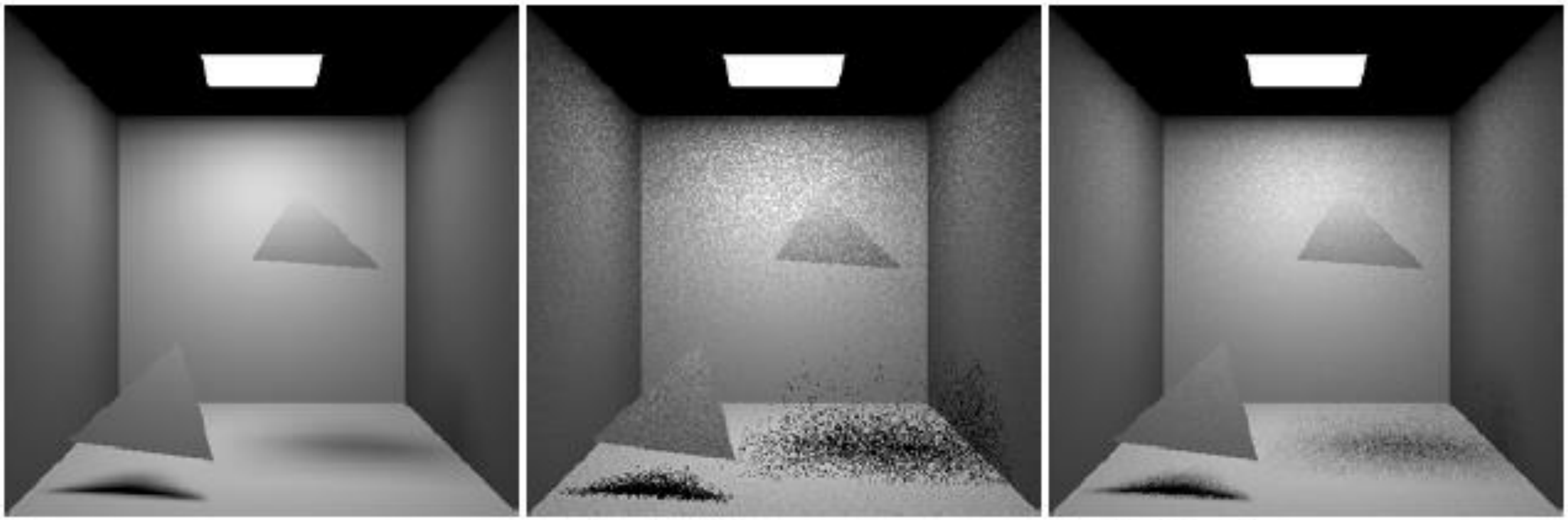
$$p(y) = \frac{1}{Area_{source}}$$

- Pick a point uniformly over light's area
  - Can stratify samples

- Estimator:

$$E(x) = \frac{Area_{source}}{N} \sum_{i=1}^{N} f_r L_{source} \frac{\cos\theta_x \cos\theta_{\bar{y}_i}}{r_{x\bar{y}_i}^2} Vis(x, \bar{y}_i)$$

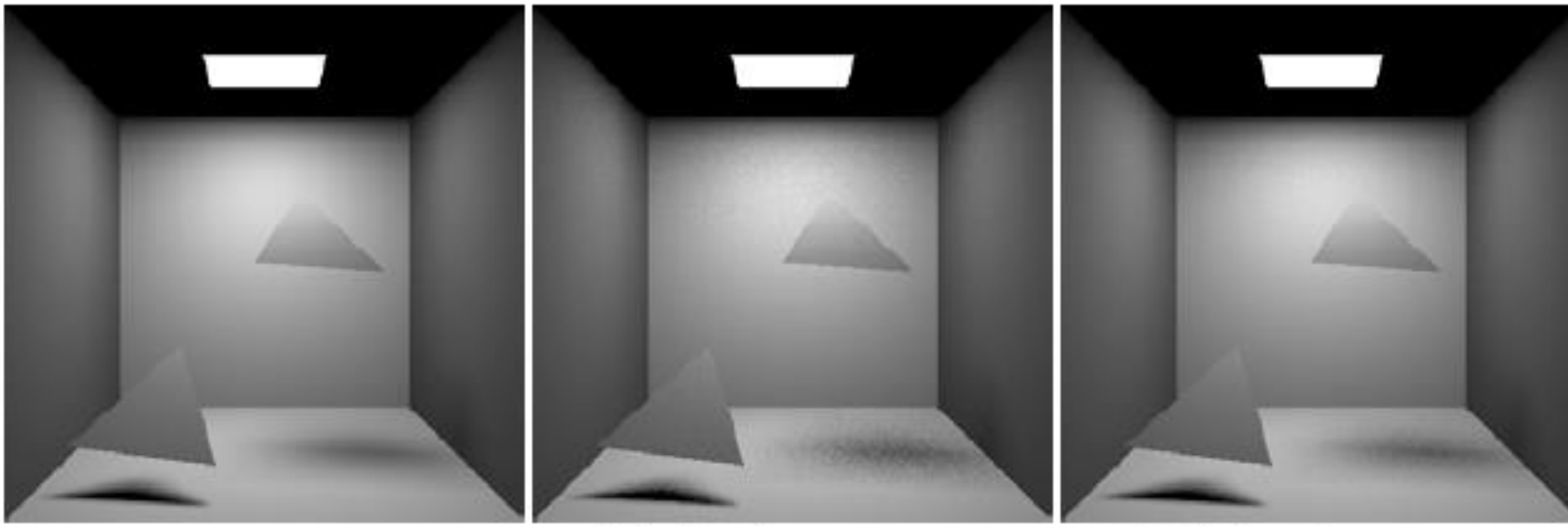
More points ...



1 shadow ray　　9 shadow rays

$$E(x) = \frac{Area_{source}}{N} \sum_{i=1}^{N} f_r L_{source} \frac{\cos\theta_x \cos\theta_{\bar{y}_i}}{r^2_{x\bar{y}_i}} Vis(x, \bar{y}_i)$$

Even more points ...



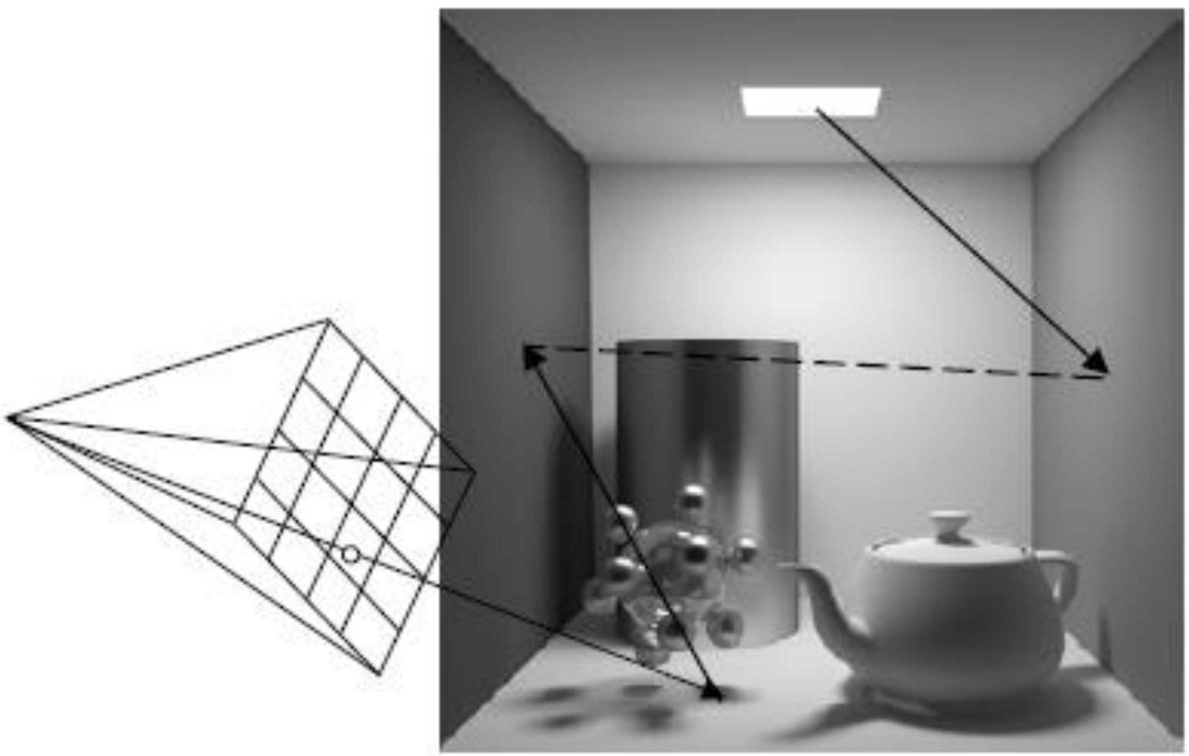
36 shadow rays

100 shadow rays

$$E(x) = \frac{Area_{source}}{N} \sum_{i=1}^{N} f_r L_{source} \frac{\cos\theta_x \cos\theta_{\bar{y}_i}}{r^2_{x\bar{y}_i}} Vis(x, \bar{y}_i)$$

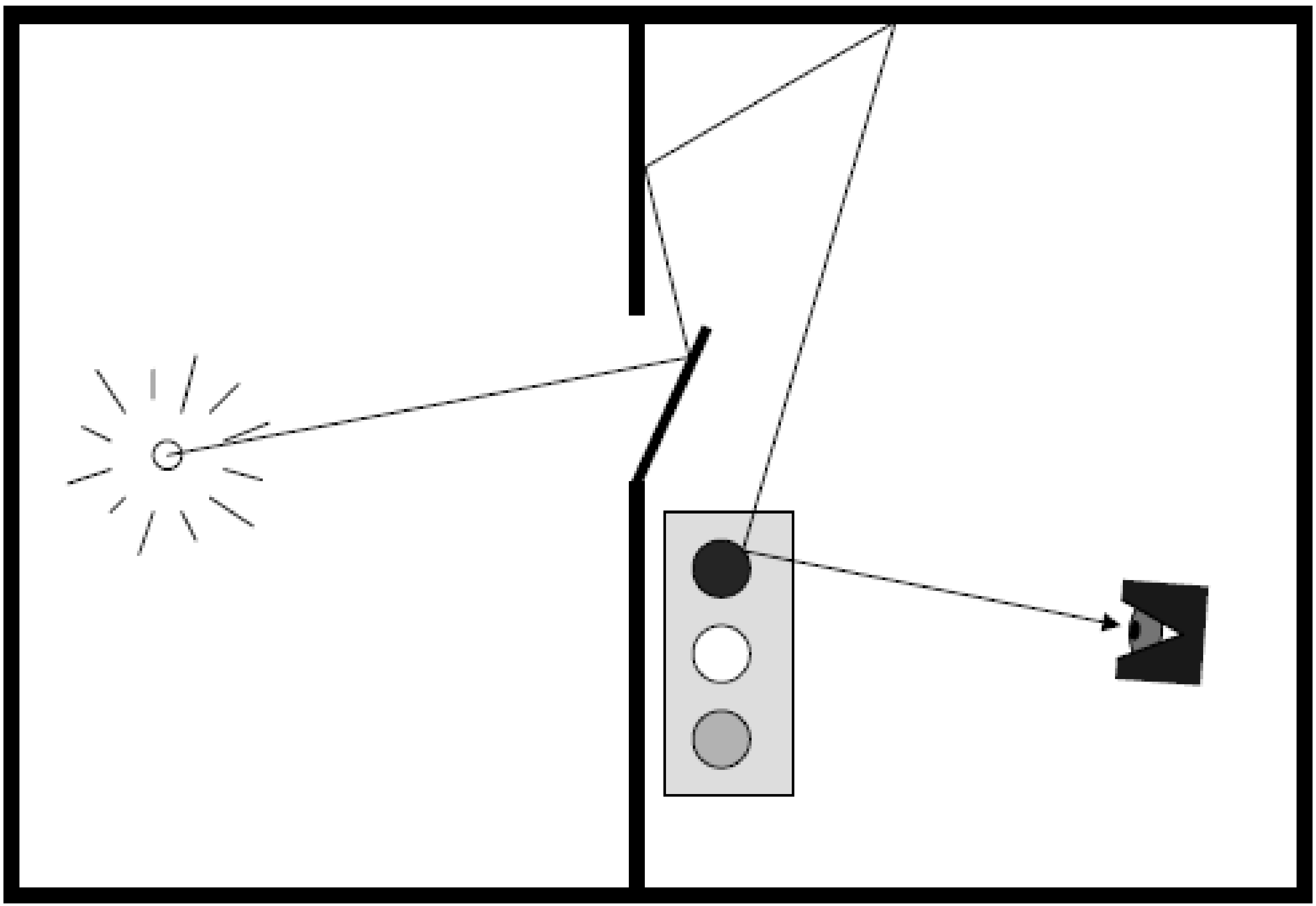
Bidirectional Path Tracing

- Or paths generated from both camera and source at the same time ...!

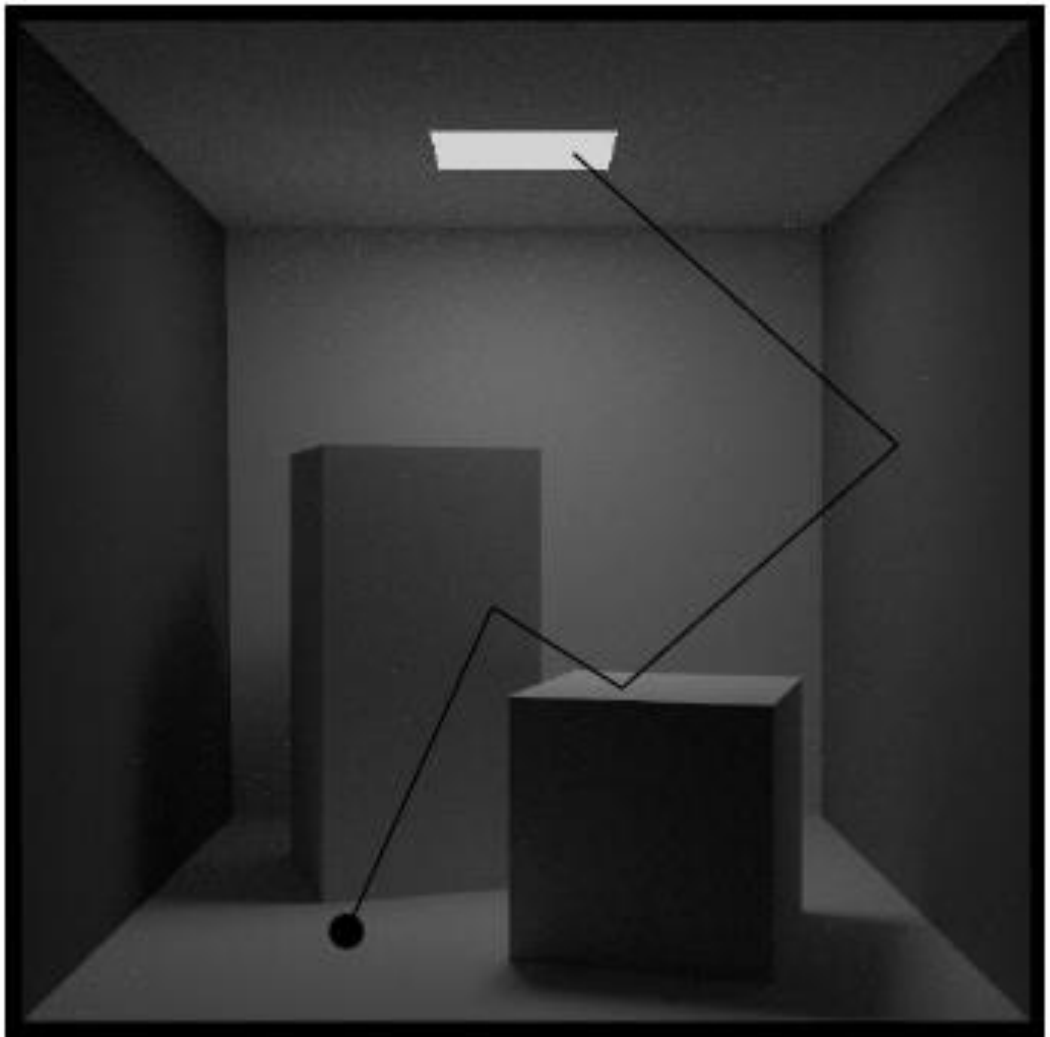


- Connect endpoints to compute final contribution

Metropolis

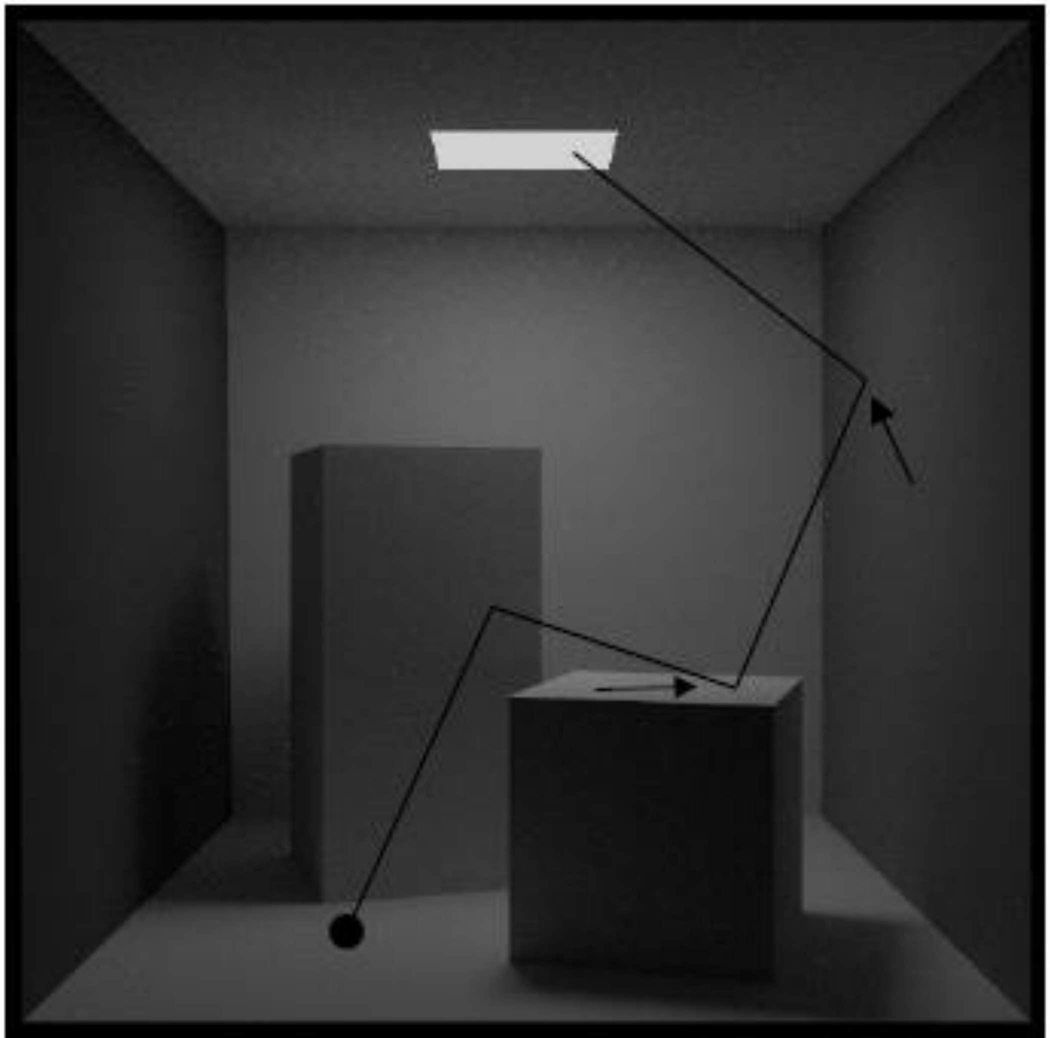


Metropolis



valid path

Metropolis



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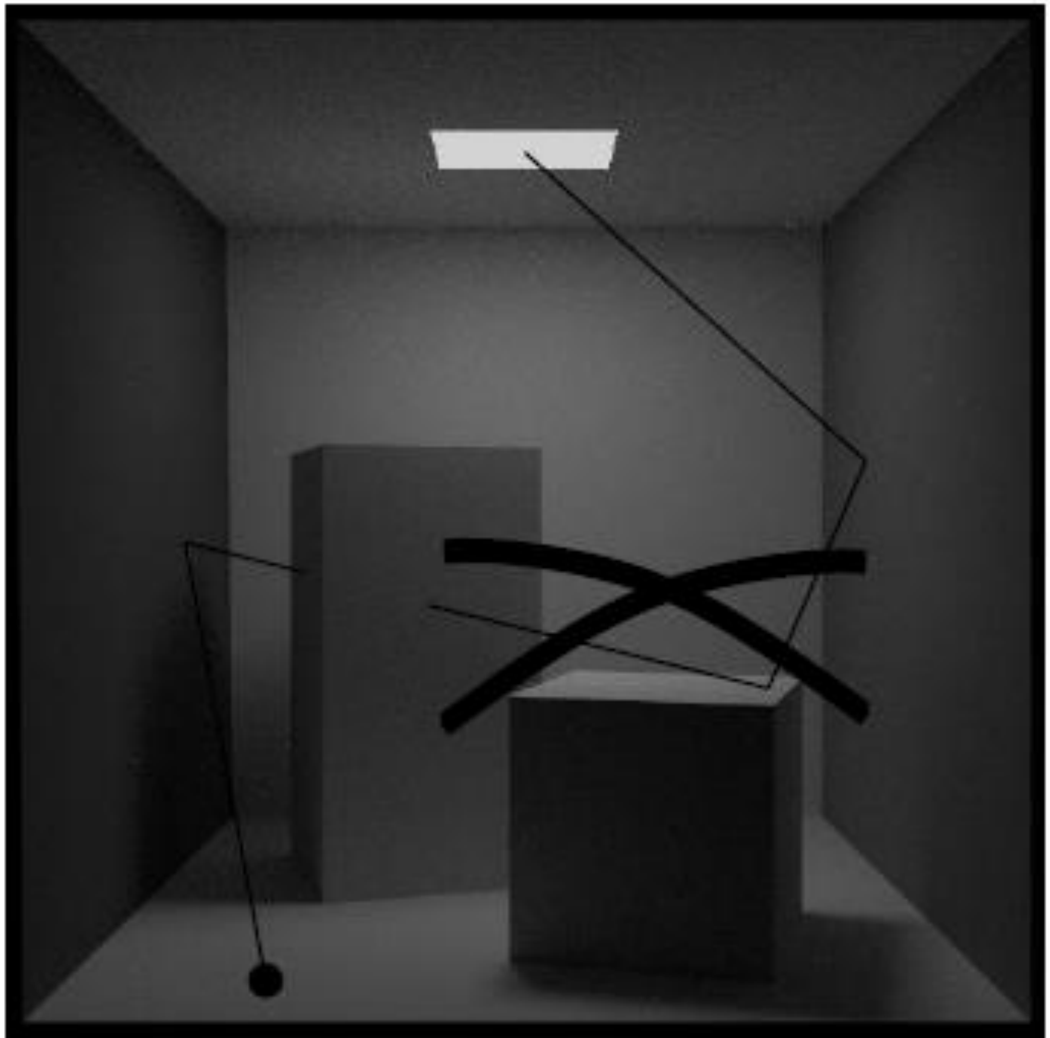
small
perturbations

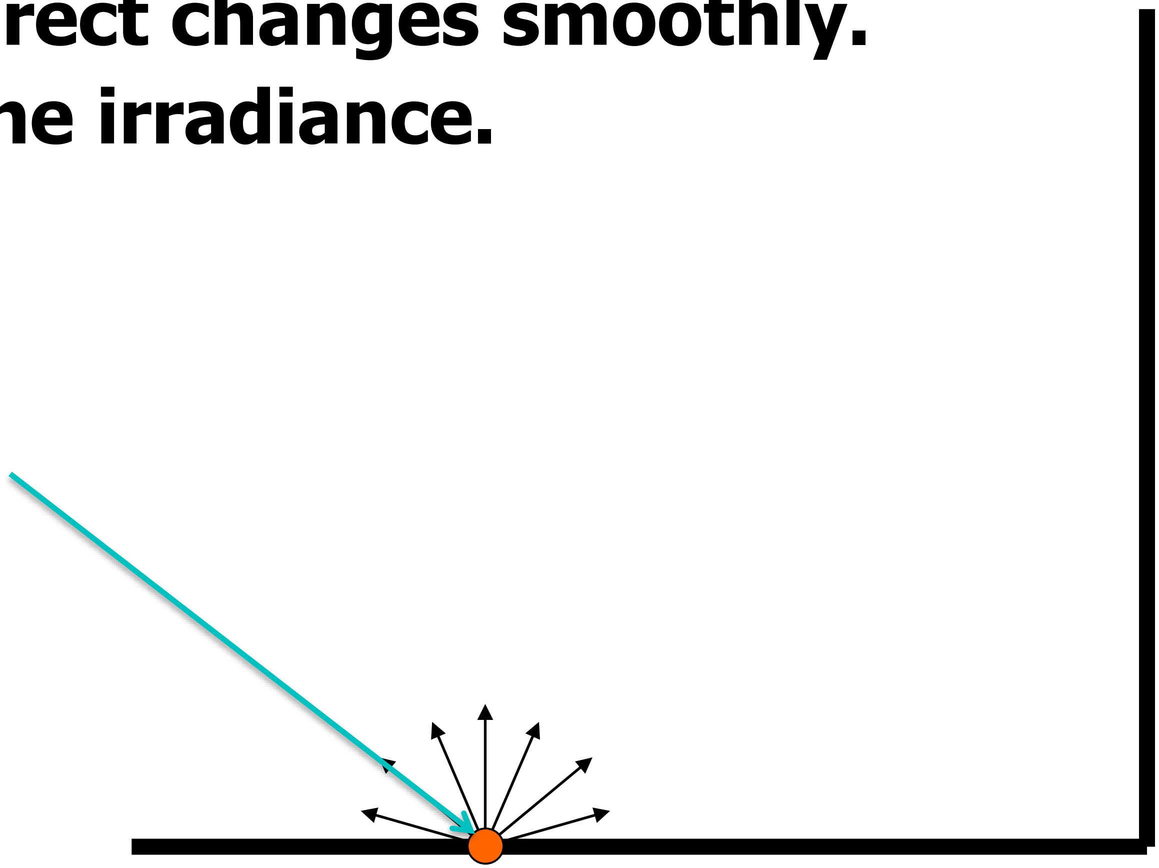
Metropolis



Accept mutations based on energy transport

Biased Methods: Irradiance Caching

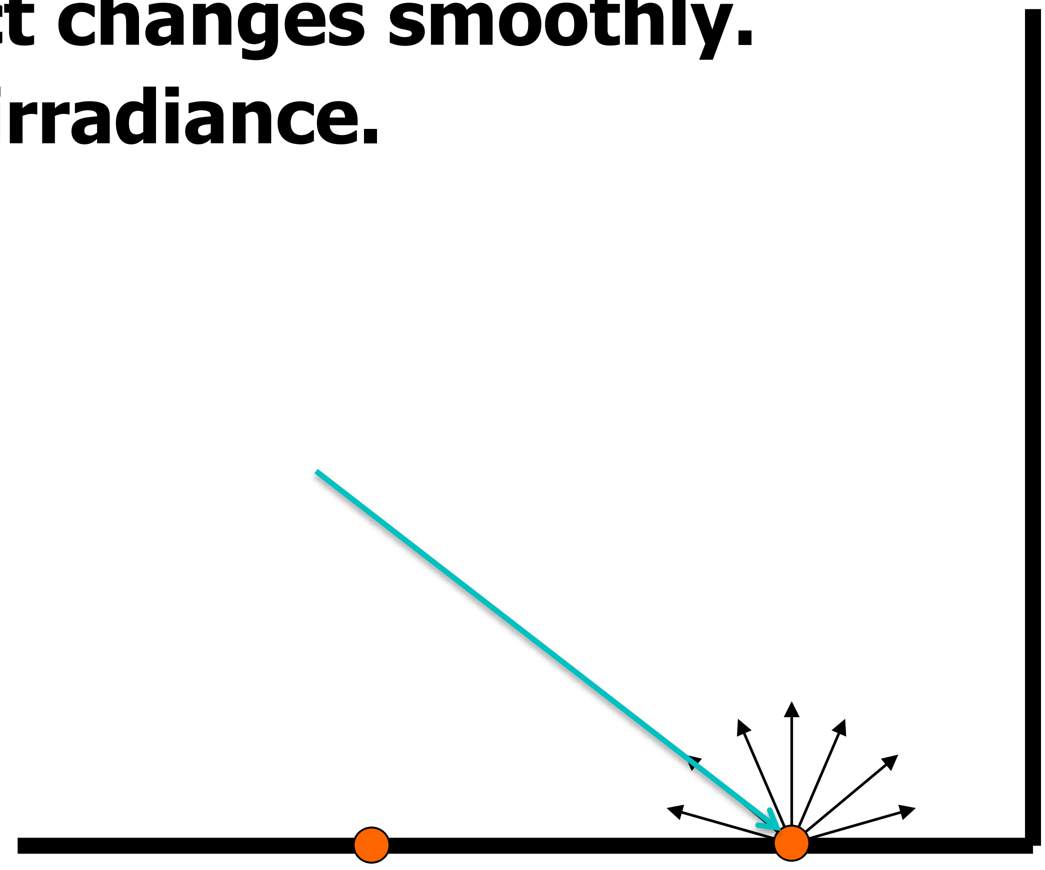
- **Indirect changes smoothly.**
- **Cache irradiance.**



From Wang's slides

Irradiance Caching

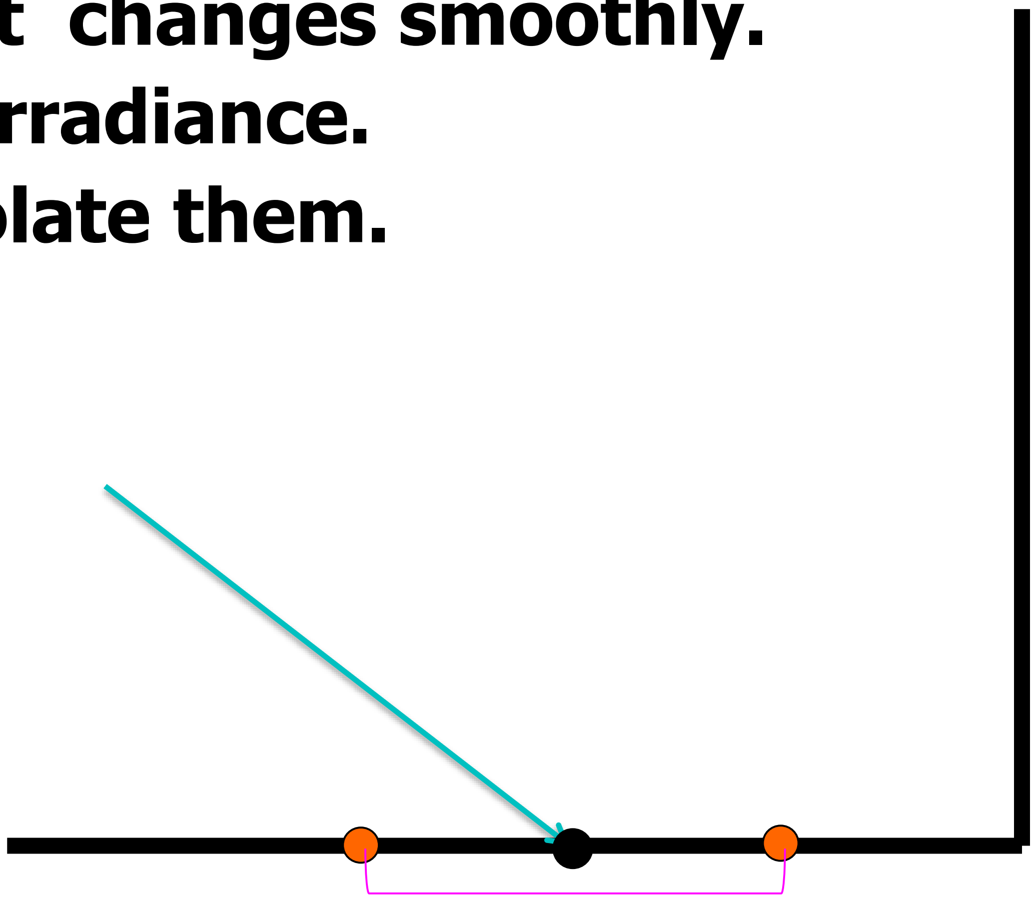
- Indirect changes smoothly.
- Cache irradiance.



From Wang's slides

Irradiance Caching

- Indirect changes smoothly.
- Cache irradiance.
- Interpolate them.

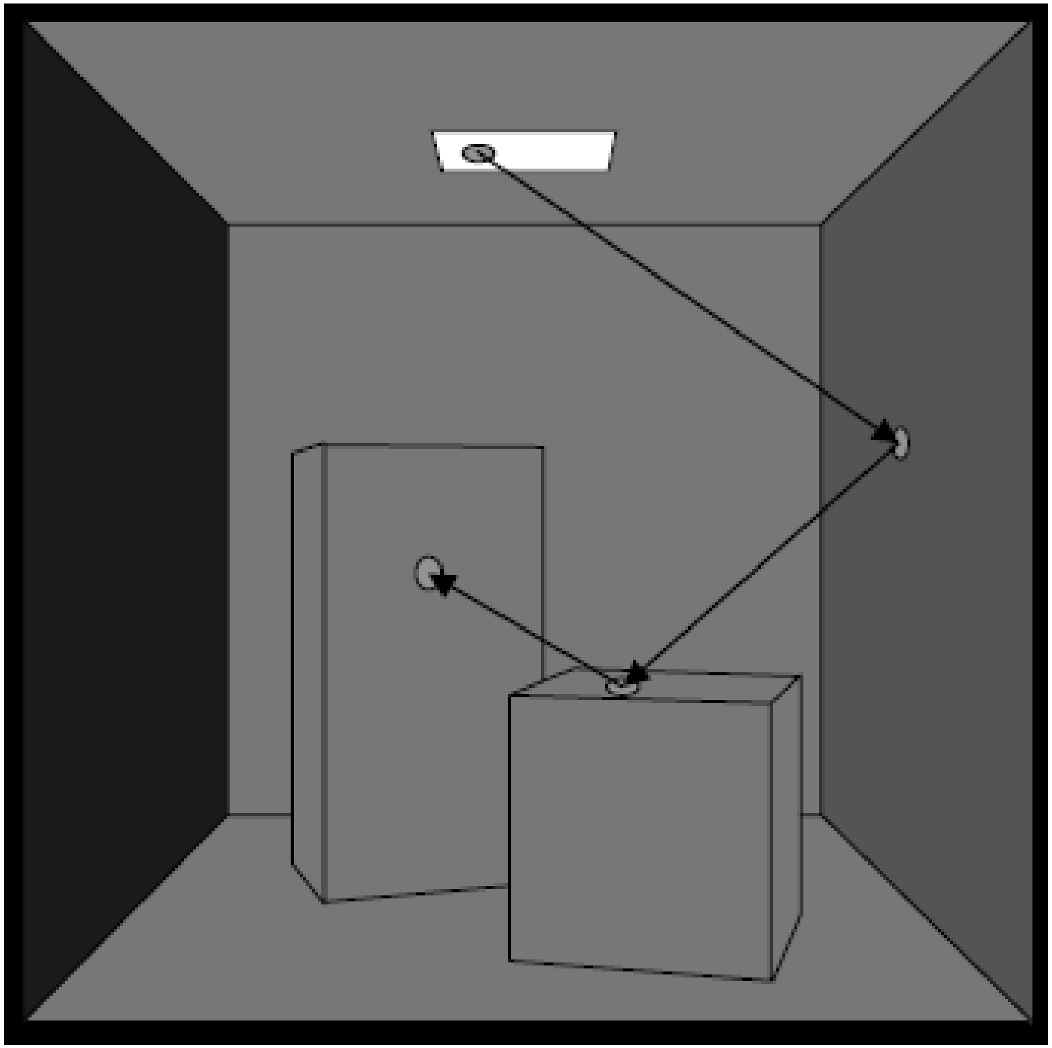


From Wang's slides

Biased Method: Photon Mapping

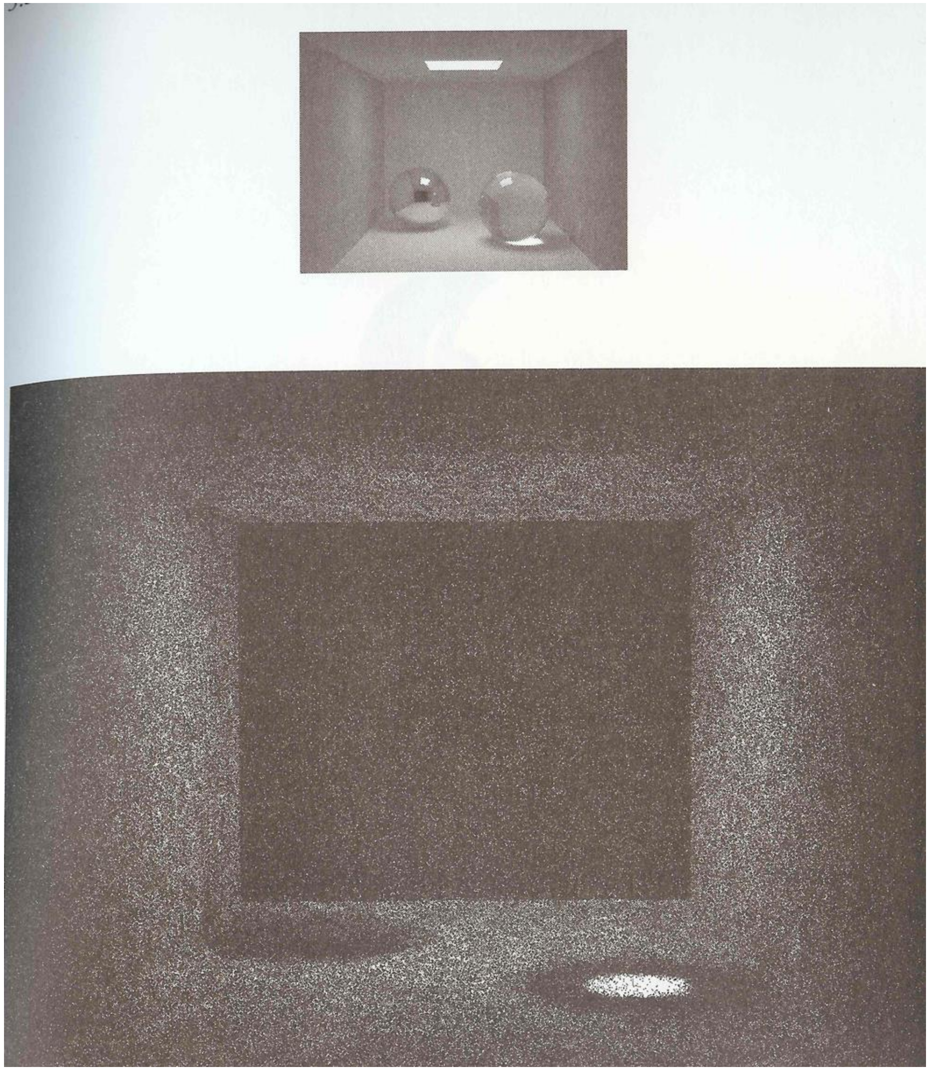
- 2 passes:
  - Shoot "photons" (light-rays) and record any hit-points
  - Shoot viewing rays and collect information from stored photons

Pass 1: shoot photons



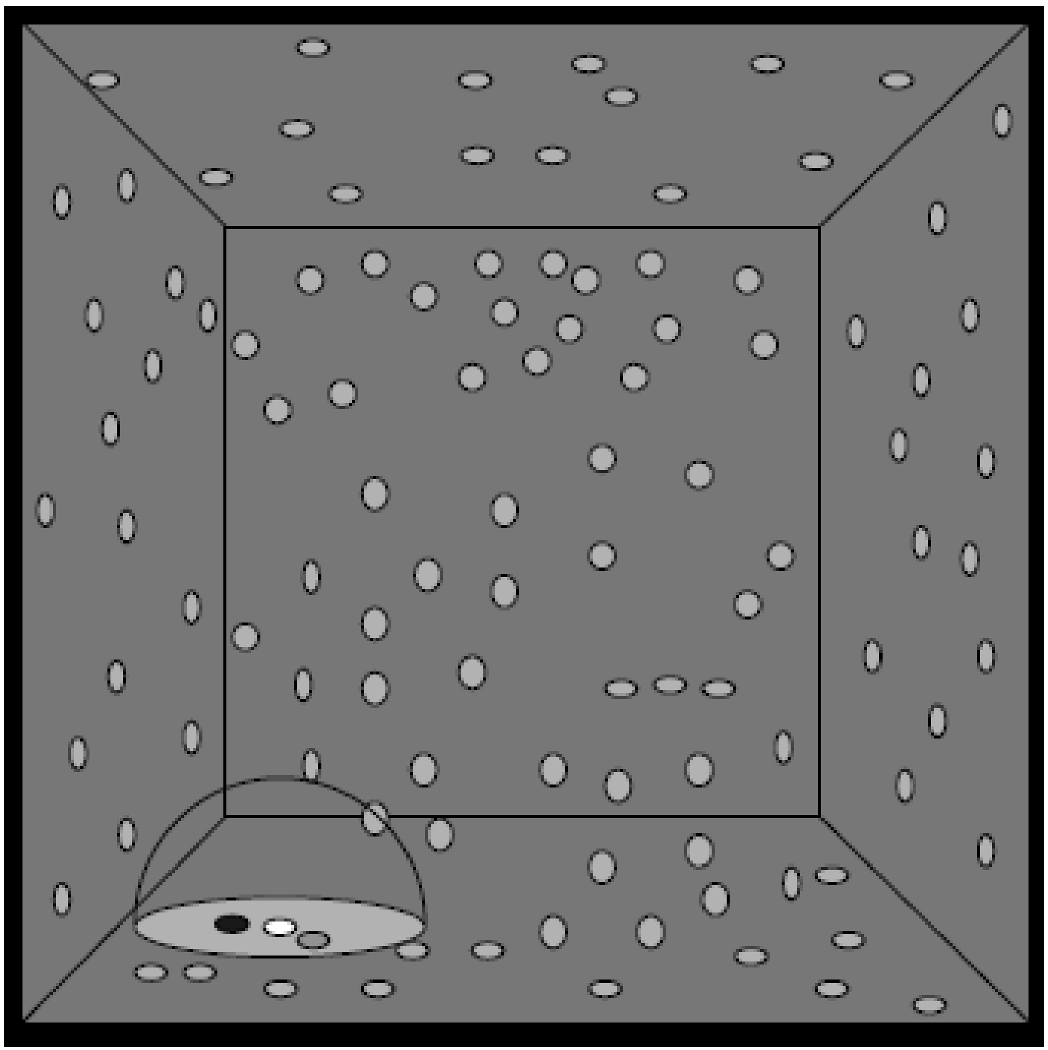
- Light path generated using MC techniques and Russian Roulette
- Store:
  - position
  - incoming direction
  - color
  - ...

Stored Photons



Generate a few hundreds of thousands of photons

Pass 2: viewing ray



- Search for N closest photons (+check normal)
- Assume these photons hit the point we're interested in
- Compute average radiance

Result

350K photons for the caustic map

Result

350K photons for the caustic map

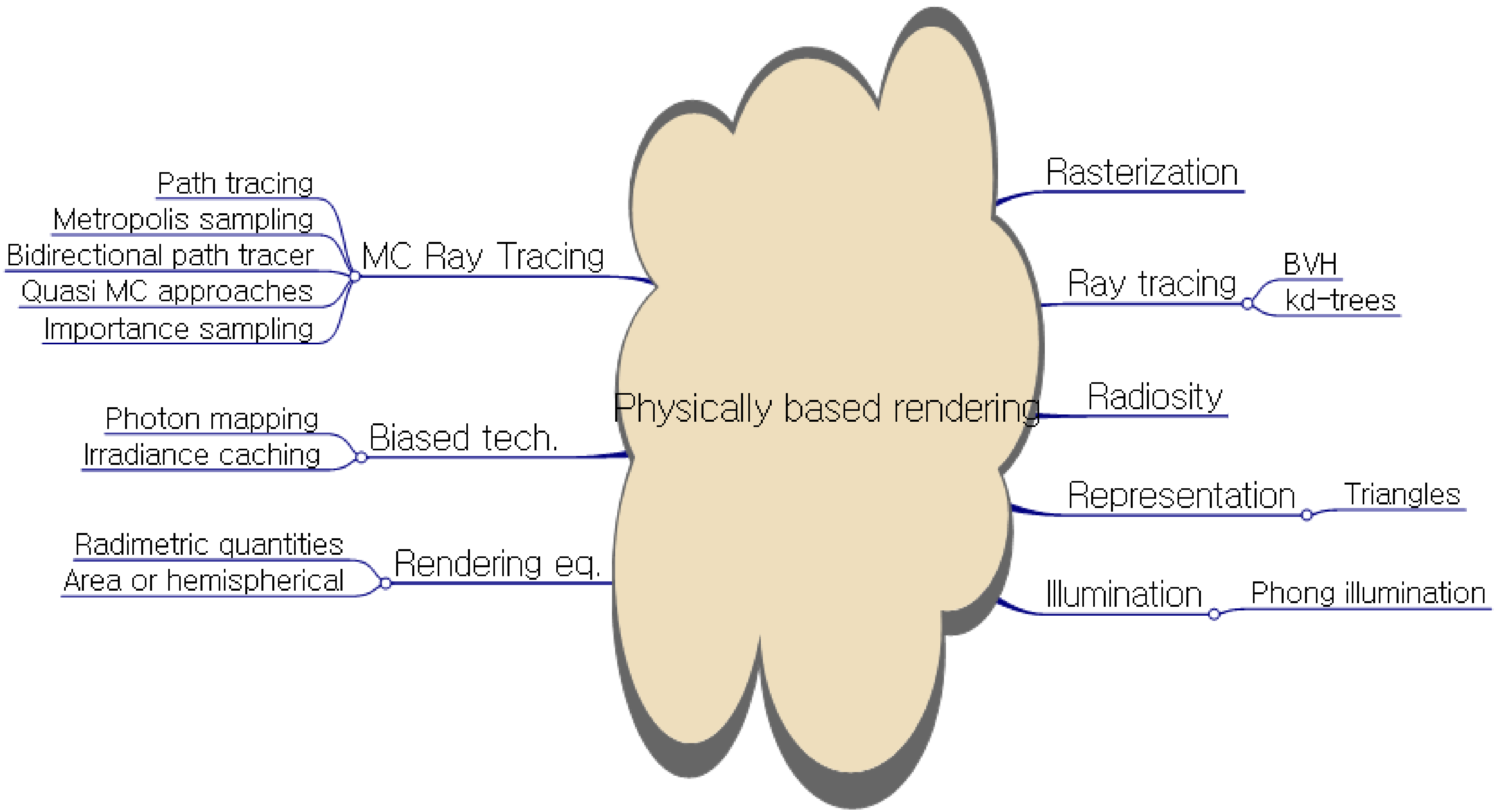
Class Objectives were:

- **Discuss acceleration methods for GI**
  - **Importance sampling, bidirectional path tracing, and metropolis**
- **Study biased techniques**
  - **Irradiance caching and photon mapping**

Summary

- Two basic building blocks
  - Rasterization (undergraduate CG)
  - Ray tracing
- Radiometry
- Rendering equation
- MC integration
- MC ray tracing
  - Unbiased methods
  - Biased methods

Summary


Path tracing
Metropolis sampling
Bidirectional path tracer
Quasi MC approaches
Importance sampling
MC Ray Tracing
Photon mapping
Irradiance caching
Biased tech.
Radimetric quantities
Area or hemispherical
Rendering eq.
Physically based rendering
Rasterization
Ray tracing
BVH
kd-trees
Radiosity
Representation
Triangles
Illumination
Phong illumination

Next Time…

- **Recent techniques**

Homework

- **Go over the next lecture slides before the class**
- **Watch 2 SIG/CVPR/ISMAR videos and submit your summaries every Mon. class**
  - **Just one paragraph for each summary**
  - **Any top-tier conf (e.g., ICRA) is okay**

Example:

Title: XXX XXXX XXXX

Abstract: this video is about accelerating the performance of ray tracing. To achieve its goal, they design a new technique for reordering rays, since by doing so, they can improve the ray coherence and thus improve the overall performance.