



Light Transport for Participating Media

20193512 Joowon Lim (임주원)

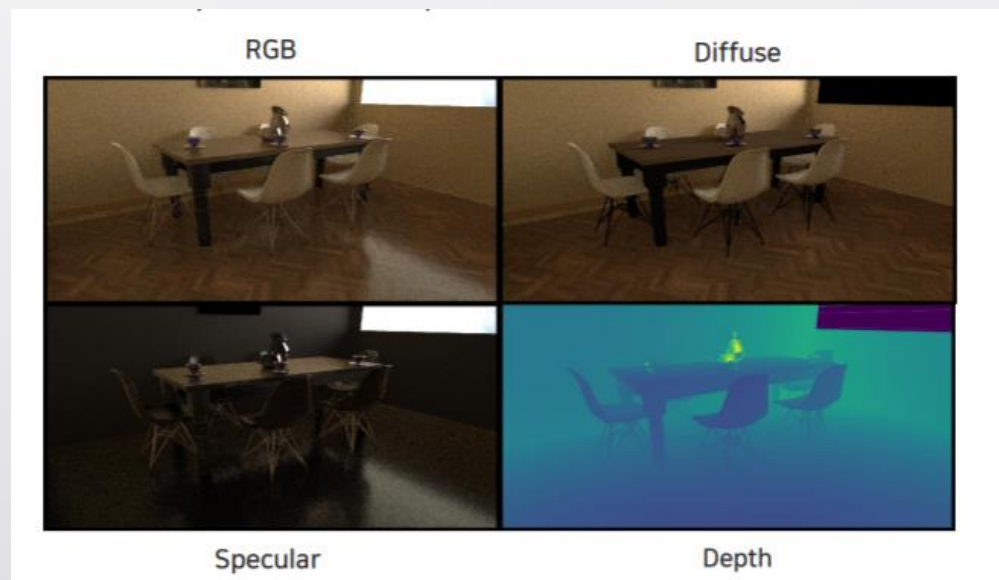
CS580 Computer graphics 2019 Spring

Review – Denoising (by Lee CheolMin)

Adaptive polynomial rendering



Kernel-predicting convolutional network



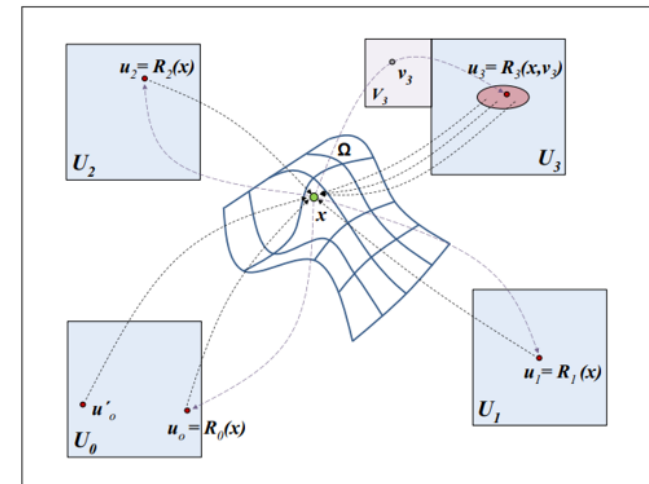
Review – MLP using inverse mapping (by Park Juho)

Reversible Jump MTL using
inverse mapping

- (1) Choose a proposal technique j with probability $w_j(S_i(\bar{\mathbf{u}}))$
- (2) Jump to proposal state $\hat{\mathbf{v}} = (j, S_j^{-1}(S_i(\bar{\mathbf{u}})))$
- (3) Always accept $\hat{\mathbf{v}}$

Charted Metropolis light transport

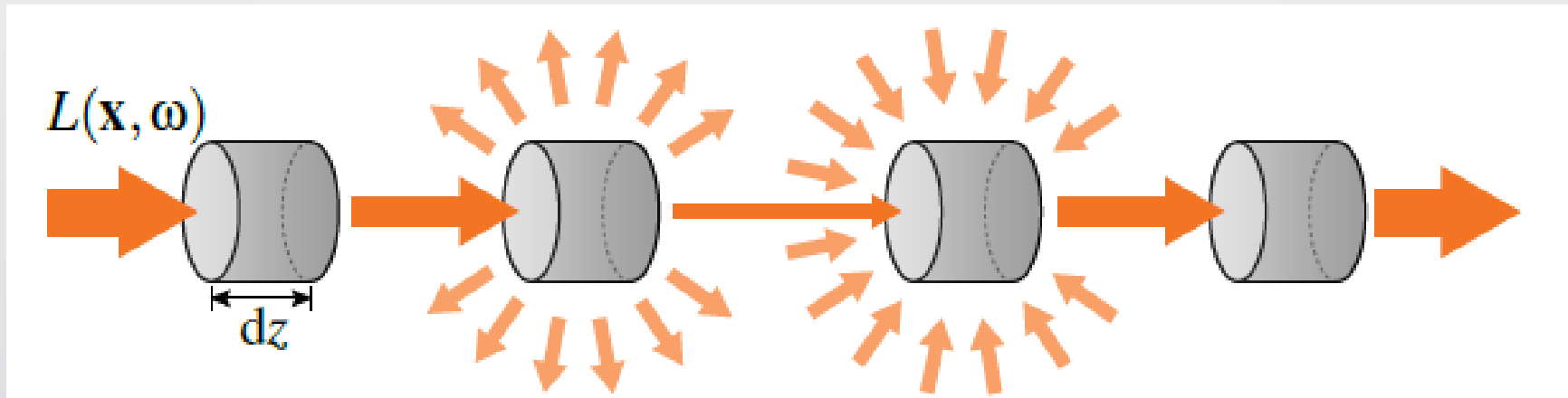
- Allow *swap* bidirectional sampling techniques
- Unlike RJMLT, path sampling function **need not be invertible**
- Get out of local maxima to other sampling techniques



Participate media

Participate media

- Participating media is a material that absorb, emit and/or scatter light.
- It includes cloud, smoke, liquid etc.



(a) Absorption (b) Out-scattering (c) In scattering (d) Emission



Participate media

- Point based light transport method
- Beyond the point: light beam, light plane, light volume

**Point-based light transport for
Participate media
with refractive boundaries**

Point-based Light Transport for Participating Media with Refractive Boundaries

- Participate media with refractive boundaries.
 - Inside : absorption, scattering
 - Surface : refracting
- Idea is to apply **PBGI** to participate media.





Point Based Global Illumination(PBGI)

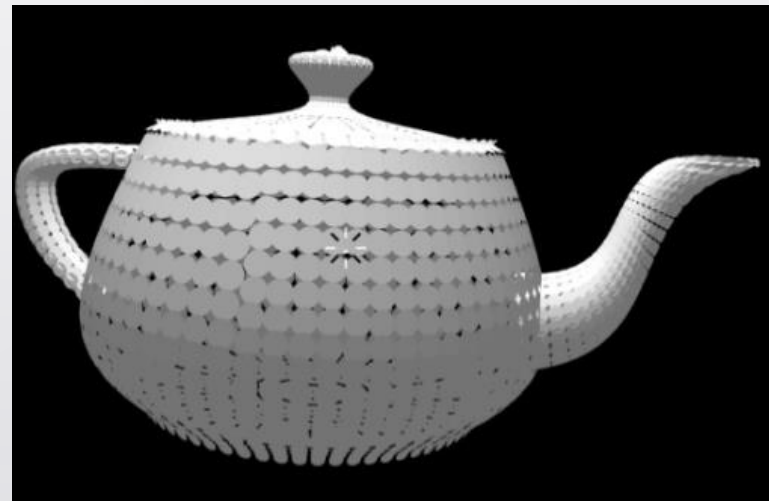
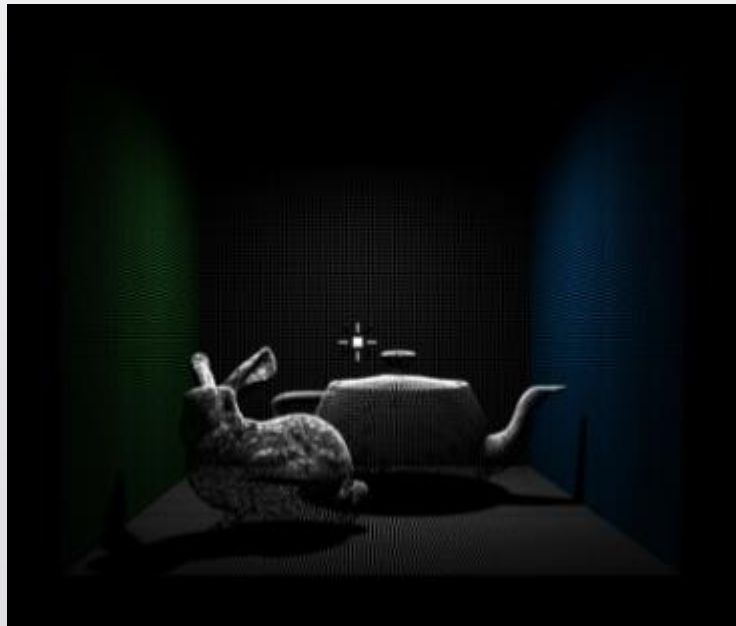
- A two step rendering algorithm to calculate the **indirect lighting** in a diffuse scene.

Step 1. Generate a diffuse **pointcloud** from the scene.

Step 2. Calculates the global illumination.

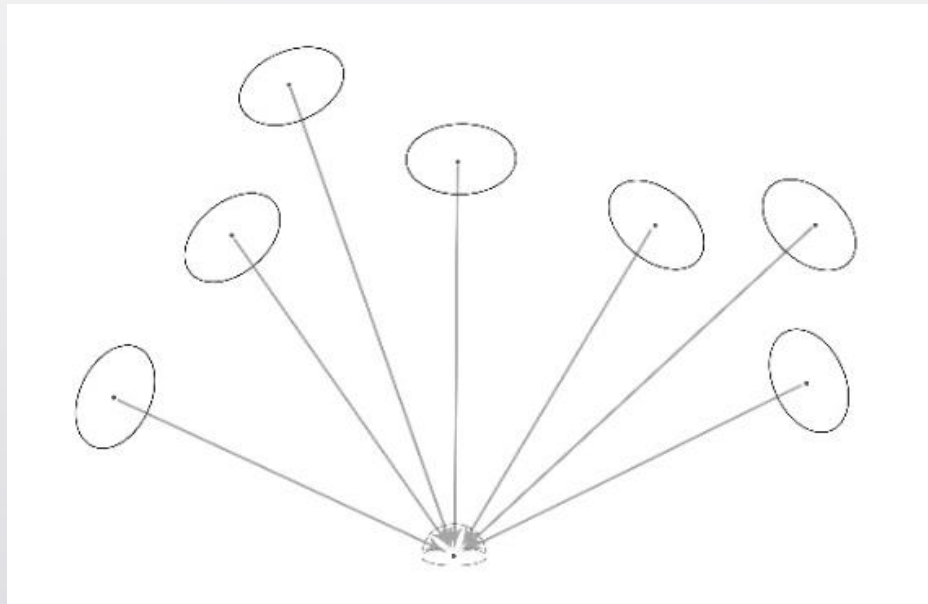
Point Based Global Illumination(PBGI)

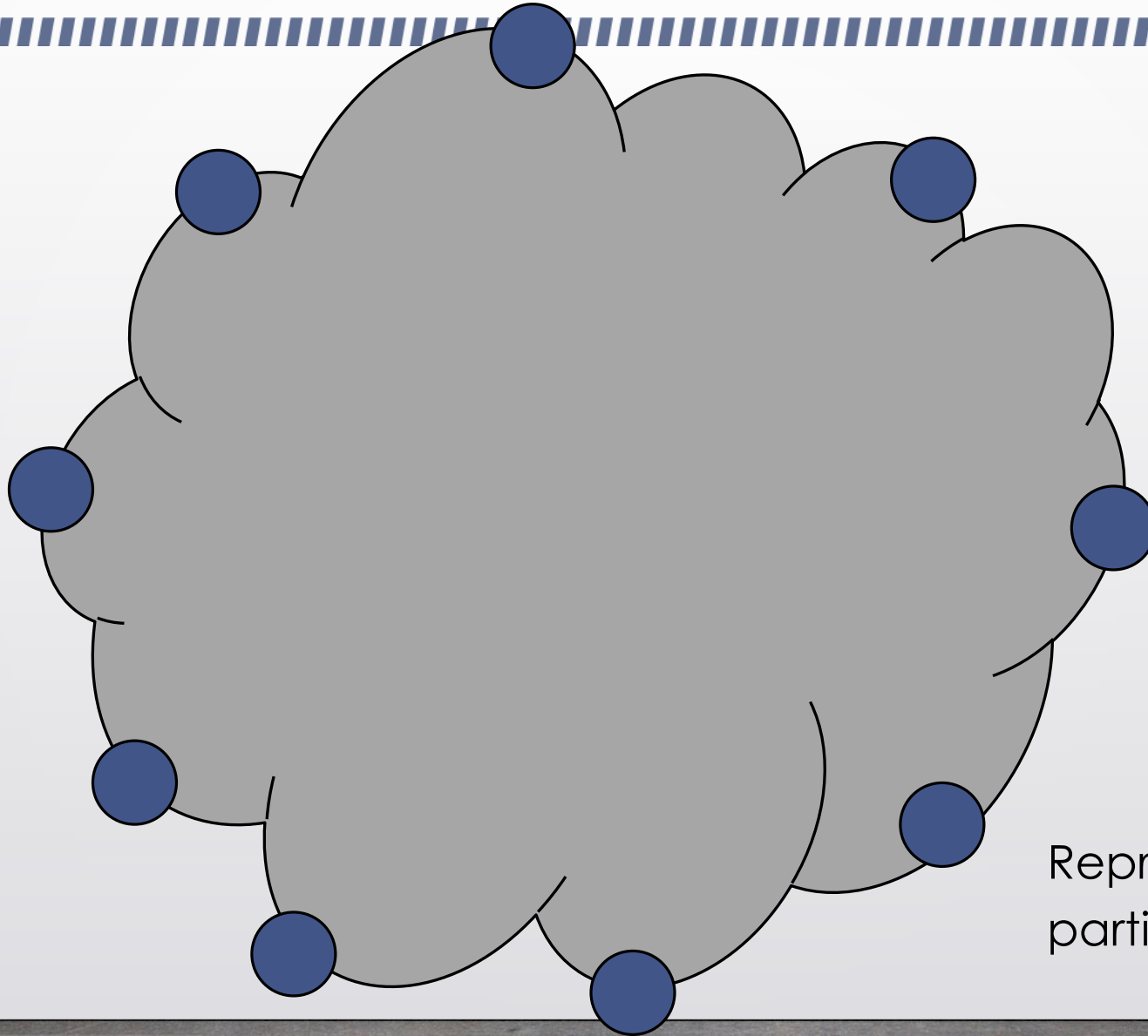
- Diffuse pointcloud is a point-base representation of the reflected direct light(indirect light source) in the scene. Use 'surfel'.



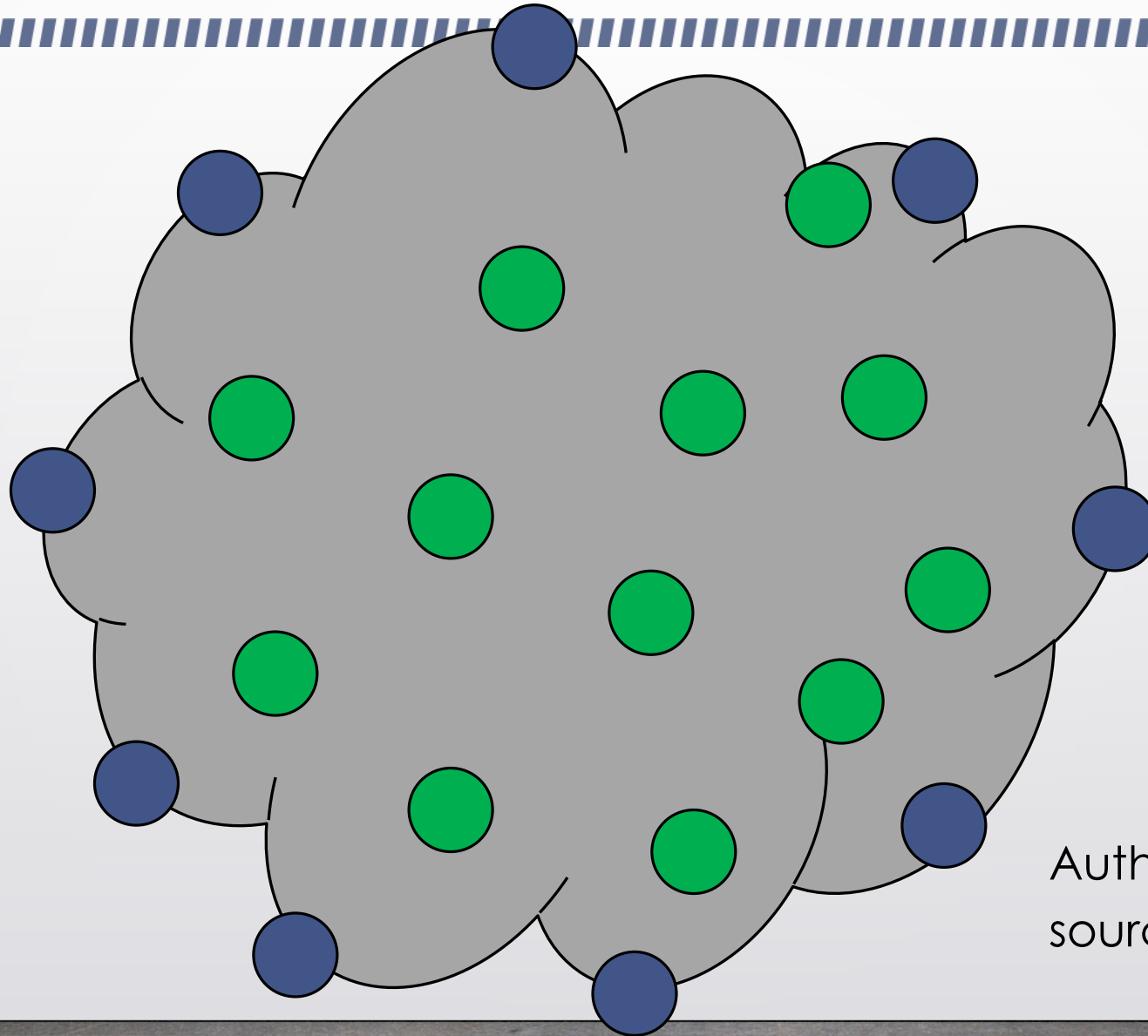
Point Based Global Illumination(PBGI)

- The incoming indirect lighting of a certain point can be generated by projecting all the individual surfels on the hemisphere of that point.





Representation of surfels in
participate media.



Author add volume light source inside the media.



Physical phenomena of the target is divided into four part

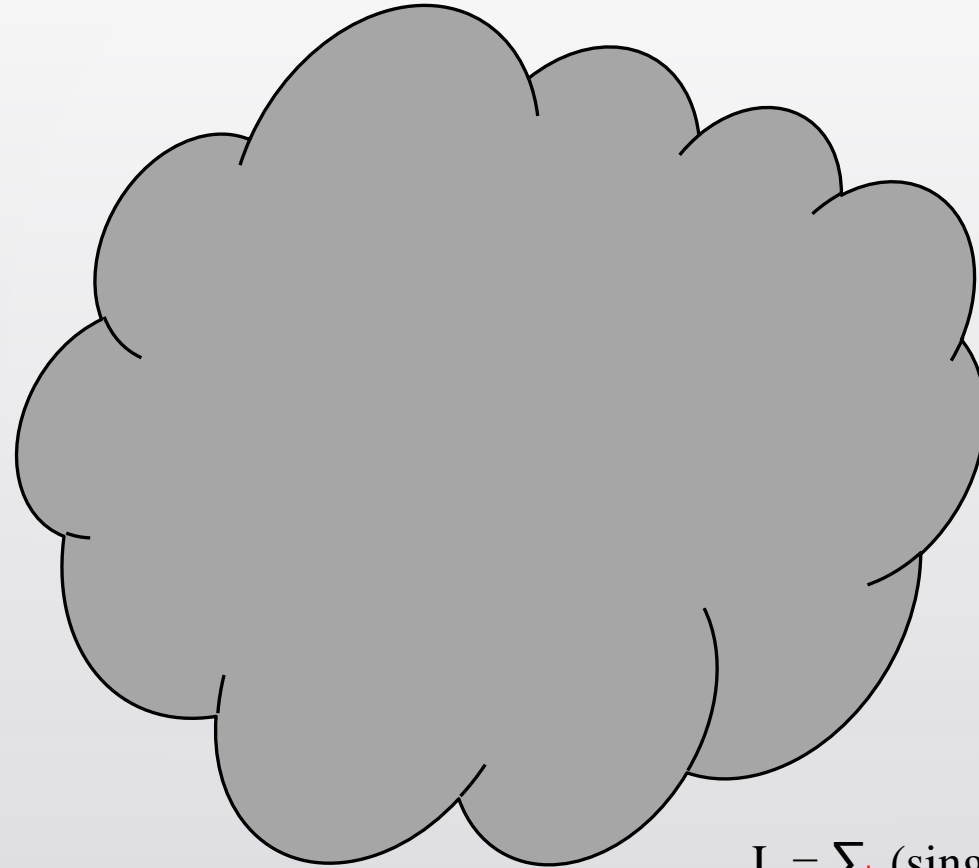
1. Boundary refraction
2. Single scattering
 - For representing light caustic
3. Double scattering
 - Not mentioned explicitly, but for more realistic rendering
4. Multiple scattering
 - For representing material property

$$L = \sum_k (\text{single } (P_k) + \text{double } (P_k) + \text{mult. } (P_k) + \text{bounced } (P_k))$$

where P_k indicates k^{th} ray sample.



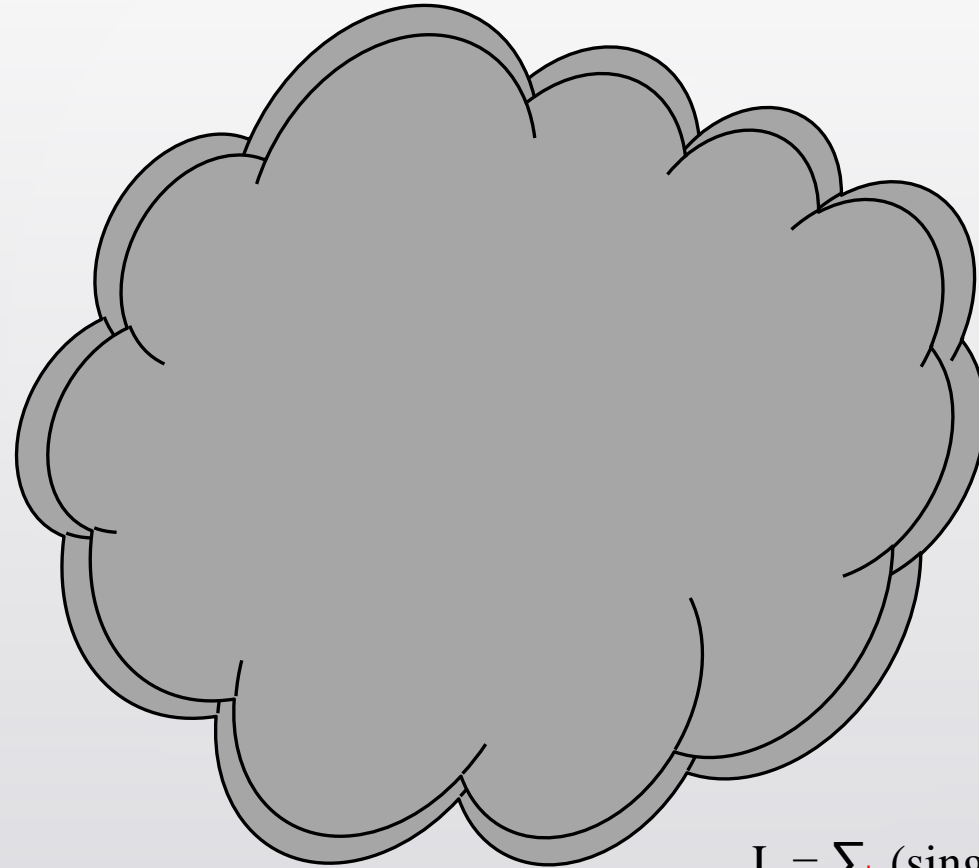
1. Boundary reflection



$$L = \sum_k (\text{single } (P_k) + \text{double } (P_k) + \text{mult. } (P_k) + \text{bounced } (P_k))$$



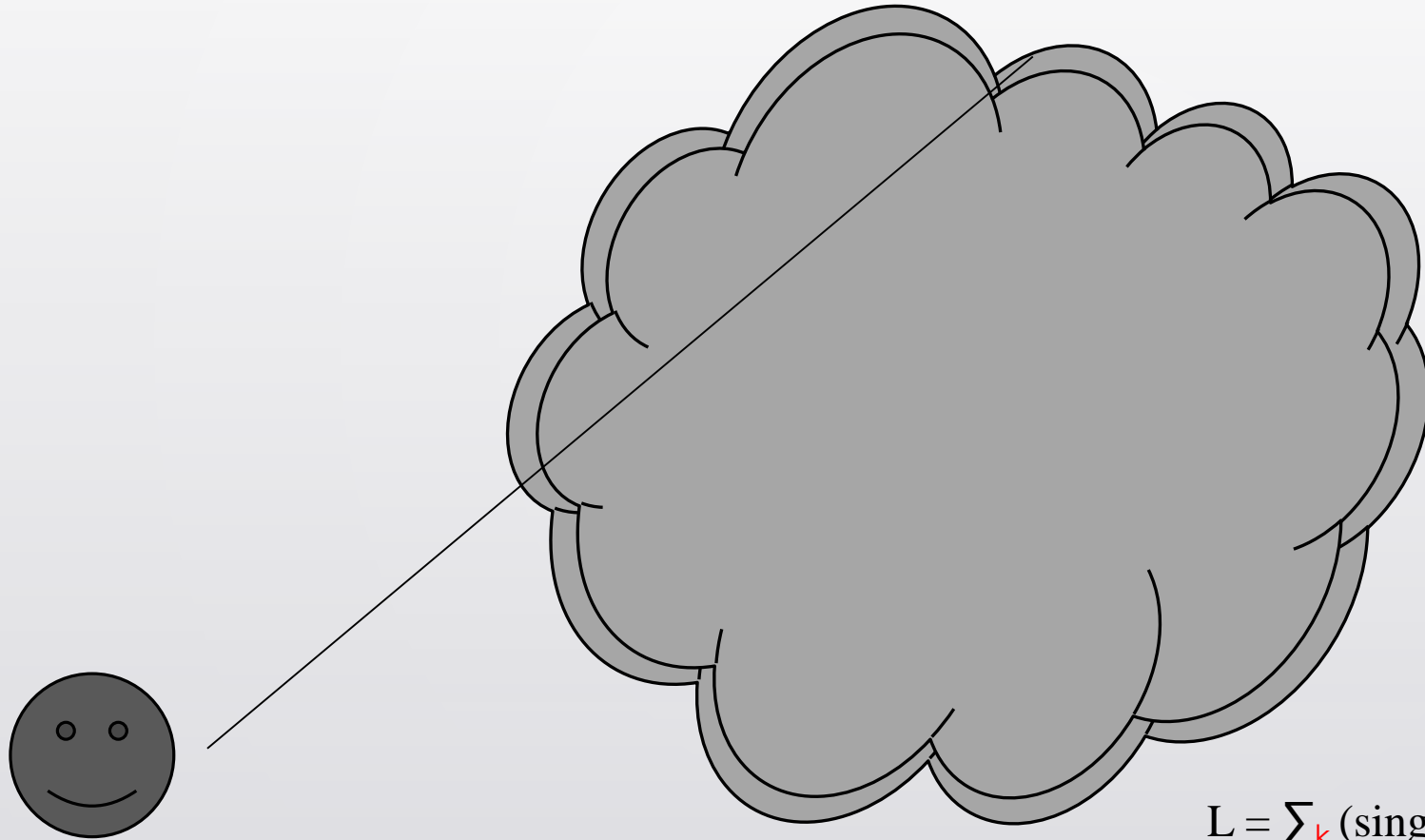
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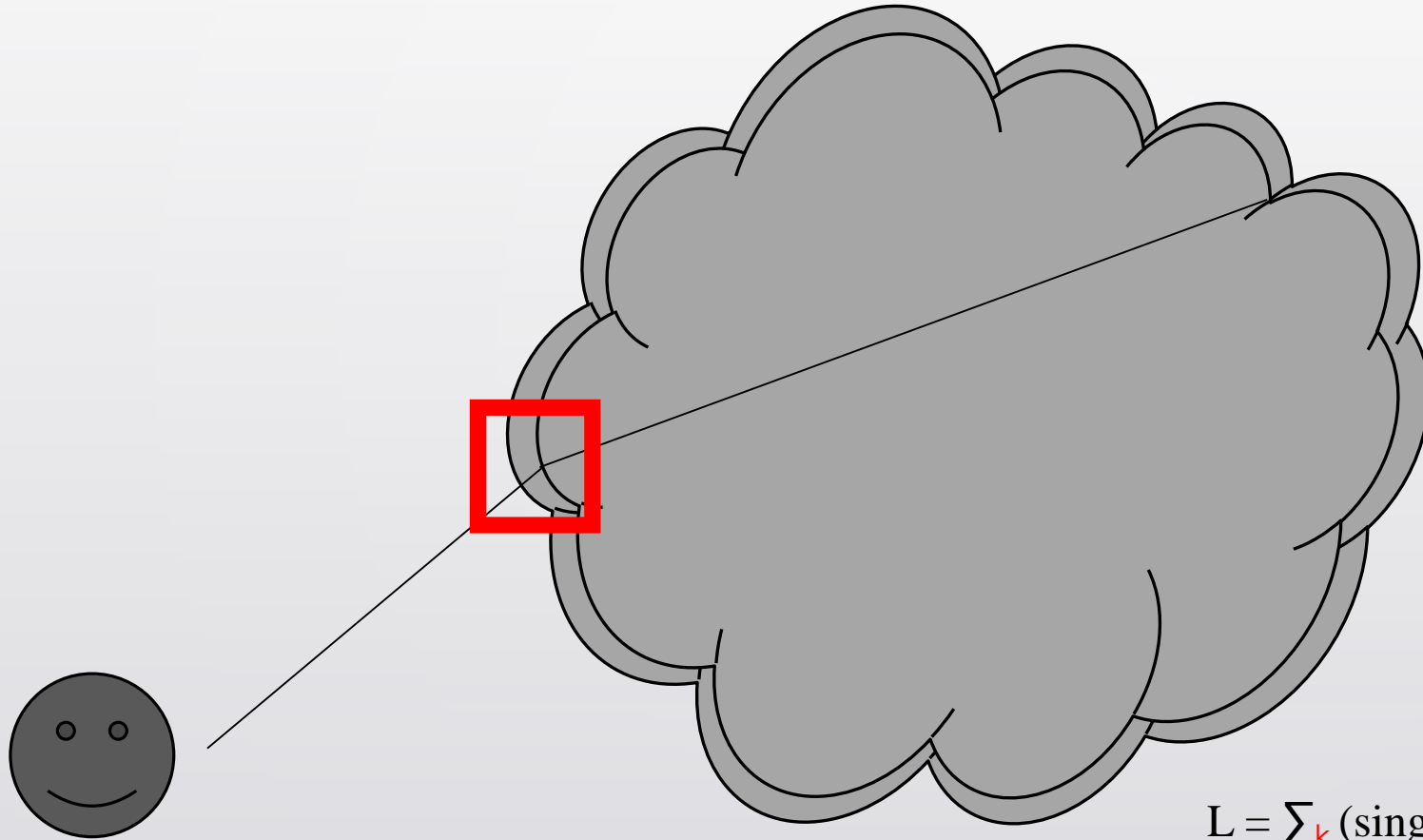
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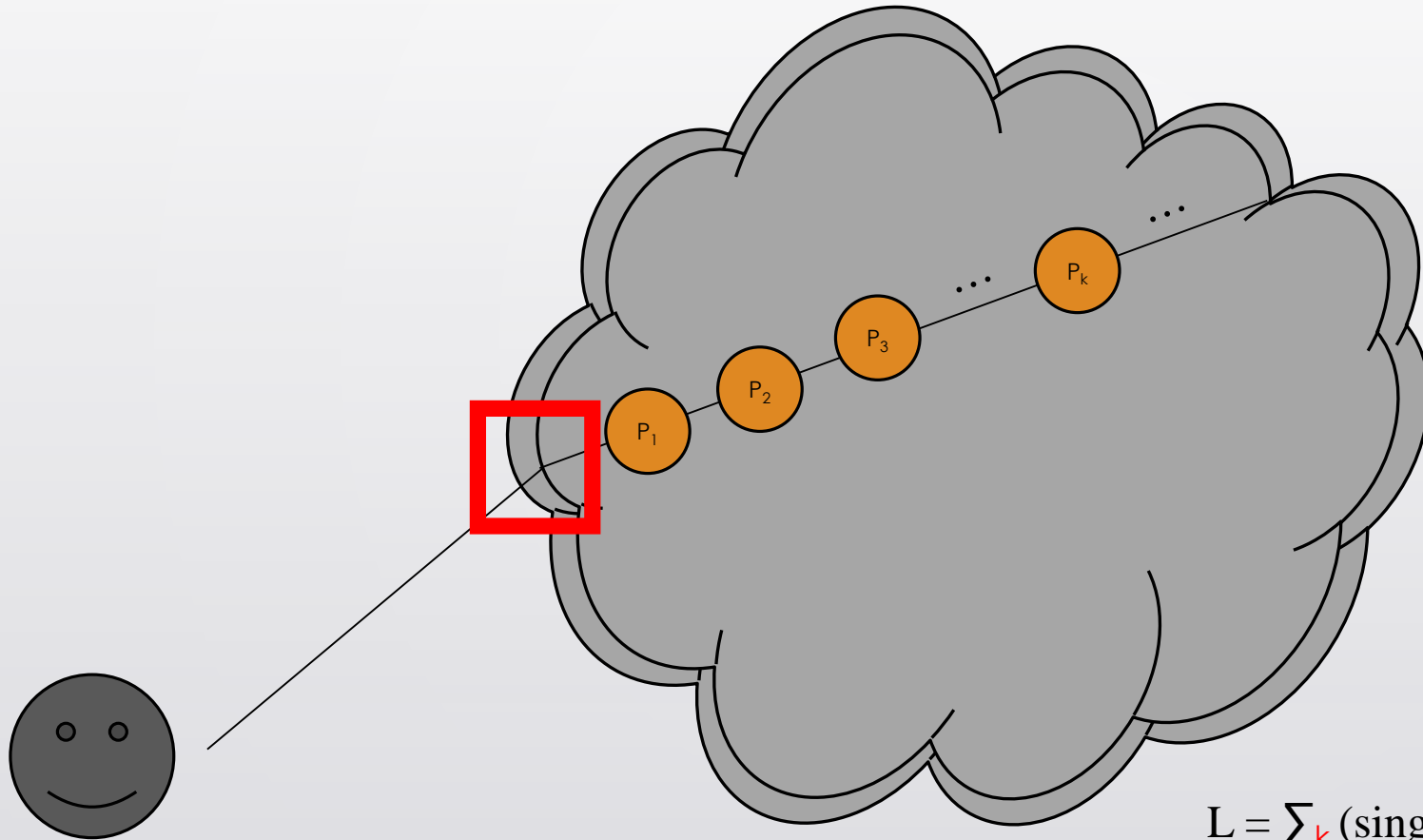


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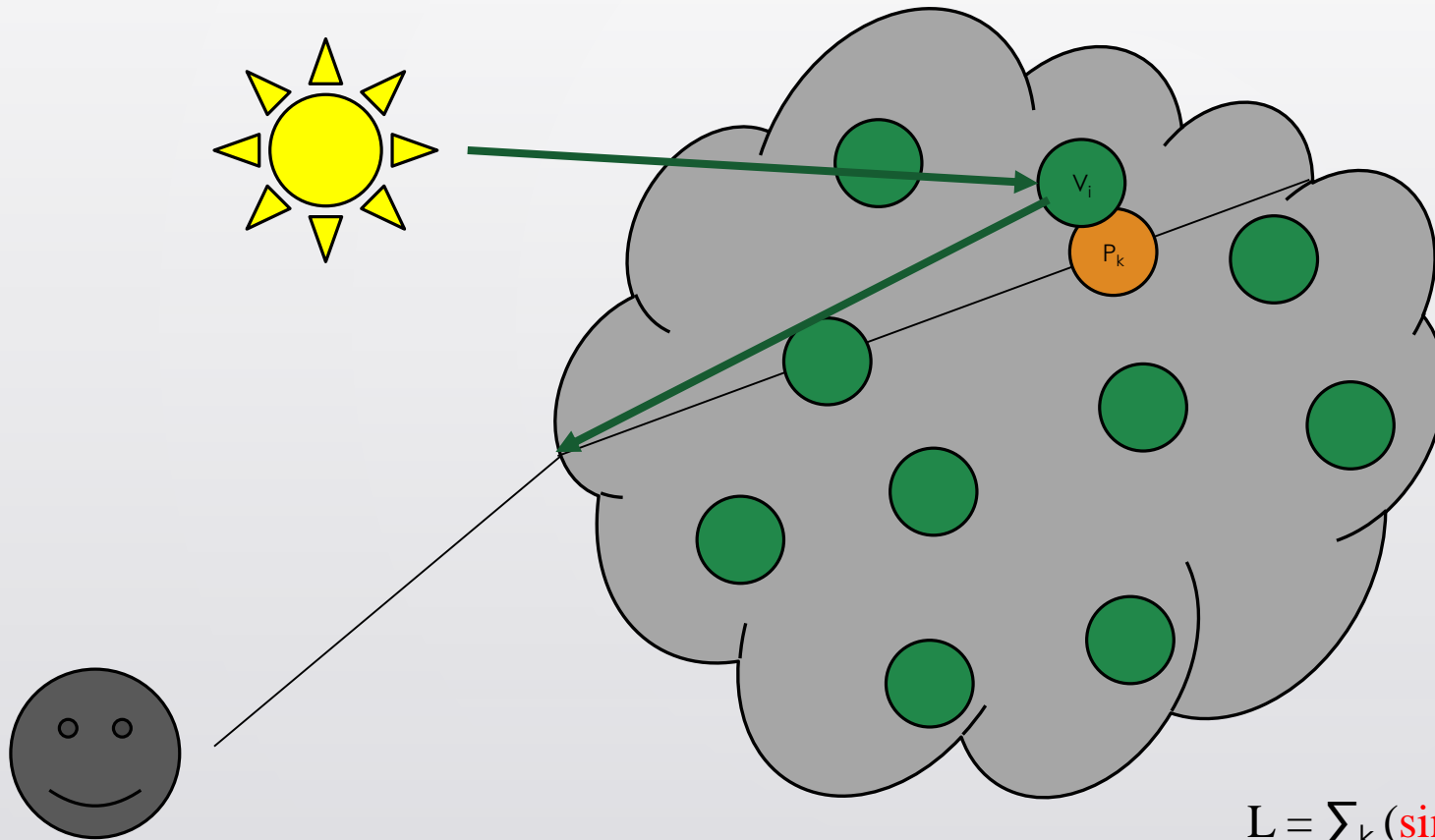
1. Boundary reflection



P_k is ray samples

$$L = \sum_k (\text{single } (P_k) + \text{double } (P_k) + \text{mult. } (P_k) + \text{bounced } (P_k))$$

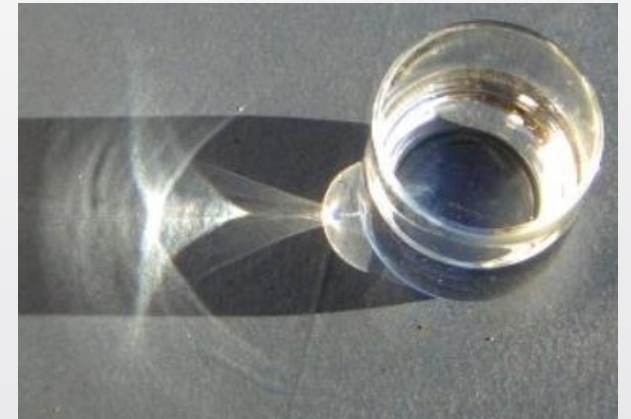
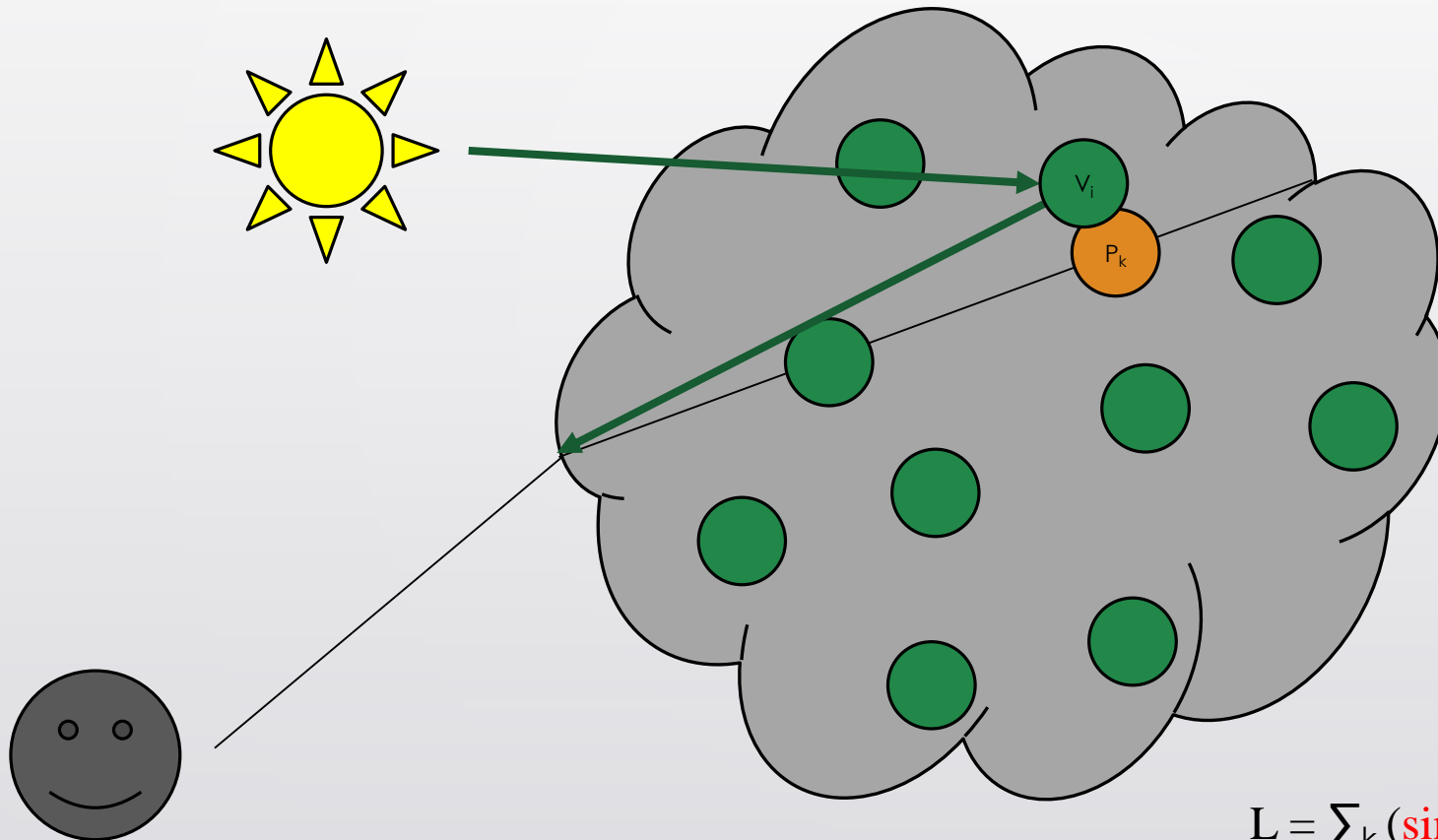
2. Single scattering



For each ray sample, out-scattering radiance of volume sample that includes the ray sample is sum up.

$$L = \sum_k (\text{single } (P_k) + \text{double } (P_k) + \text{mult. } (P_k) + \text{bounced } (P_k))$$

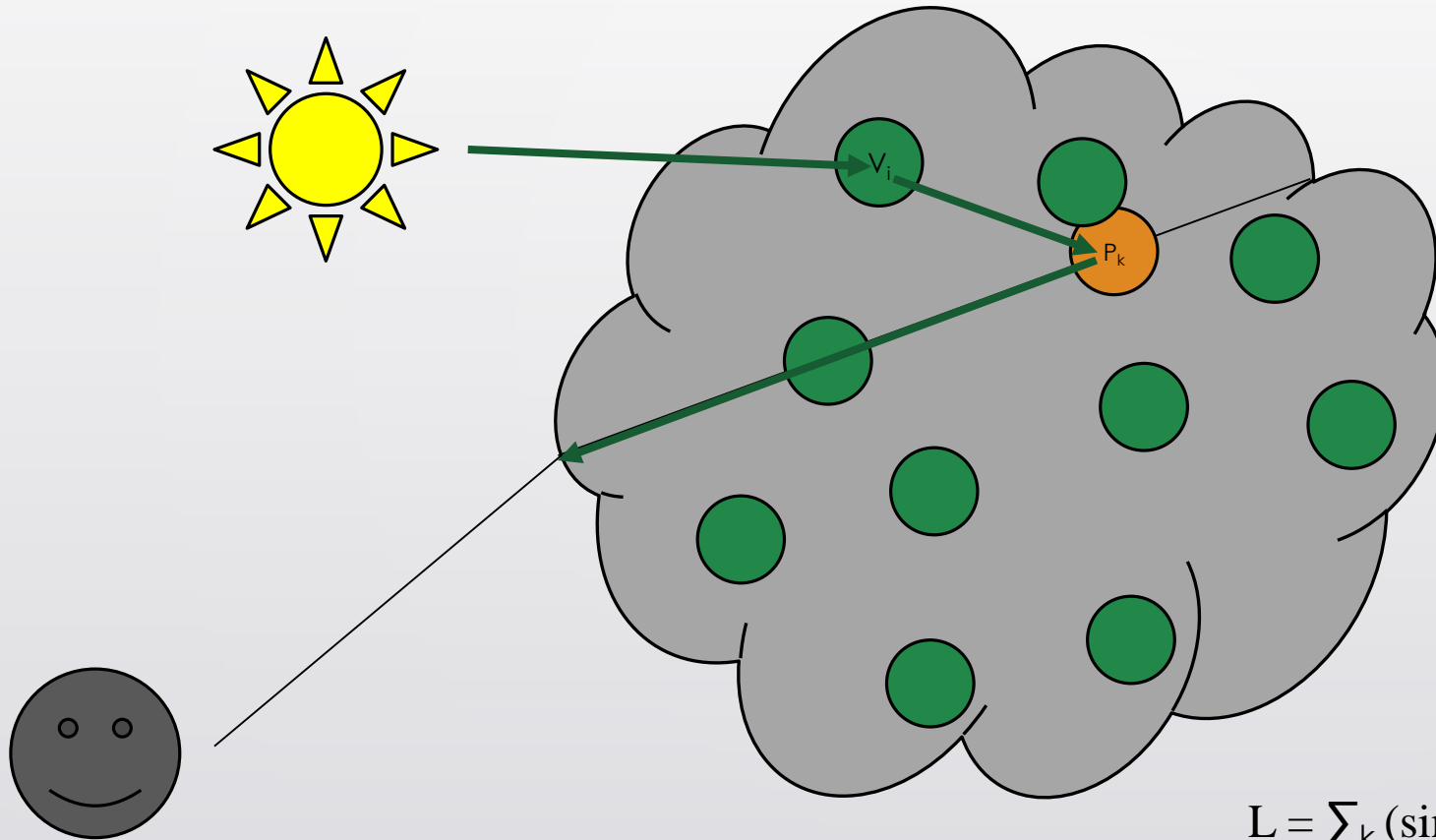
2. Single scattering



Caustic : light pattern made by reflection and refraction

$$L = \sum_k (\text{single } (P_k) + \text{double } (P_k) + \text{mult. } (P_k) + \text{bounced } (P_k))$$

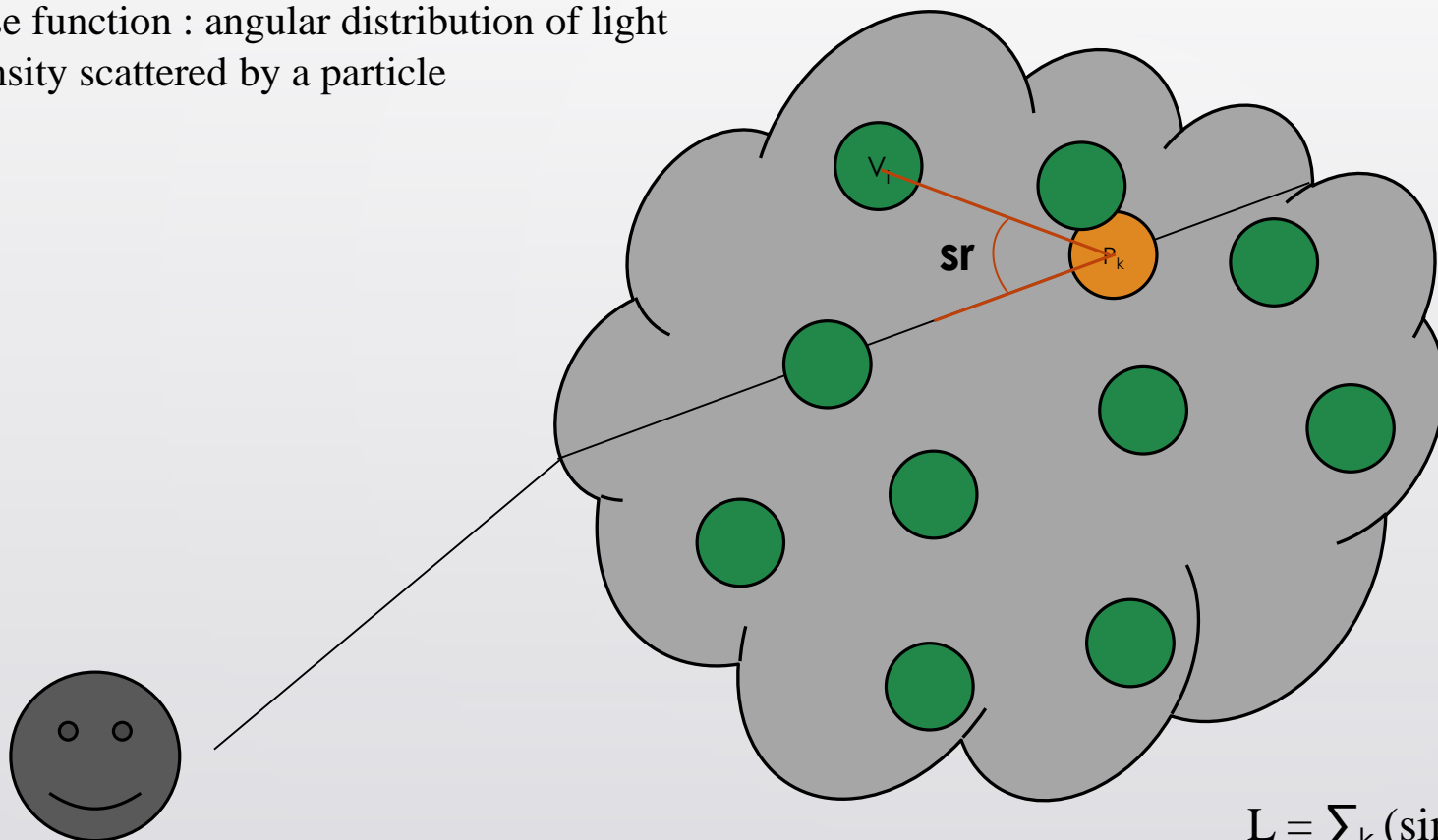
3. Double scattering



$$L = \sum_k (\text{single } (P_k) + \text{double } (P_k) + \text{mult. } (P_k) + \text{bounced } (P_k))$$

3. Double scattering

Phase function : angular distribution of light intensity scattered by a particle



For each ray sample, find volume samples that fits our criterion and add the radiance value of them.

Criterion : If it is possible for light path $V_i P_k$ to scatter into camera direction. Use solid angle sr and phase function* of light vector $V_i P_k$.

$$L = \sum_k (\text{single } (P_k) + \text{double } (P_k) + \text{mult. } (P_k) + \text{bounced } (P_k))$$

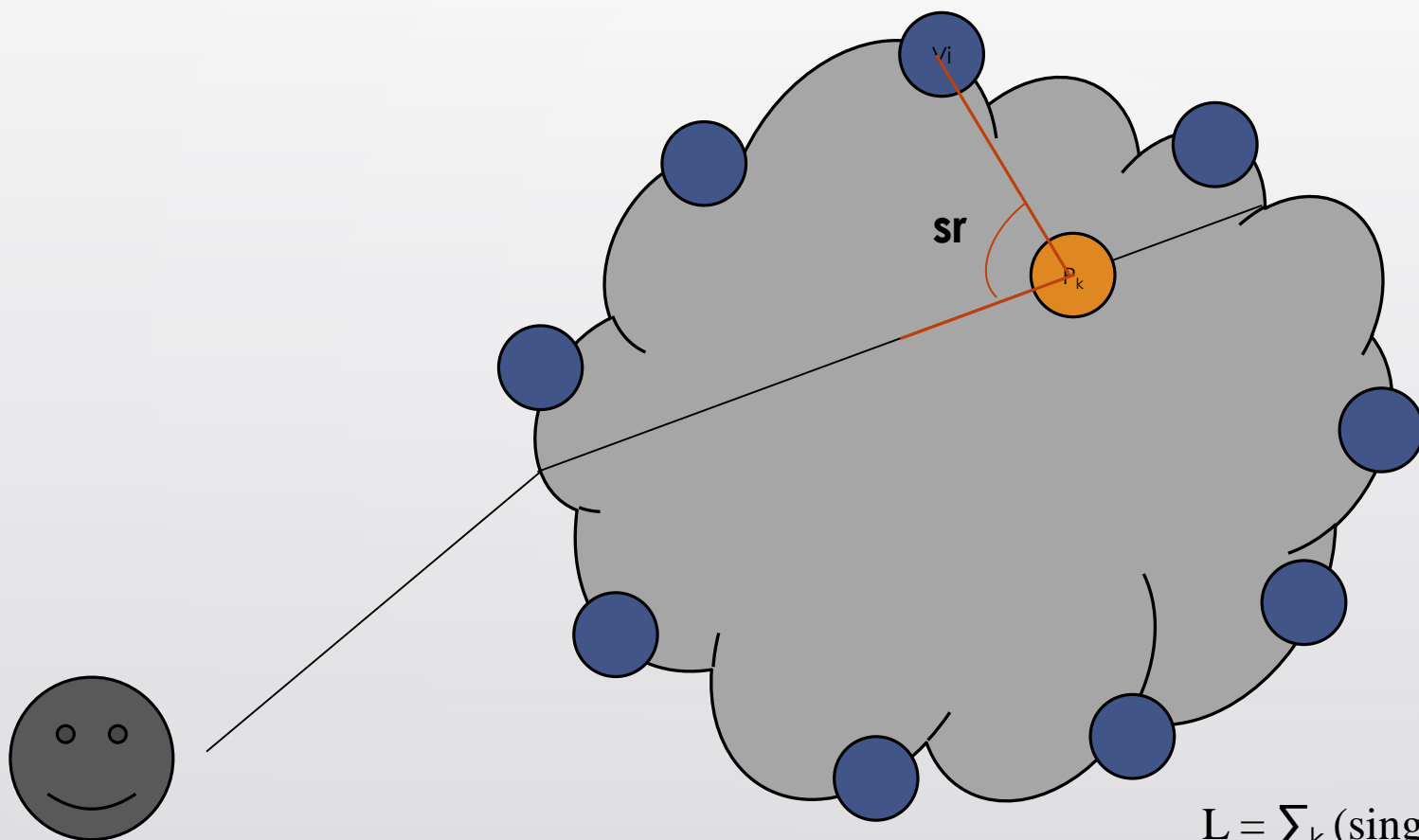


4. Multiple scattering

- Use precomputed table.
- We take a point light source sending photons in a single direction in an **infinite** medium
- Then, simulate photon propagation and accumulates the results using Monte Carlo simulation.
- Represents some material property.

$$L = \sum_k (\text{single } (P_k) + \text{double } (P_k) + \text{mult. } (P_k) + \text{bounced } (P_k))$$

5. Bounced multiple scattering



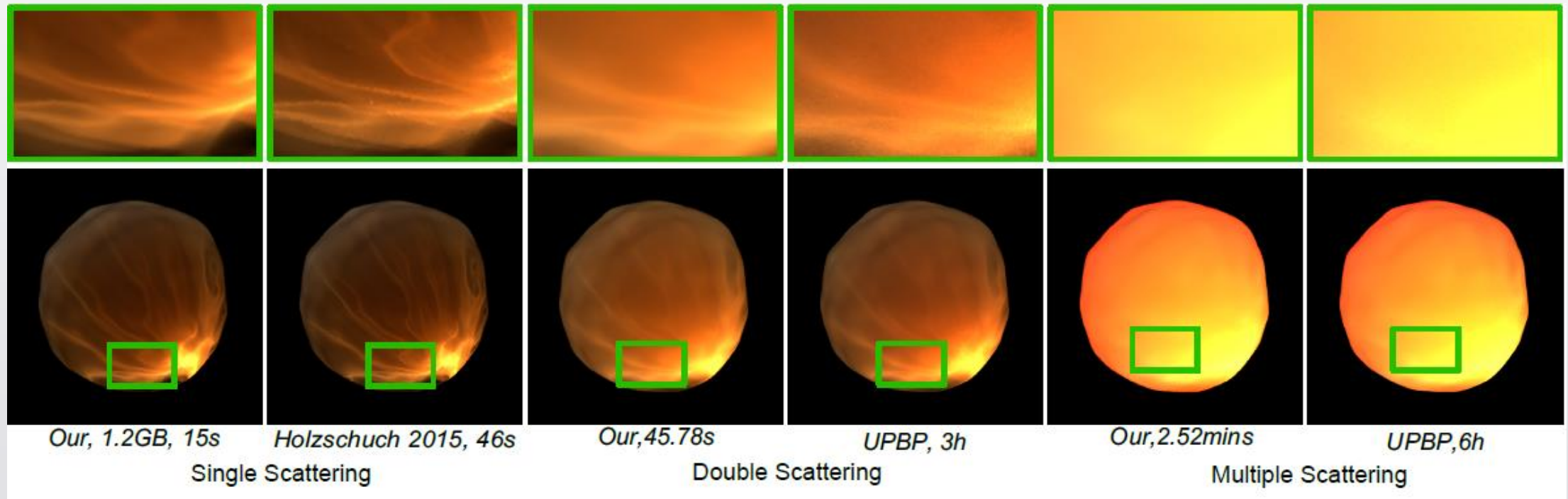
Our material is actually not an infinite medium. Light is bounced when it hits the refractive surface.

Bounced light is computed with surface samples. Accumulate all the radiance of surface samples, if light $V_i P_k$ can be scattered into camera direction.

$$L = \sum_k (\text{single } (P_k) + \text{double } (P_k) + \text{mult. } (P_k) + \text{bounced } (P_k))$$



Result : Individual component analysis



Result - overall

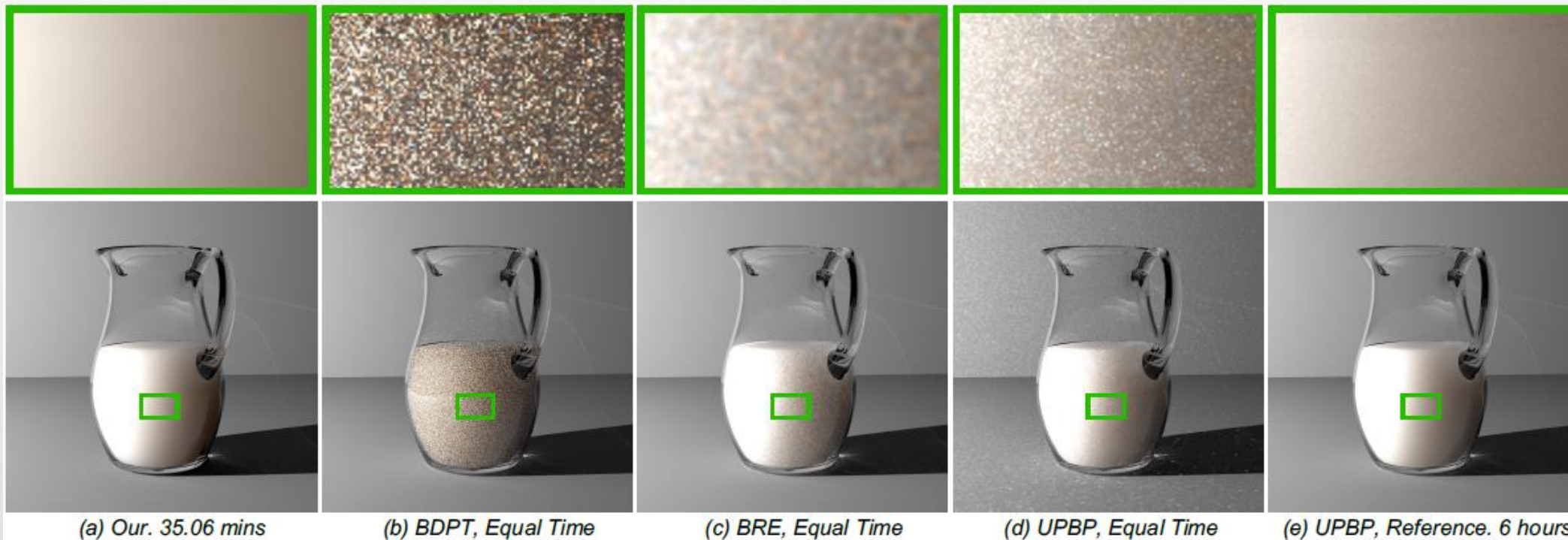


Figure 9: Material: milk, $\alpha = \{0.9999, 0.9997, 0.9991\}$, $\ell = \{0.8422, 0.7521, 0.6848\}$. For this material, with a very large albedo and a small mean free path, multiple scattering effects dominate.

**Beyond Points and Beams :
Higher-Dimensional photon samples for
volumetric light transport**

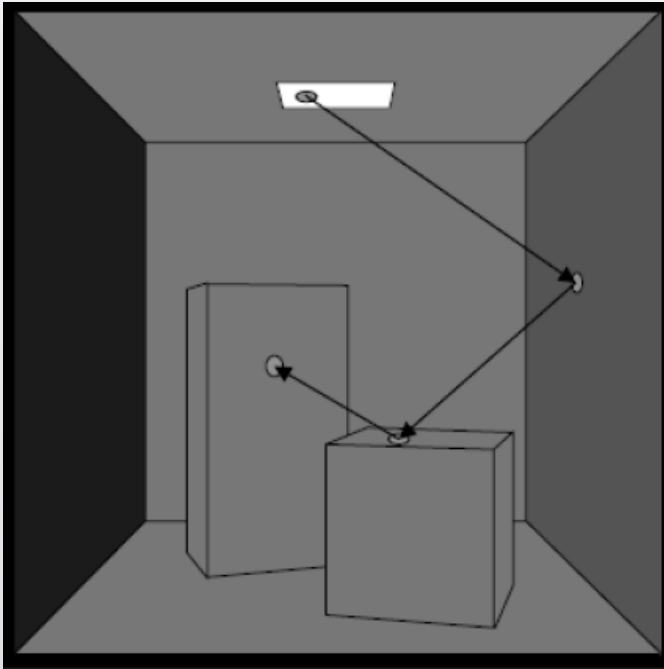


Beyond Points and Beams : Higher-Dimensional photon samples for volumetric light transport

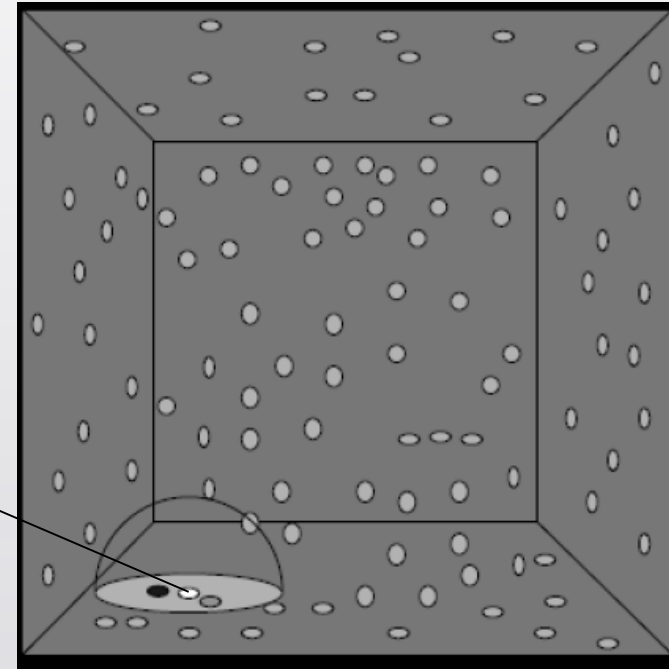
- Generalized theory of density estimation
- Theoretical error analysis

Photon mapping

1. Shoot “photons” and record any hit-points
2. Shoot viewing rays and collect information from stored photons.

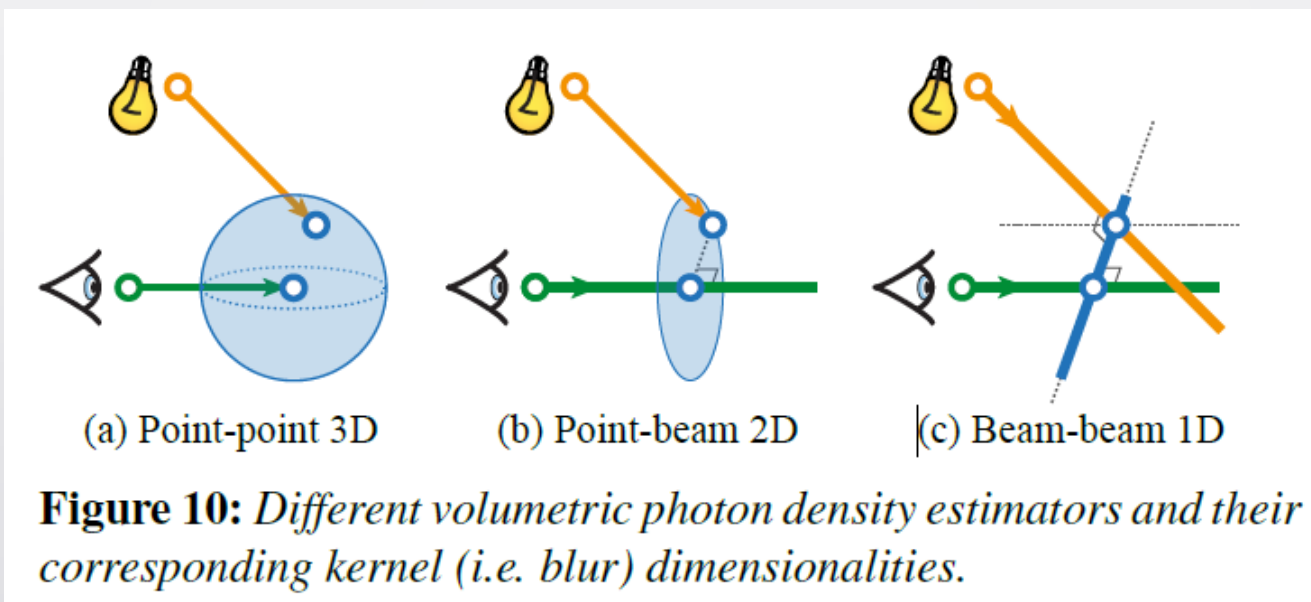


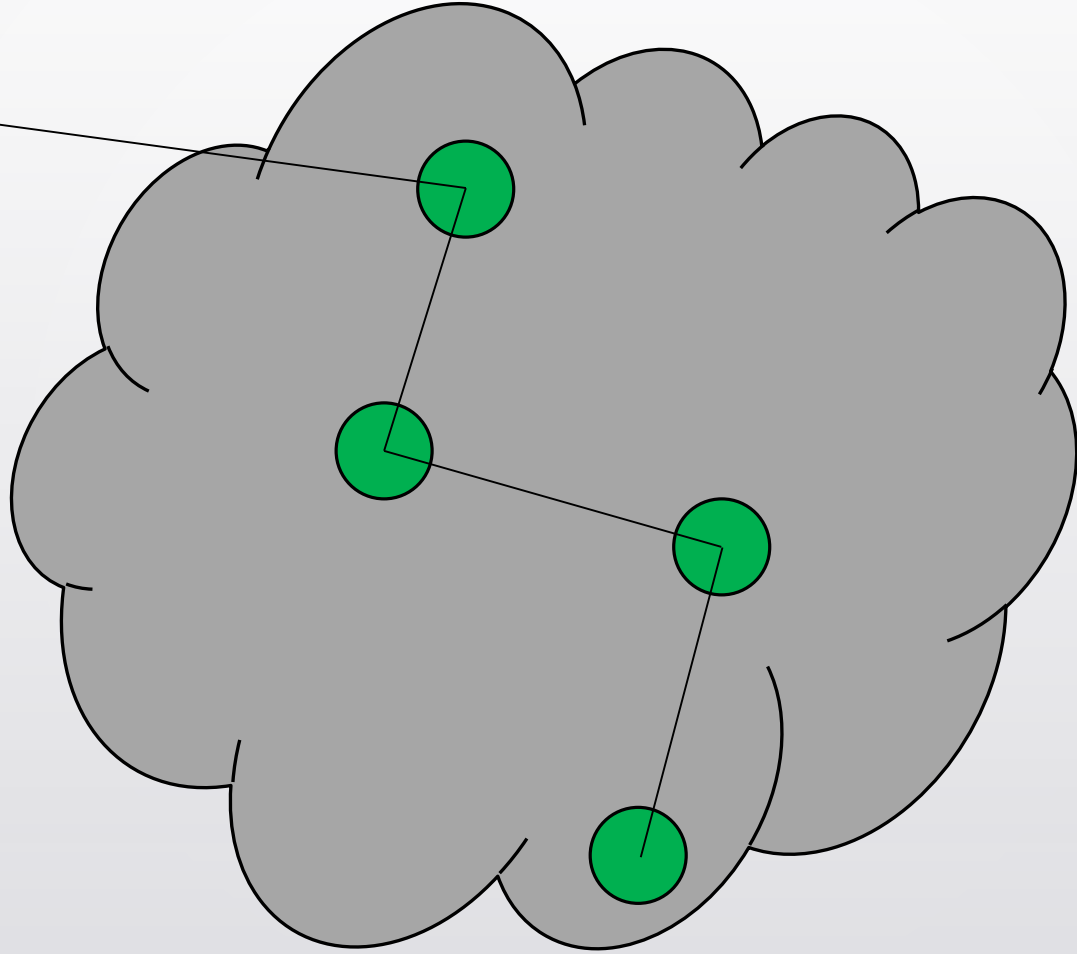
Density estimation



Density estimation?

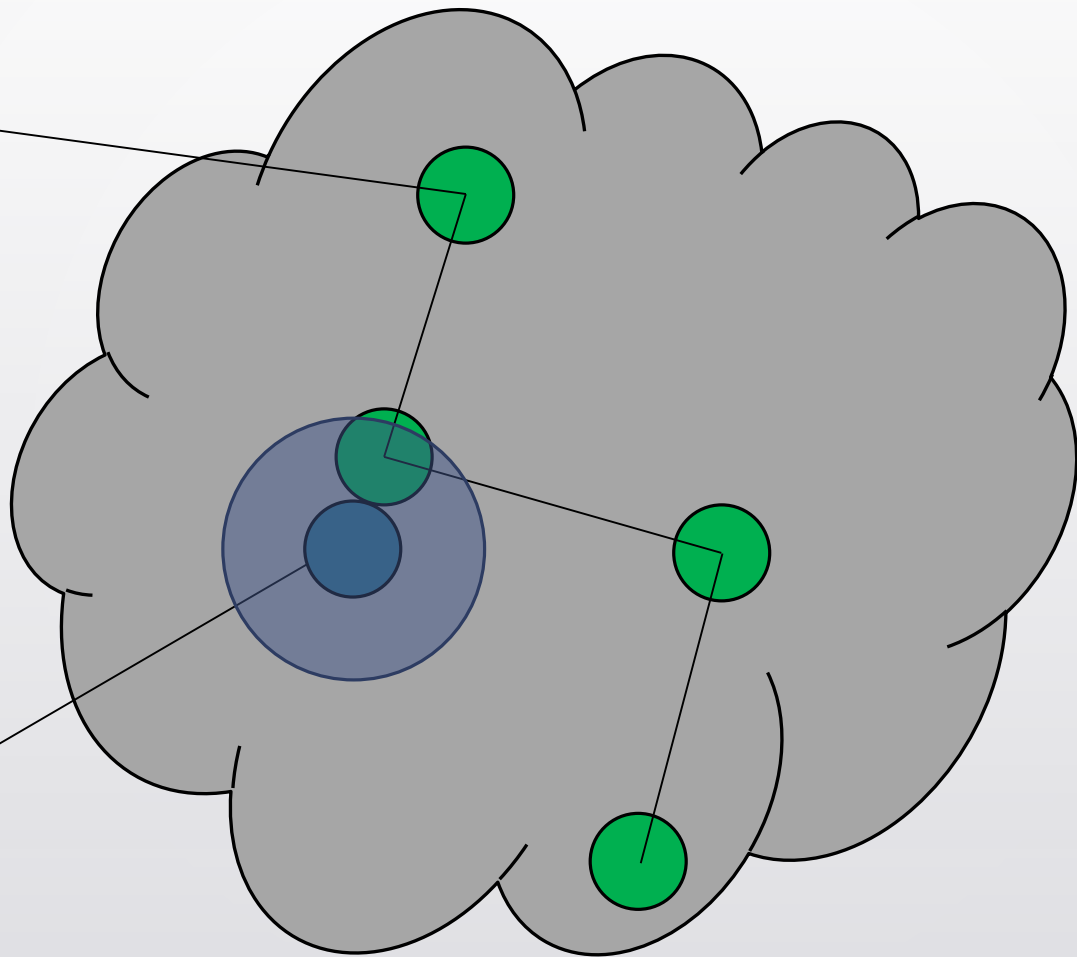
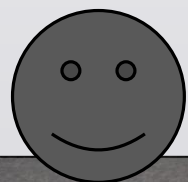
Estimation process to estimate density of outgoing radiance around the points seen from the camera.



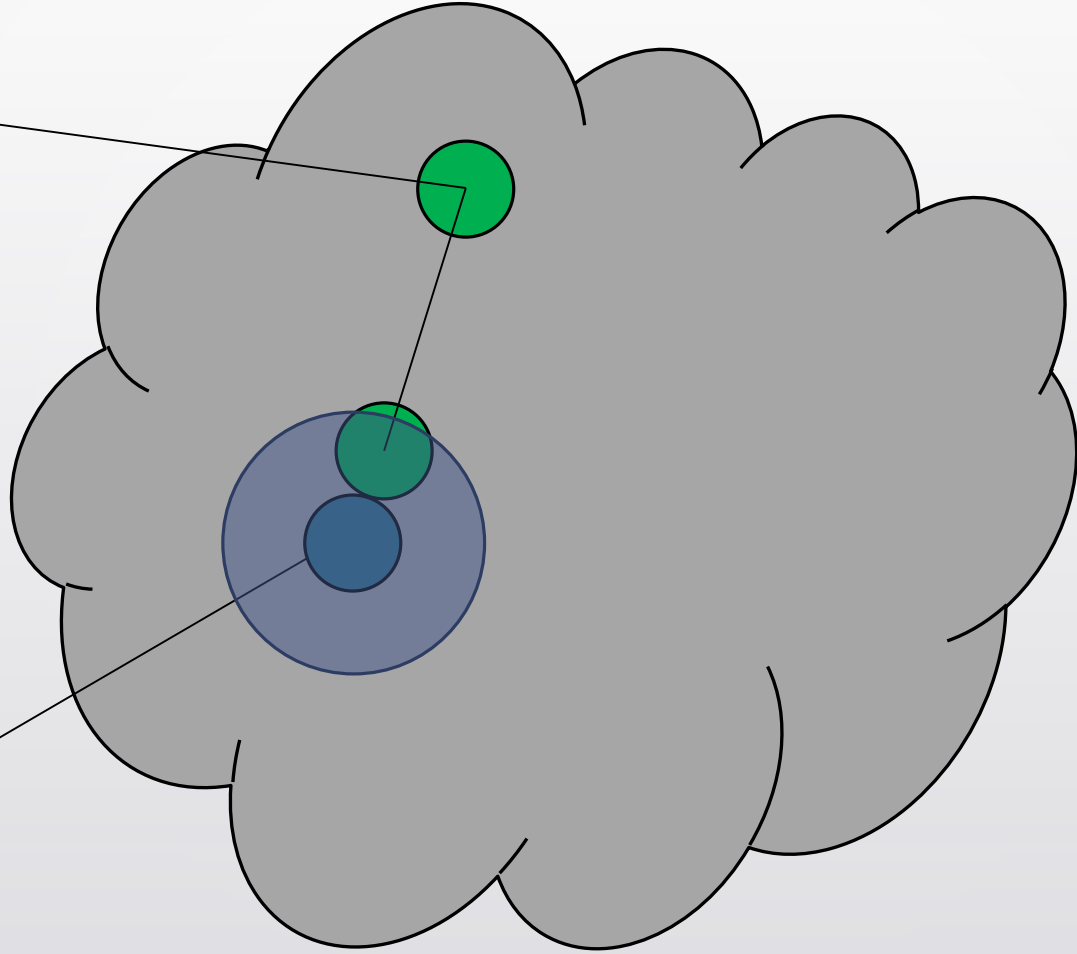
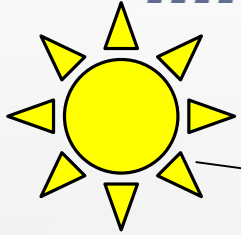


Shoot photon. Then it will scatter randomly with distance sampling.

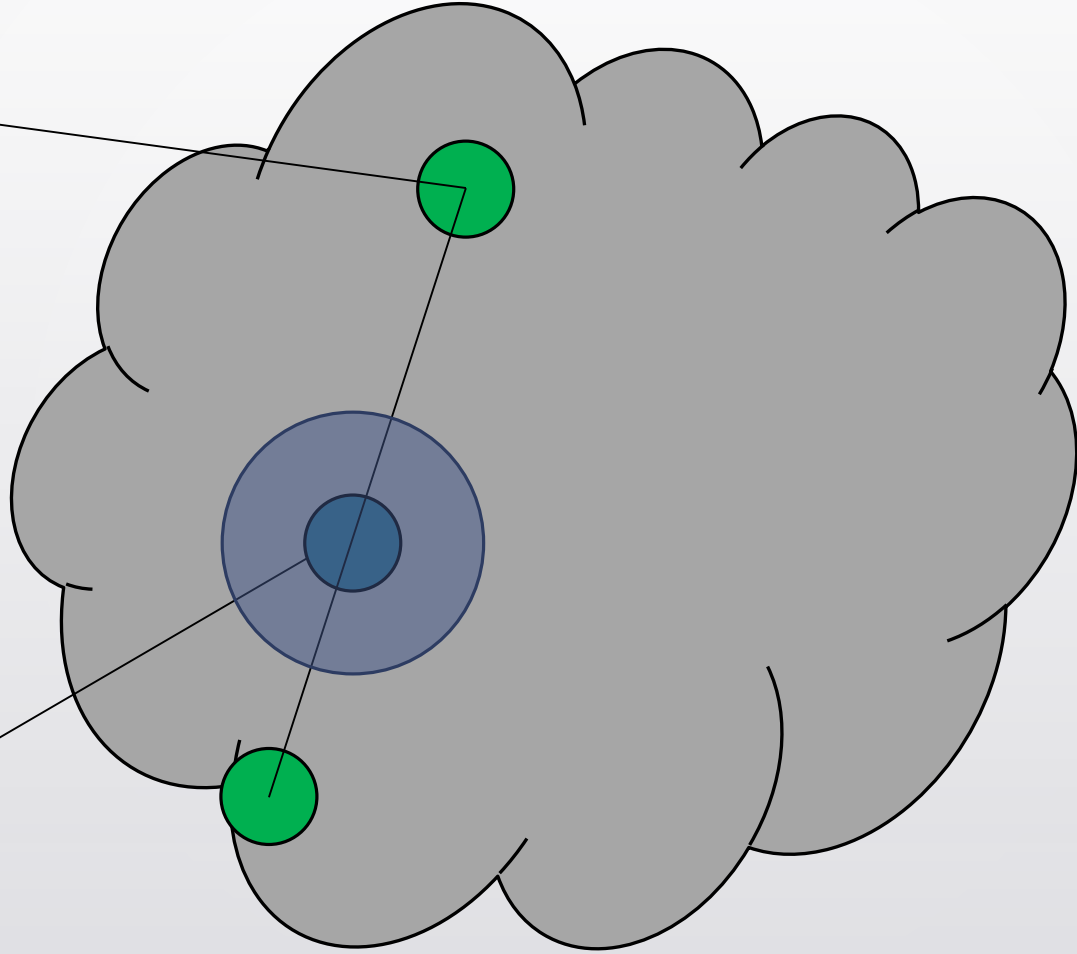
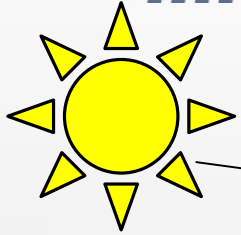




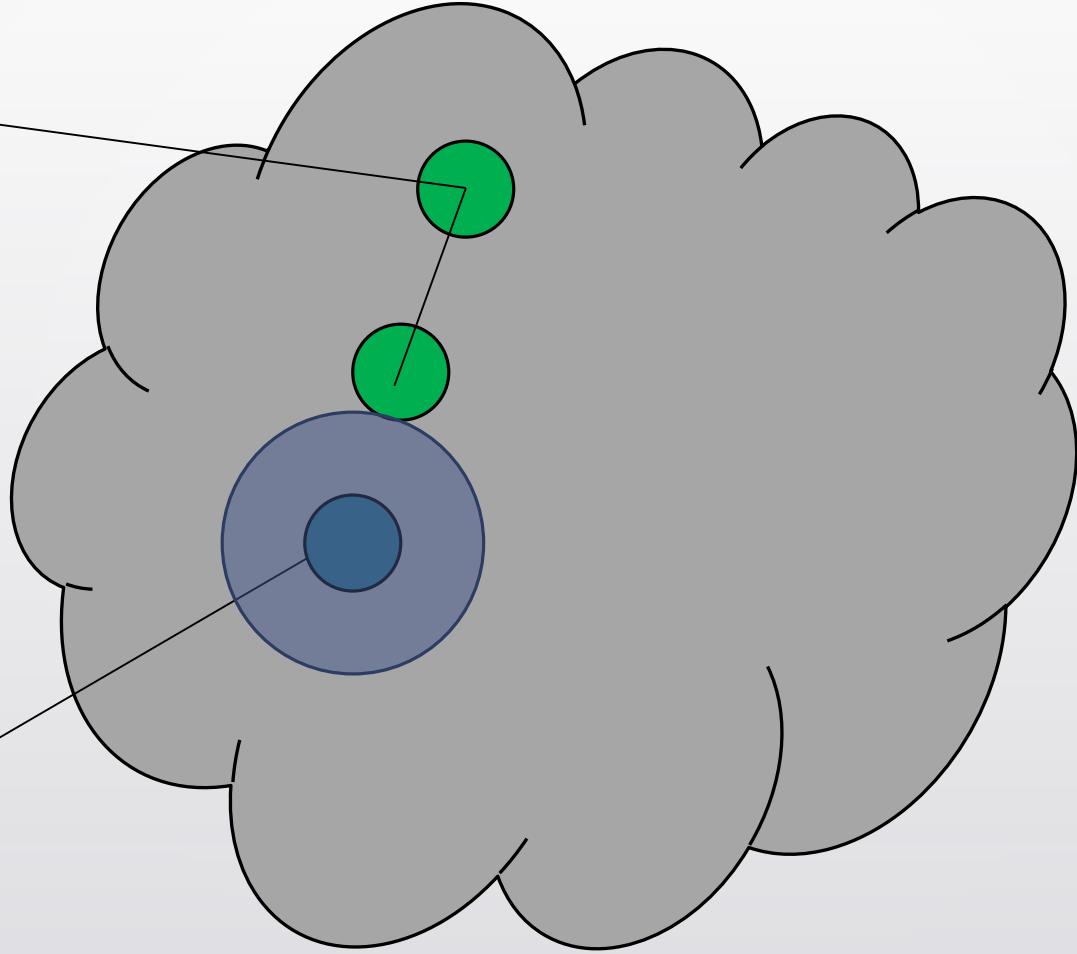
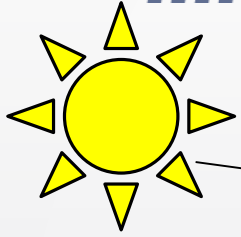
Shoot camera ray. For given point, it estimates radiance of surrounding photons.



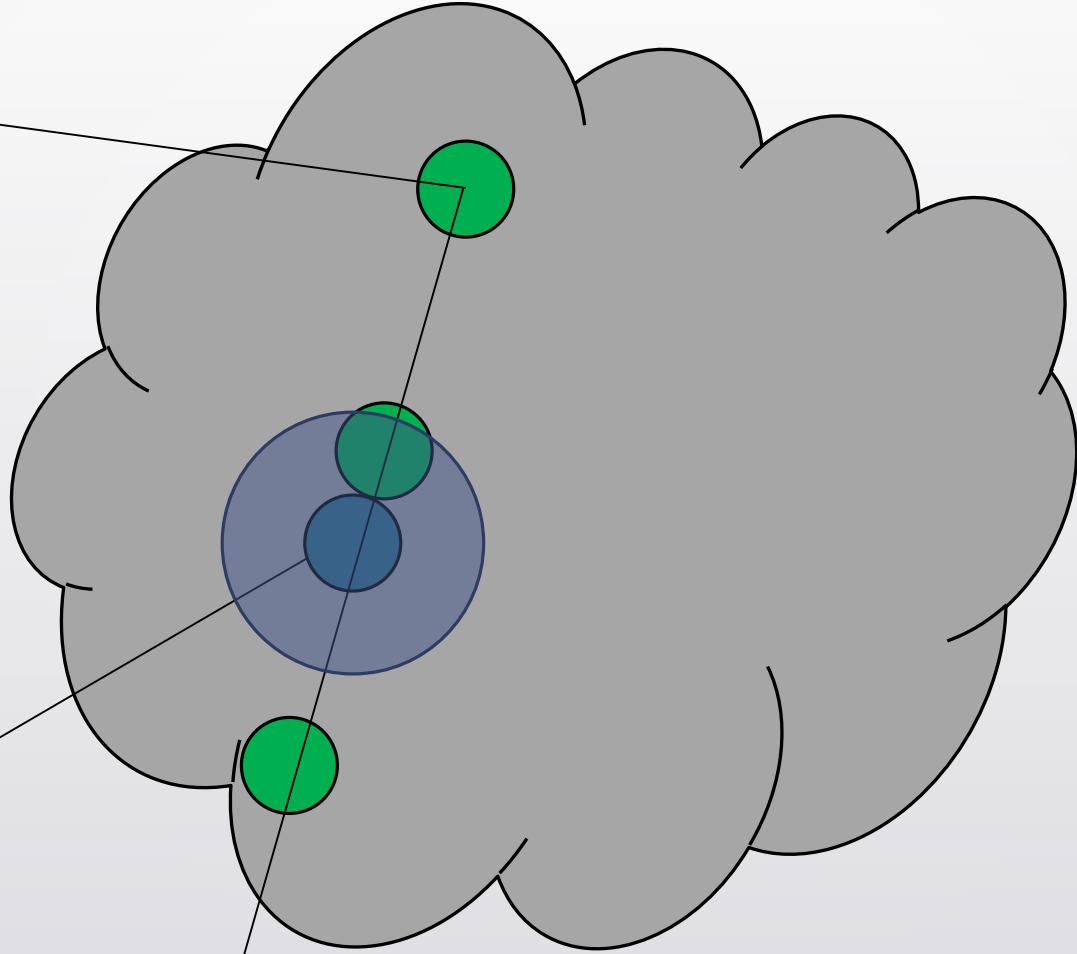
But the location of each photon is determined by the distance sampling.
→ Variance occurs



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→ Variance occurs

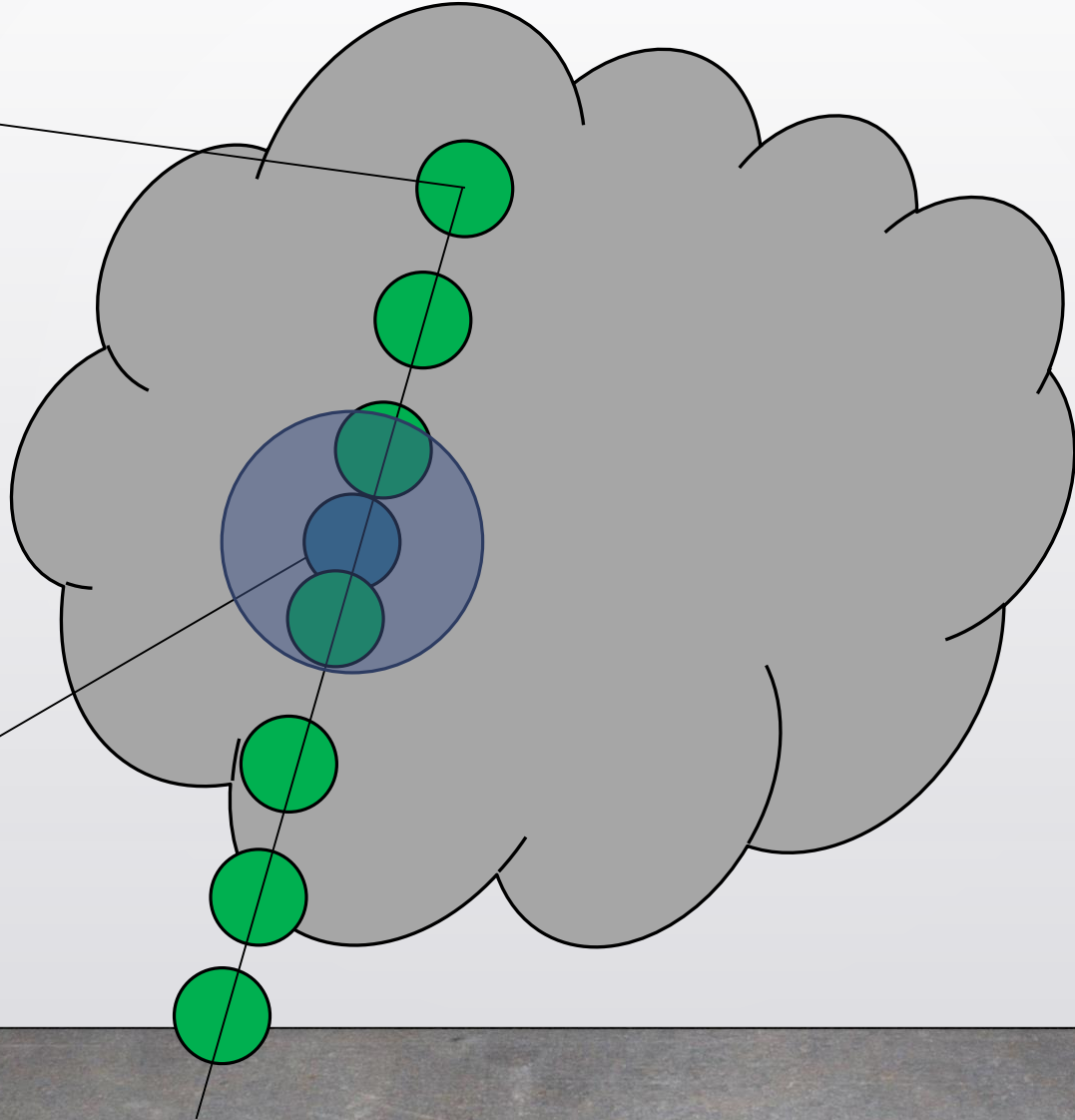
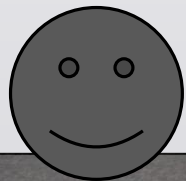


But the location of each photon is determined by the distance sampling.
→ Variance occurs



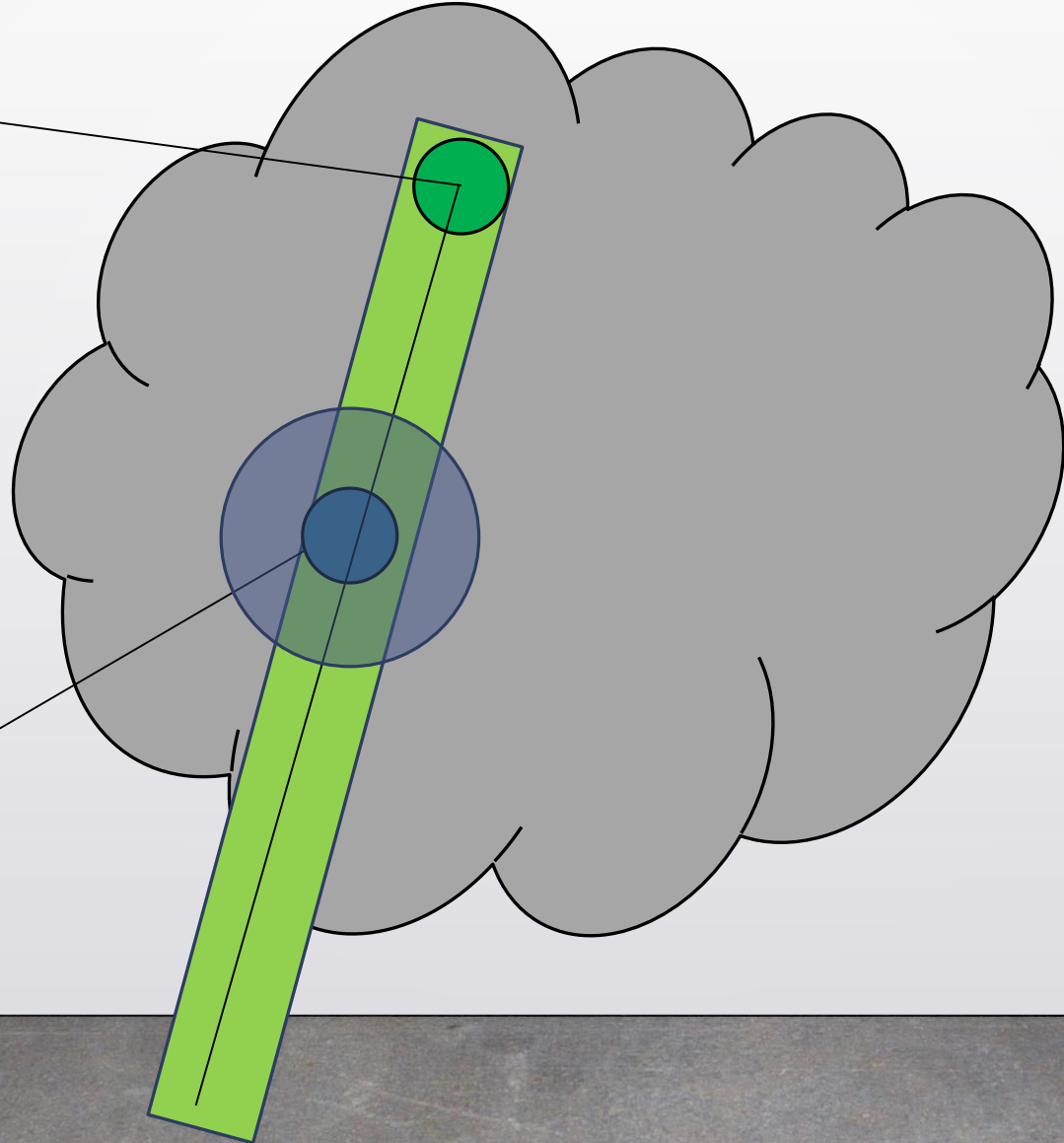
Let's use method called "Marching"

Locate many photon samples to decrease the variance.



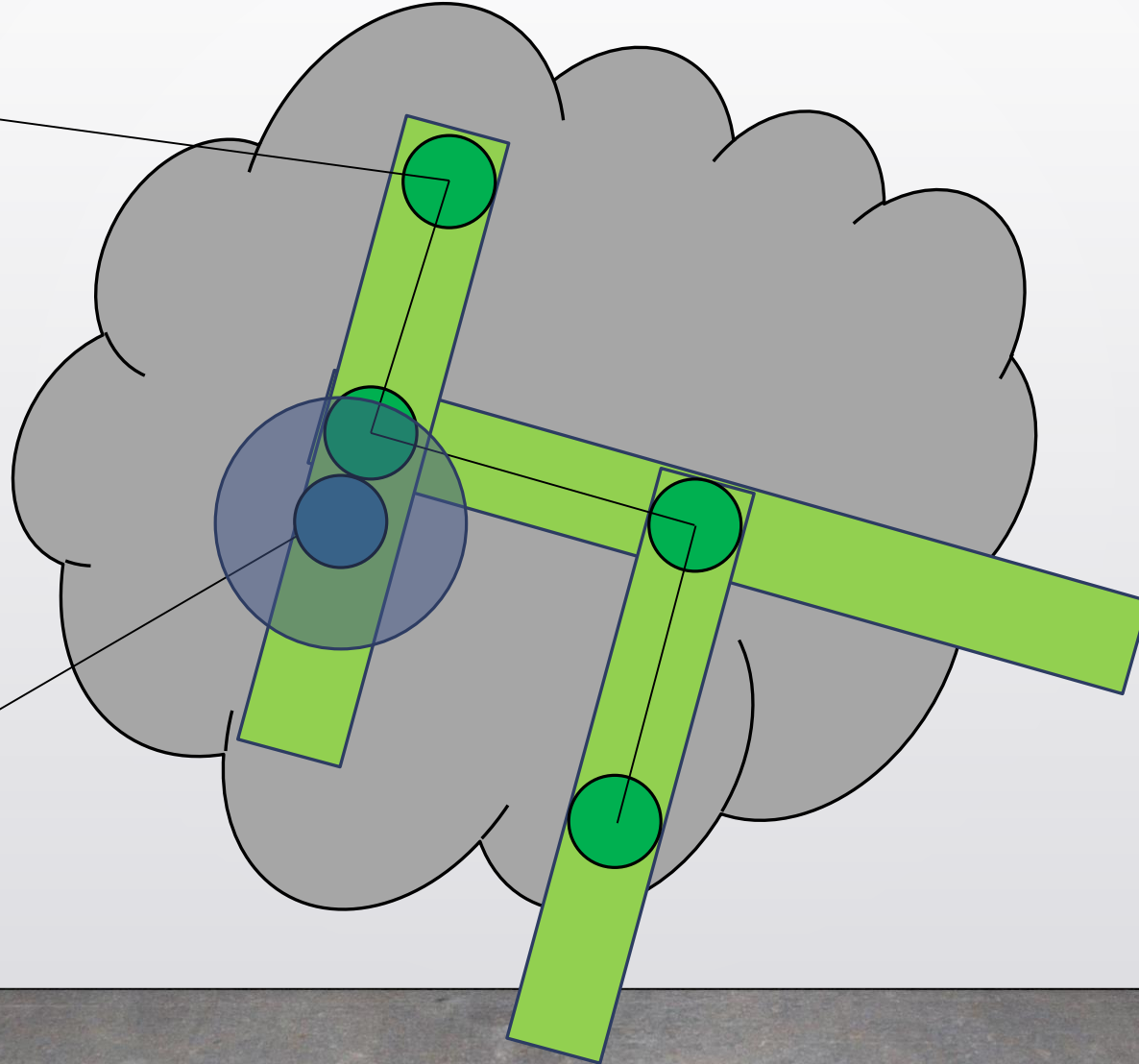
Sample more to further decrease the variance.

If we keep decrease the sample distance, the limit would be...



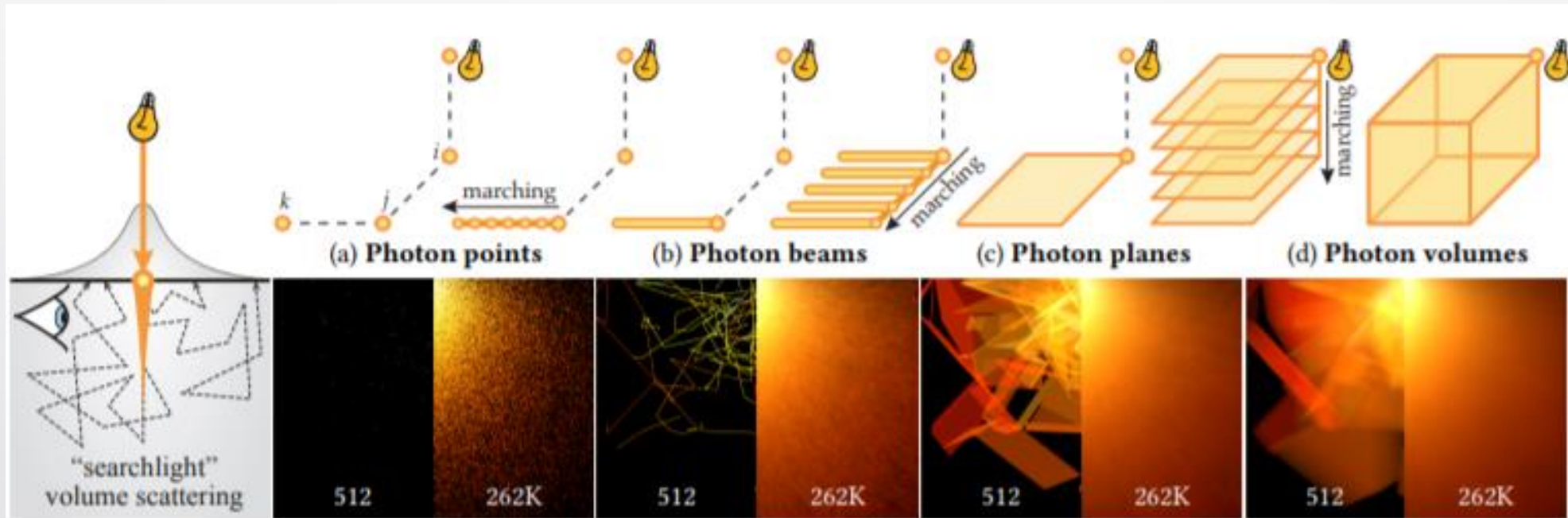
Sample more to further decrease the variance.

If we keep decrease the sample distance, the limit would be... a **line**!



Then, we can represent the photon mapping not only with point but also with the line segment.

More and More...



Variance reduces as the dimension of density estimator increases.

Additionally, the bias decreases.

Result



Thank you 😊



QUIZ

1. What does the author used to represent the refraction of the surface?
 - (a) Refracted ray path
 - (b) Surface light sample
 - (c) Volume light sample

2. When the dimension of density estimator increases,
bias (increases/decreases) and variance (increases/decreases).