Light Transport for Participating Media

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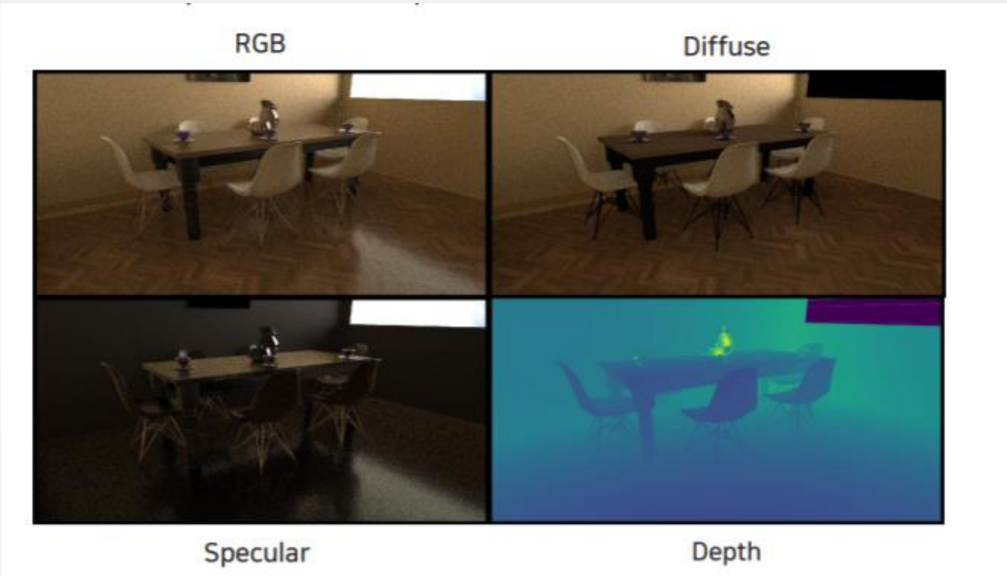
CS580 Computer graphics 2019 Spring

Review – Denoising (by Lee CheolMin)

Adaptive polynomial rendering

Kernel-predicting convolutional network



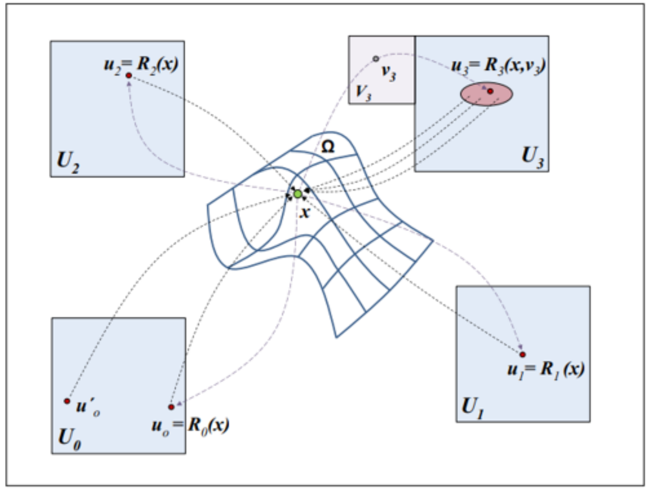
Review – MLP using inverse mapping (by Park Juho)

Reversible Jump MLT 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

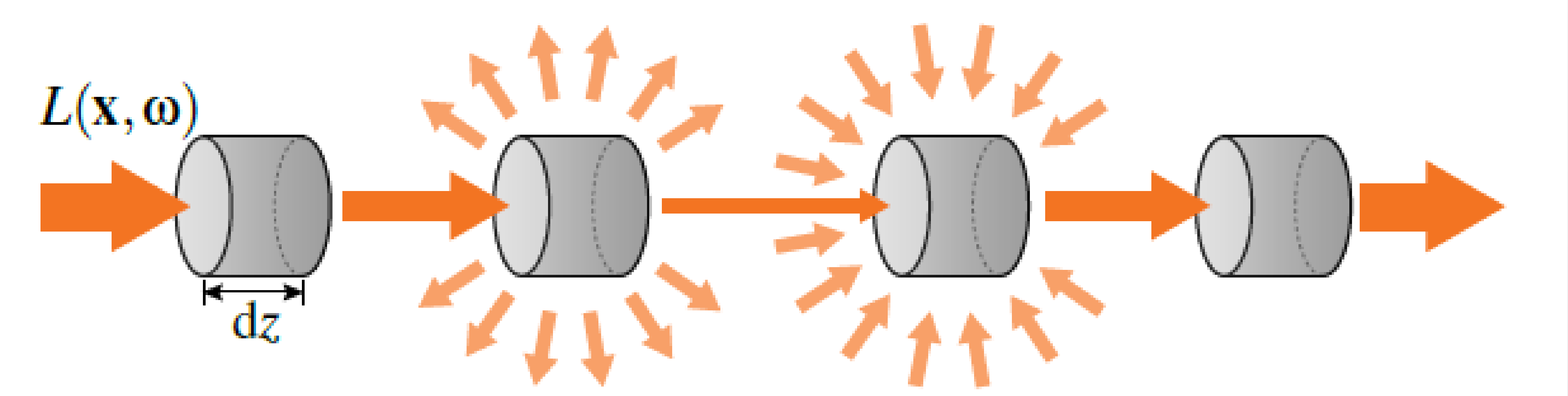
- Allow *swap* bidirectional sampling techniques
- Unlike RJMLT, path sampling function need not be invertible
- Get out of local maxima to other sampling techniques



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

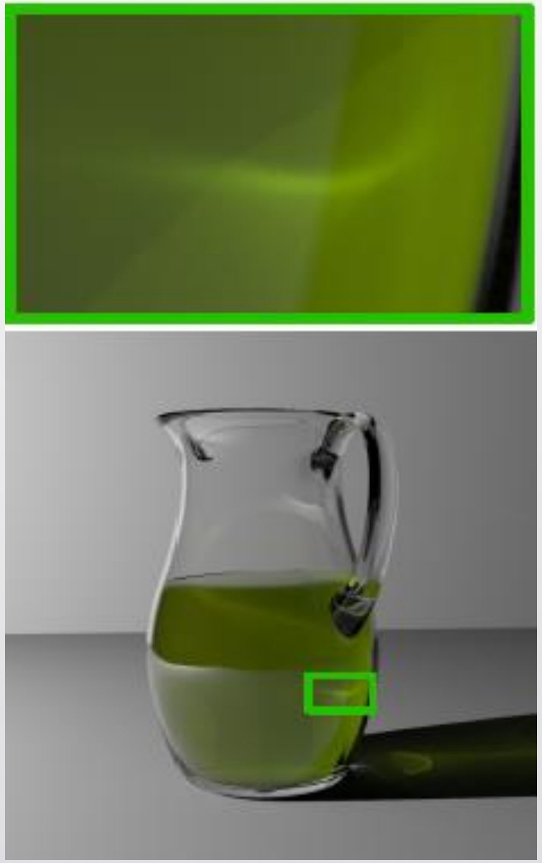
Point-based Light Transport for Participating Media with Refractive Boundaries

- Participate media with refractive boundaries.

  Inside : absorption, scattering

  Surface : refracting

- Idea is to apply **PBGI** to participate media.



Point Based Global Illumination(PBGI)

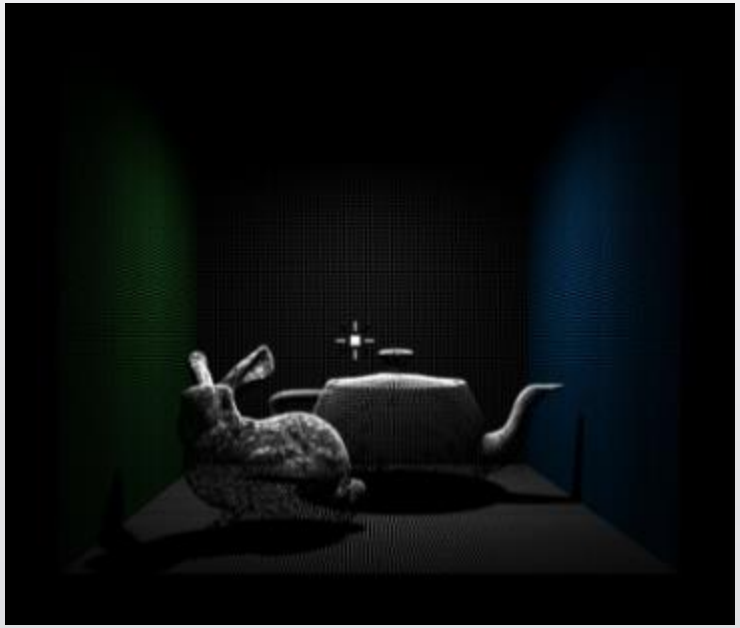
- A two step rendering algorithm to calculate the **indirect lighting** in a diffuse scene.

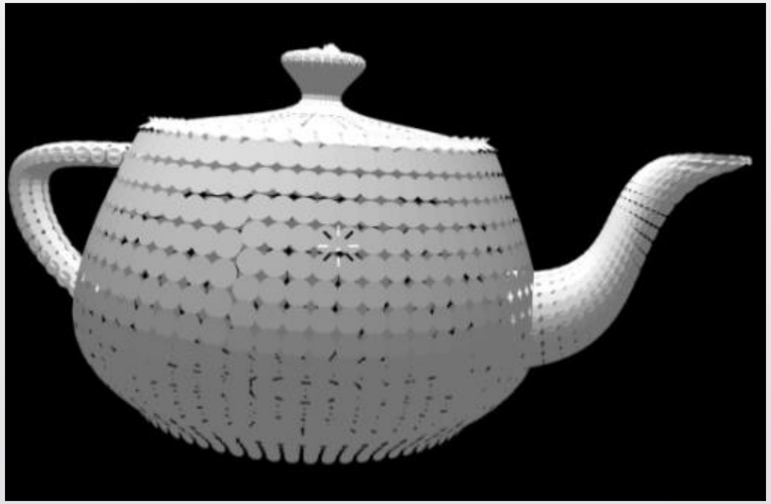
Step 1. Generate a diffuse **pointcloud** from the scene.

Step 2. Calculates the global illumination.

Point Based Global Illumination(PBGI)

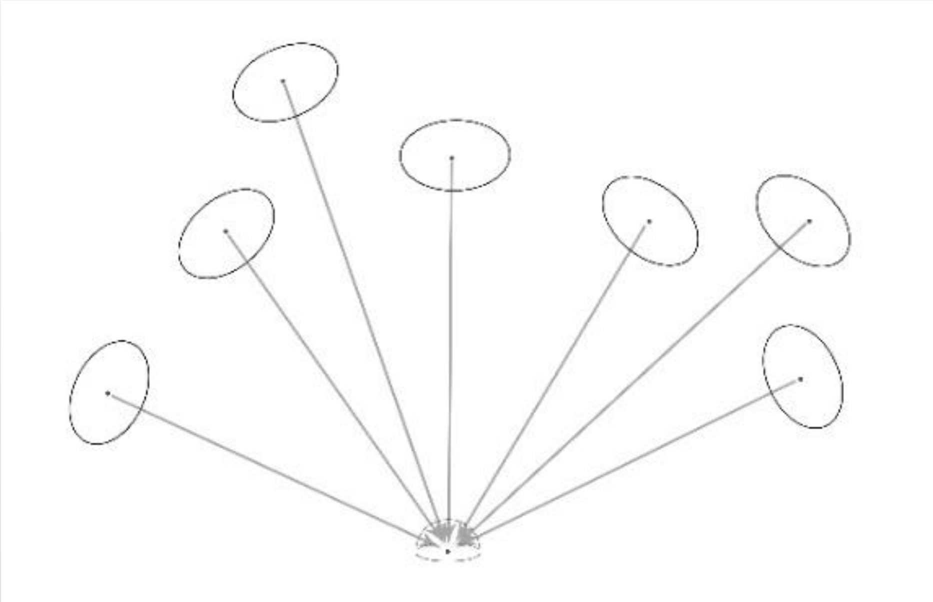
- Diffuse pointcloud is a point-base representation of the reflected direct light(indirect light source) in the scene. Use 'surfel'.

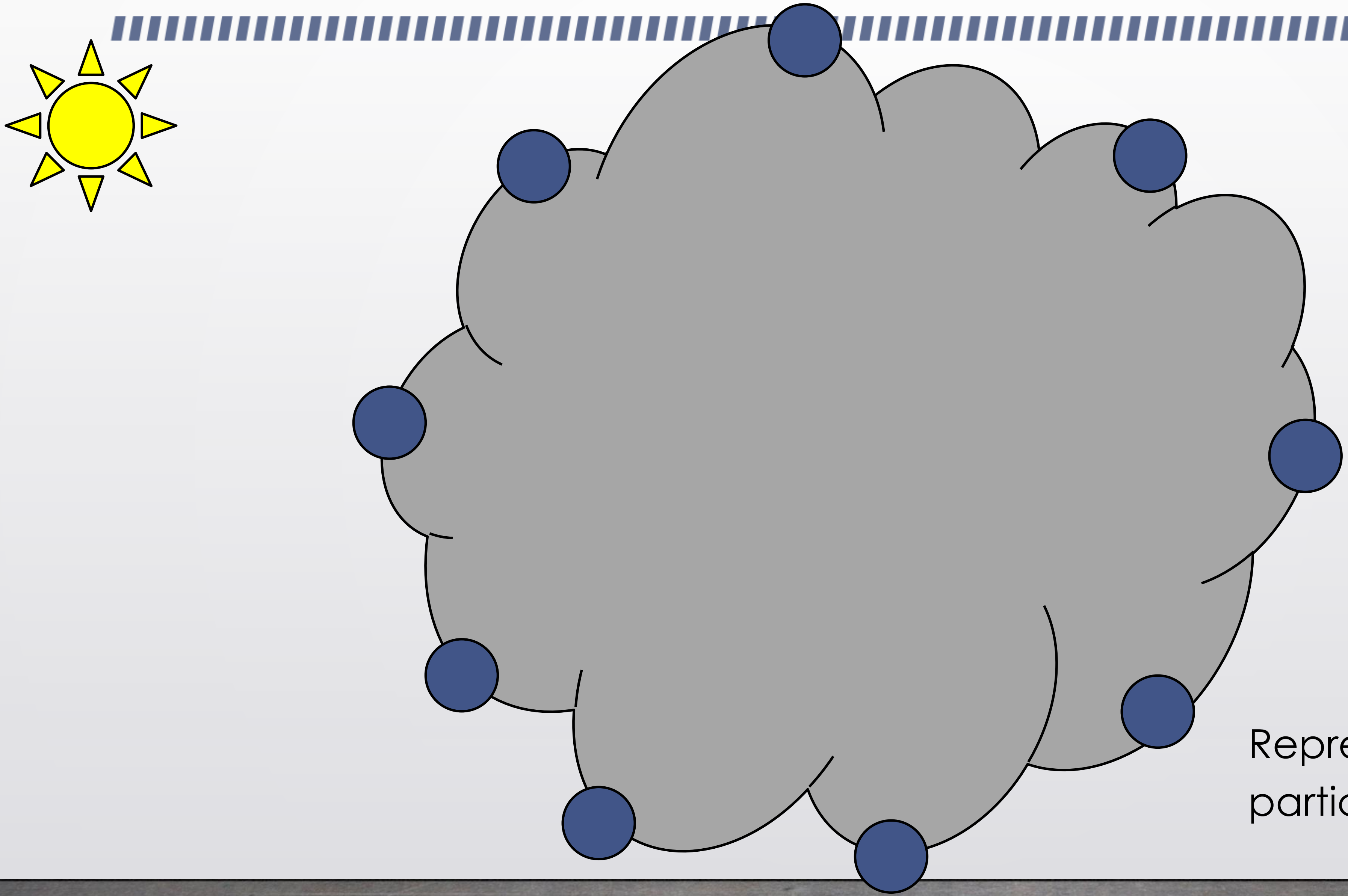




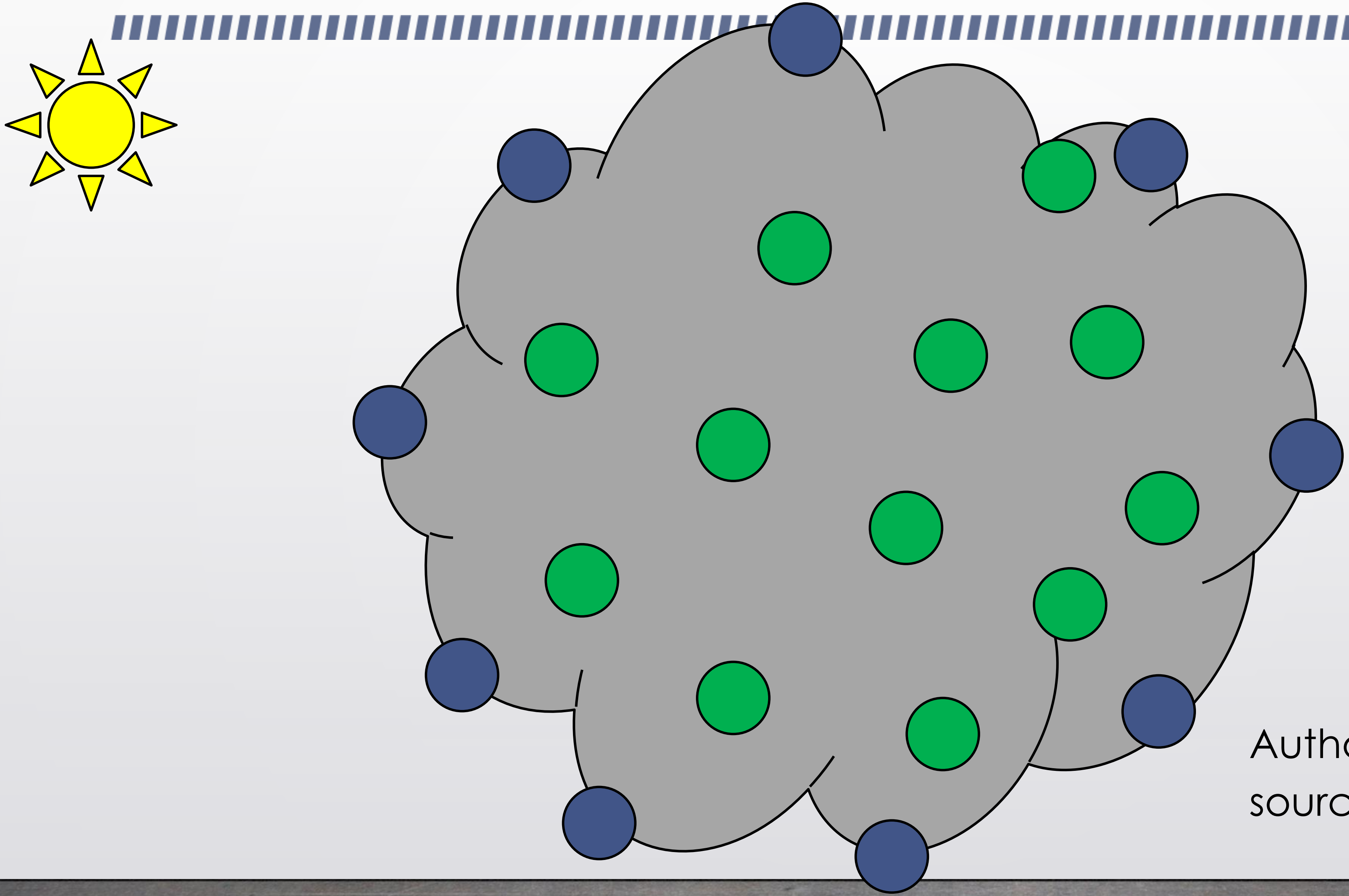
Point Based Global Illumination(PBGI)

- 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.

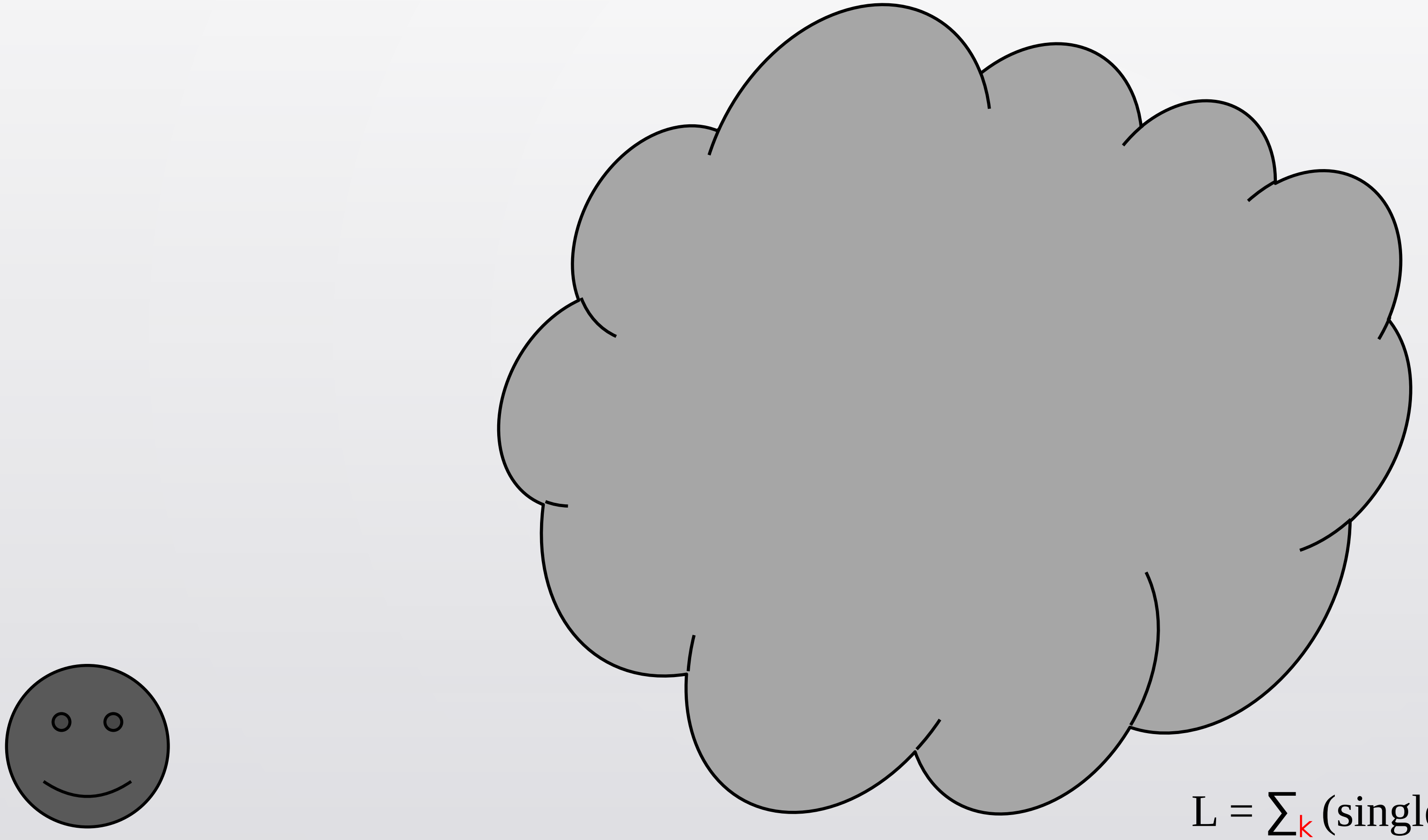
Physical phenomena of the target is divided into four part

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



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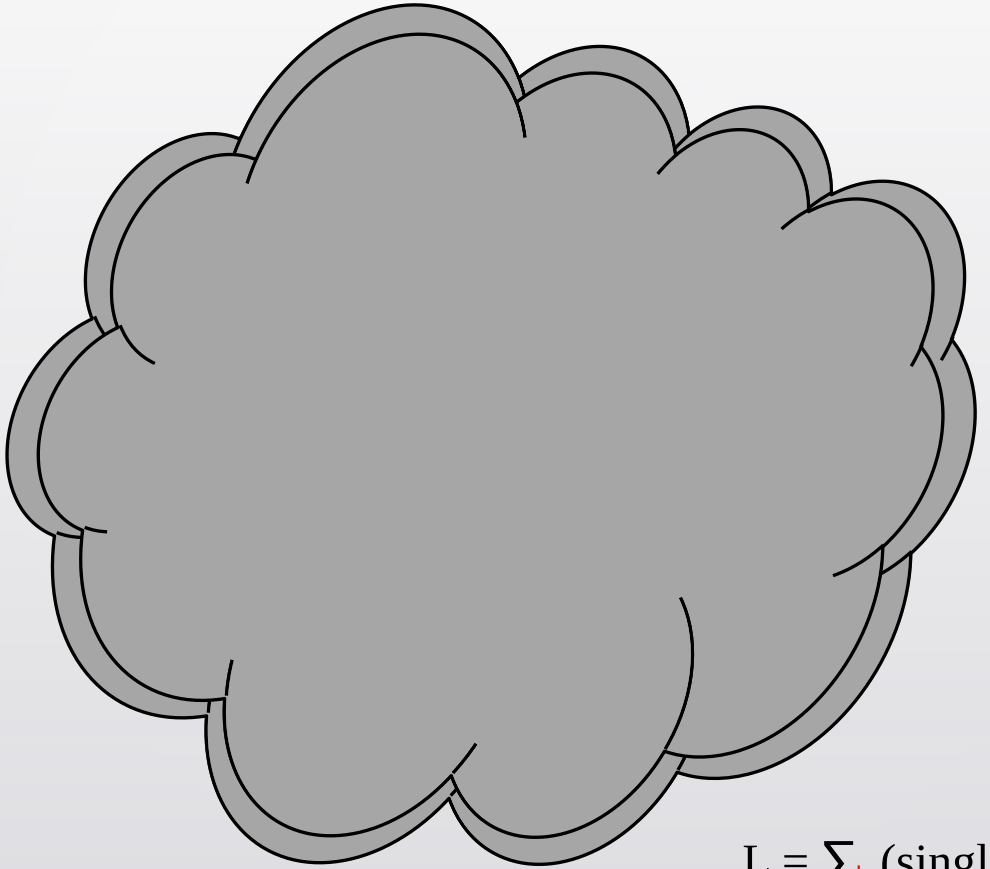

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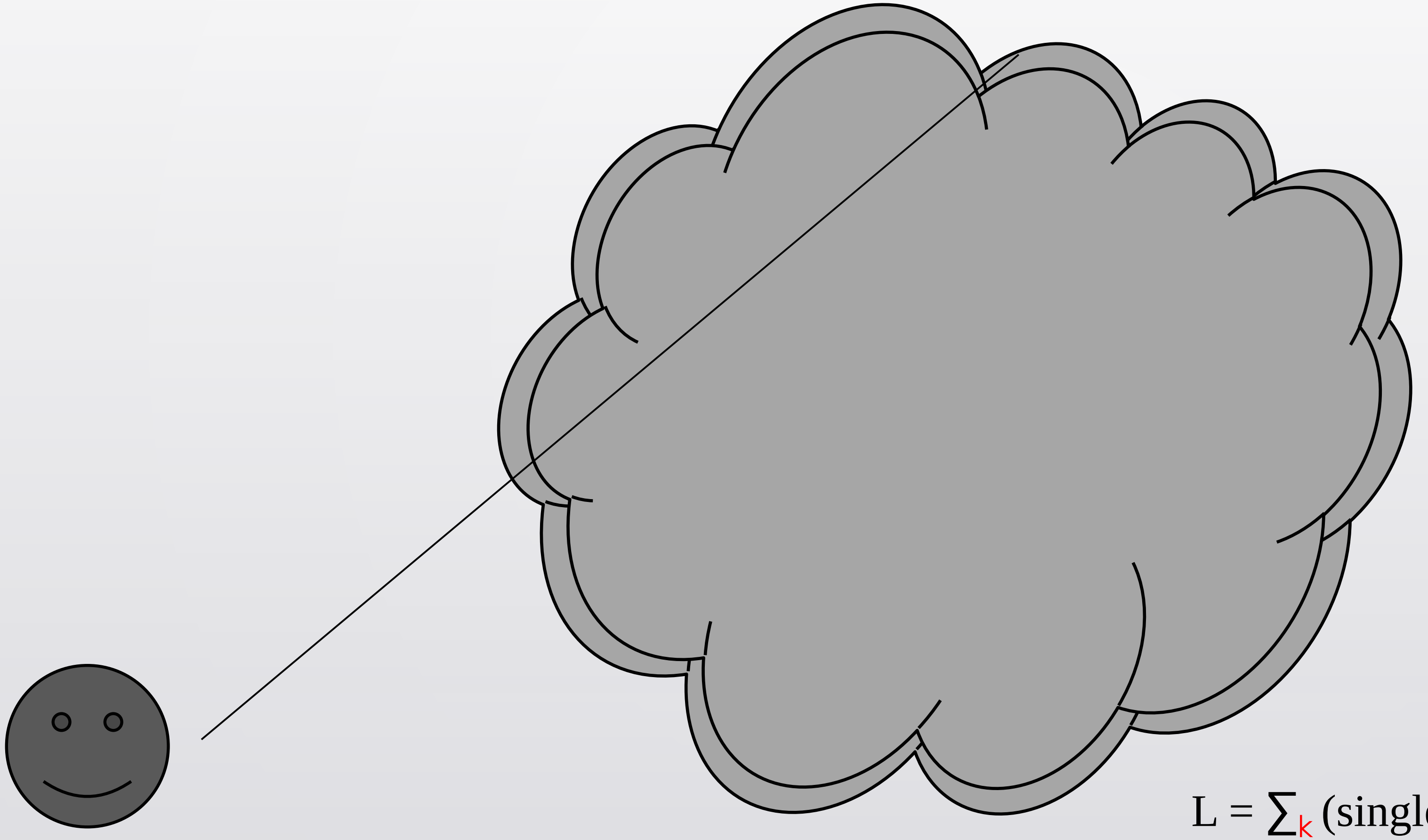

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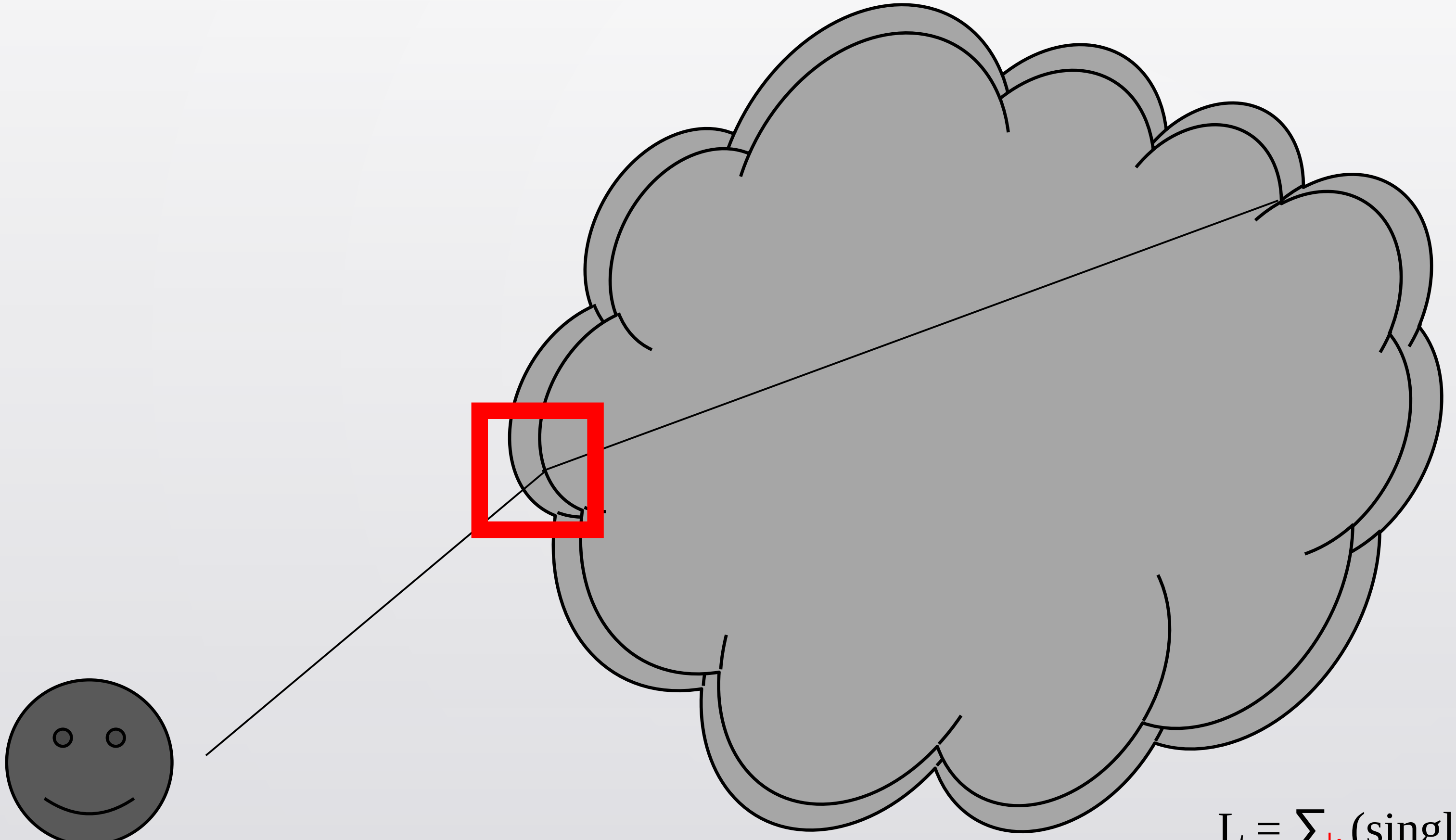

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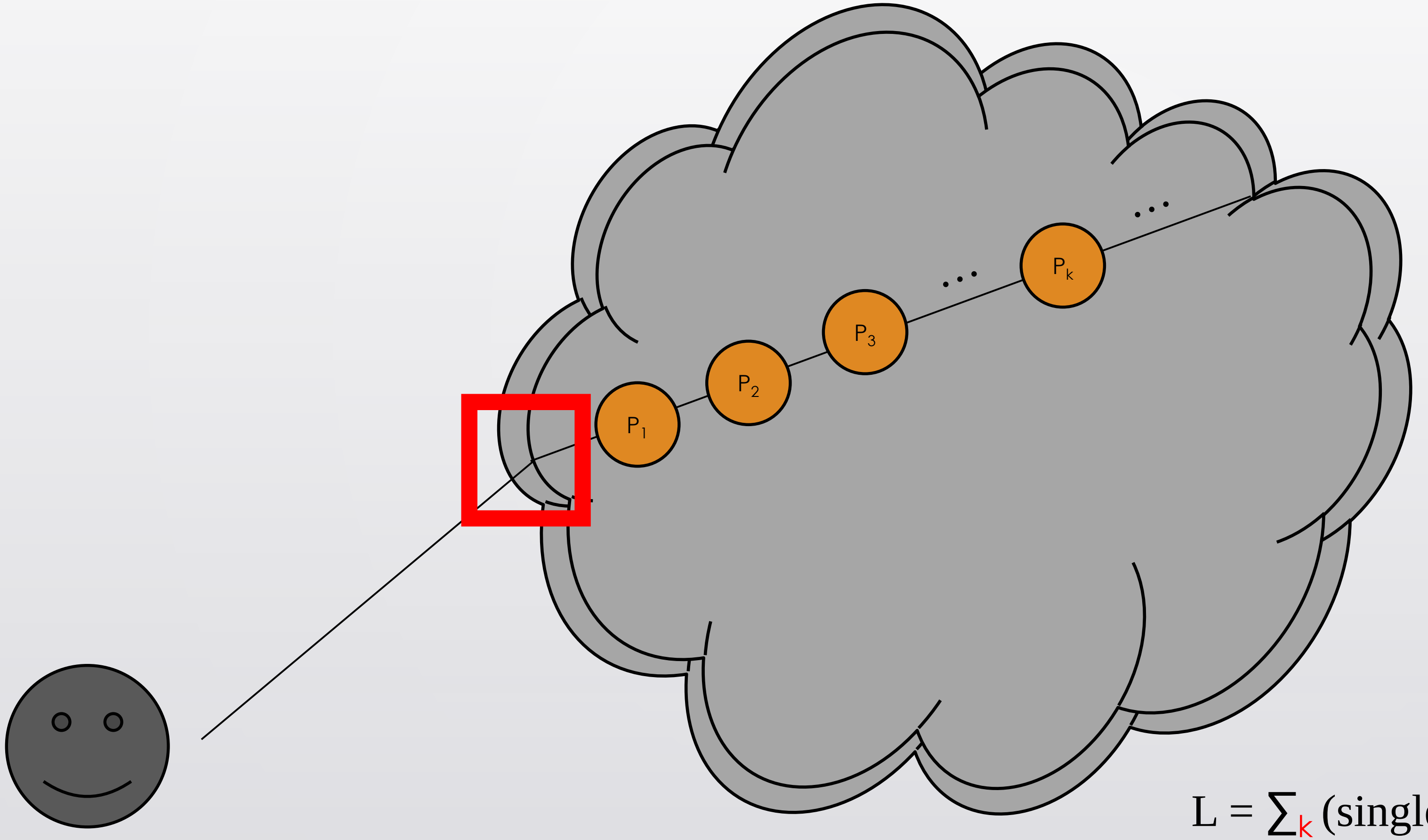
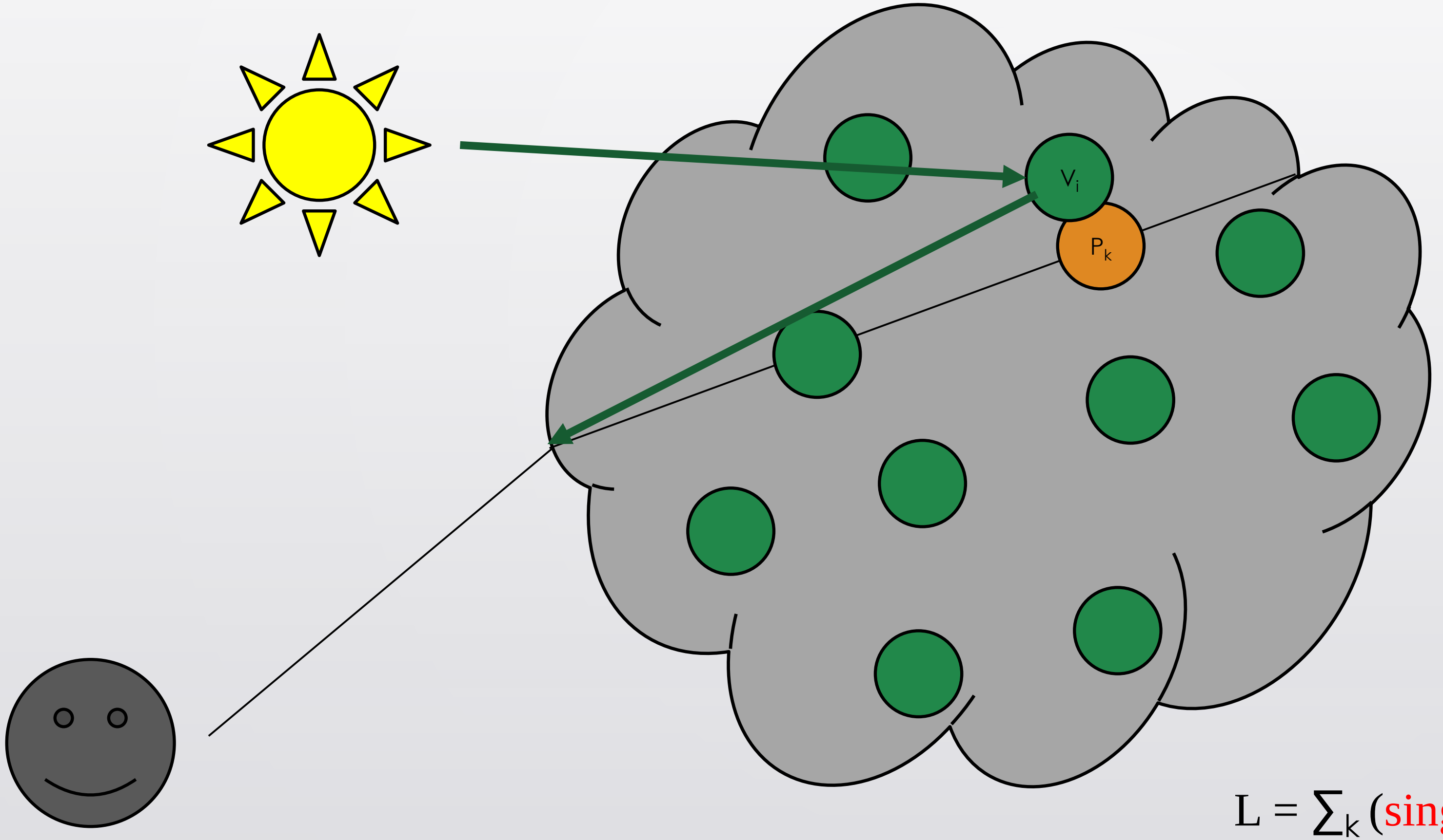


P_k is ray samples

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

2. Single scattering



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

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

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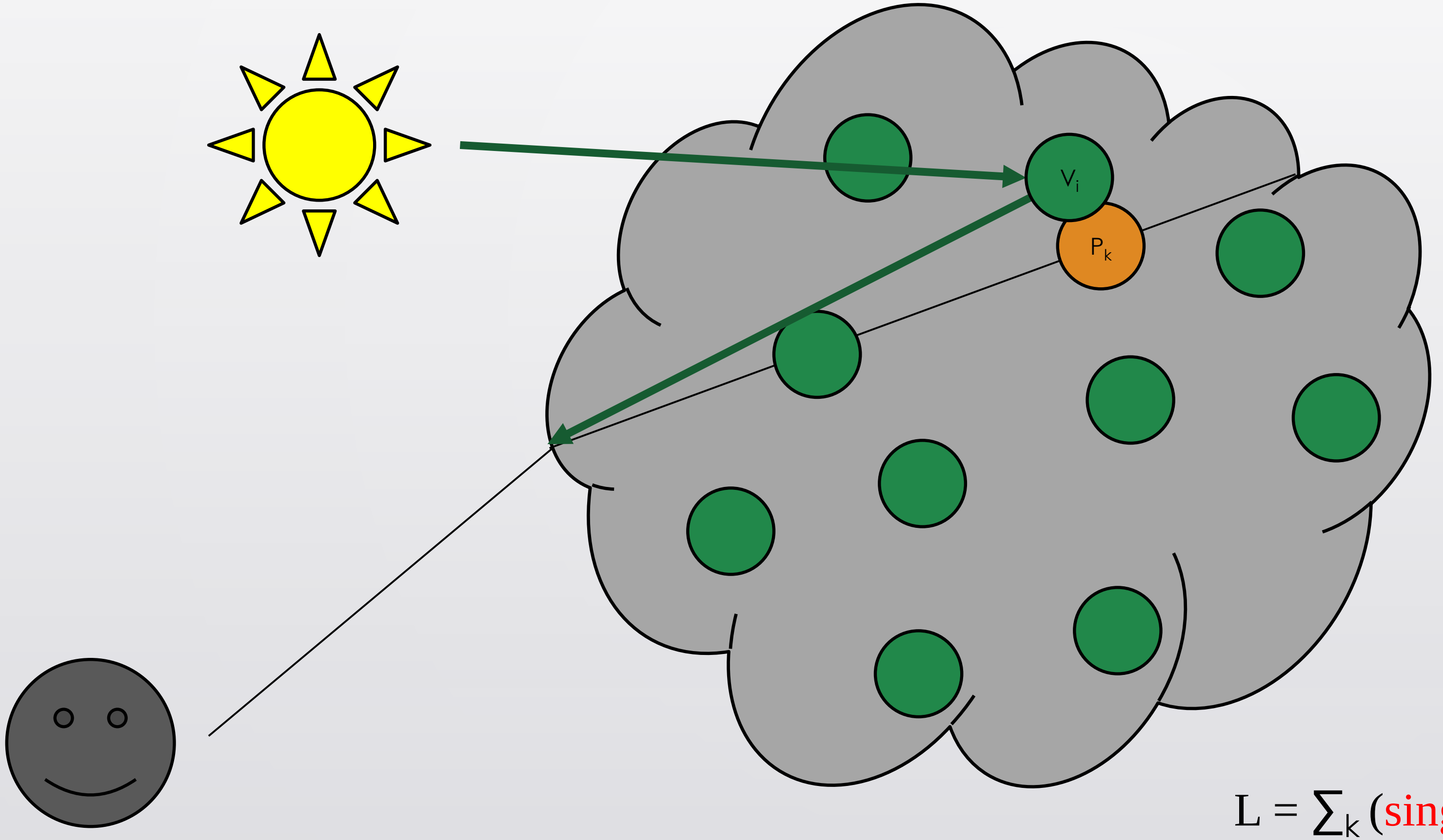
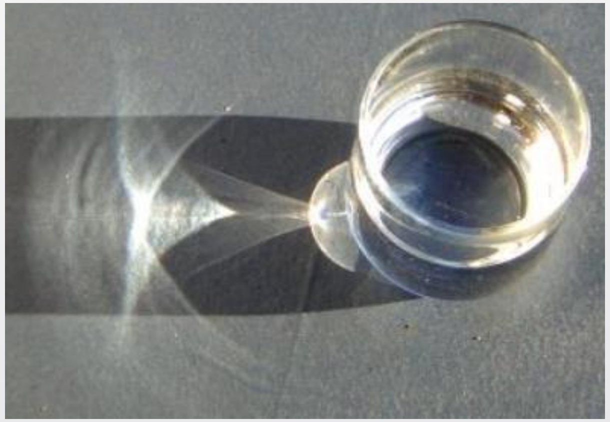
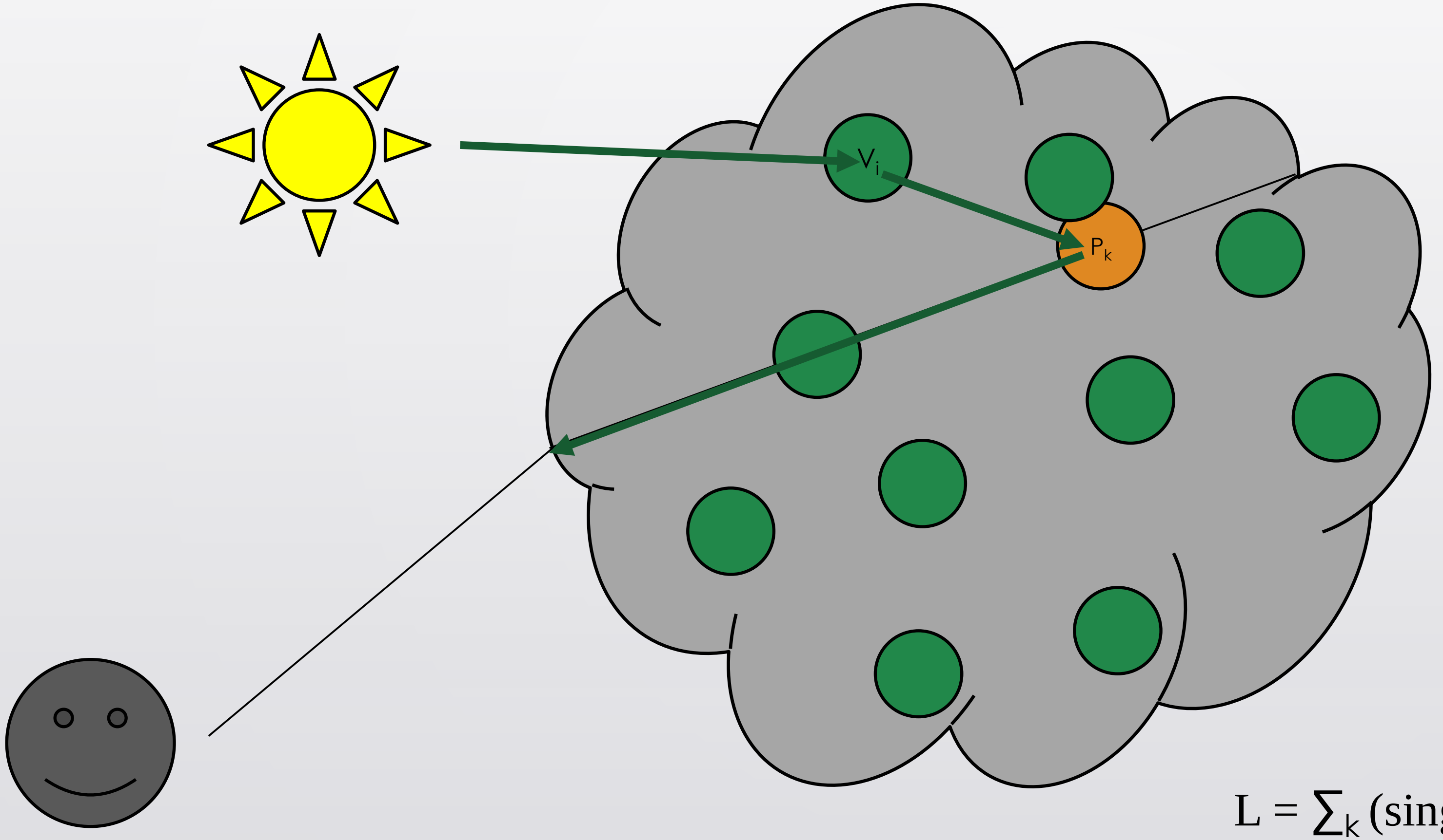




Caustic : light pattern made by reflection and refraction

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

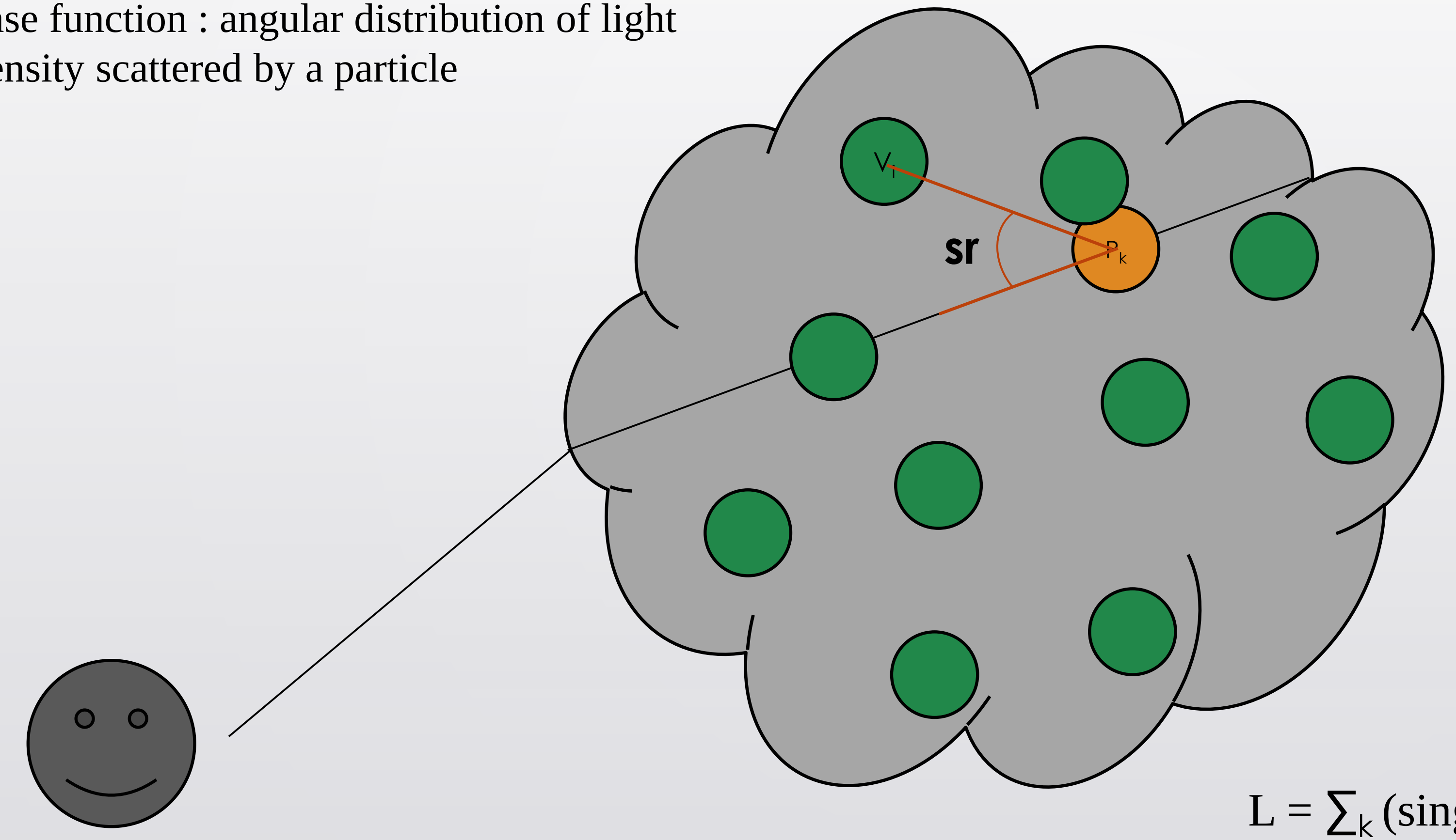
3. Double scattering



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

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_iP_k to scatter into camera direction. Use solid angle **sr** and phase function* of light vector V_iP_k.

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

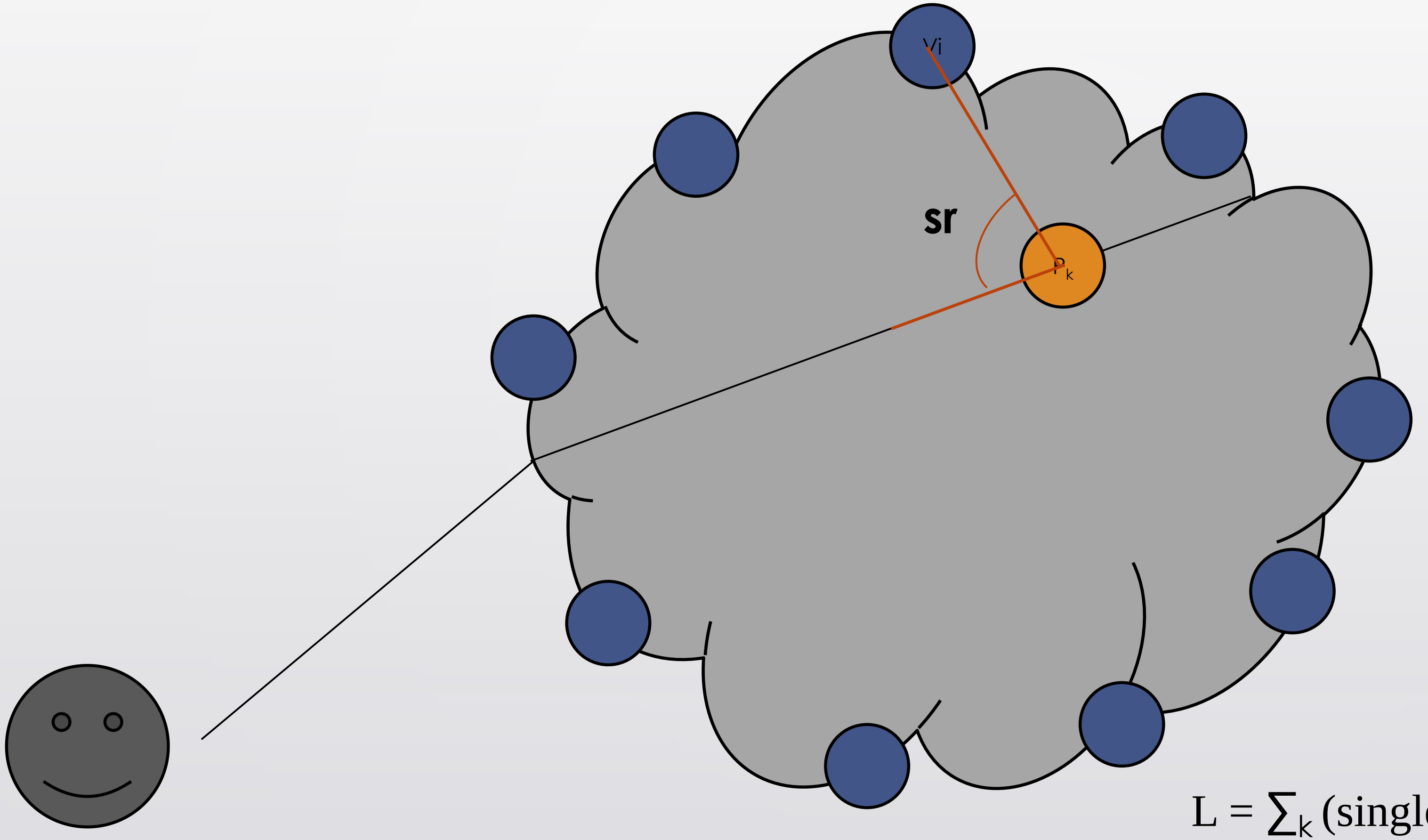
4. Multiple scattering

- 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

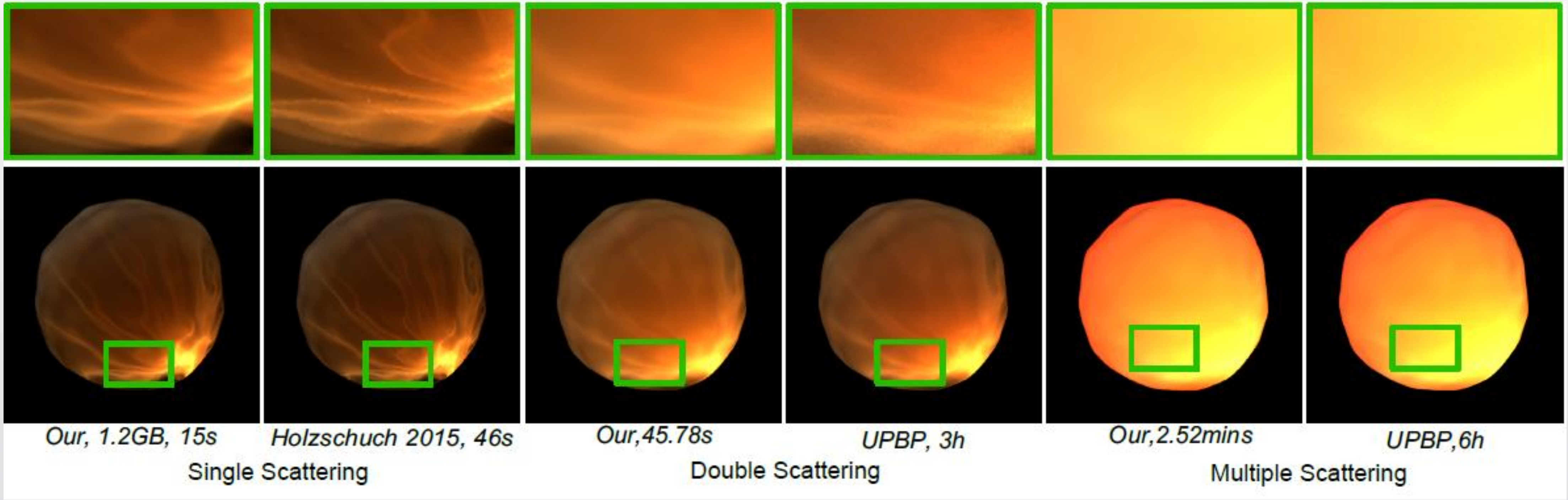


Our material is actually not an infinite medium. Light is bounced when it hits the refractive surface.

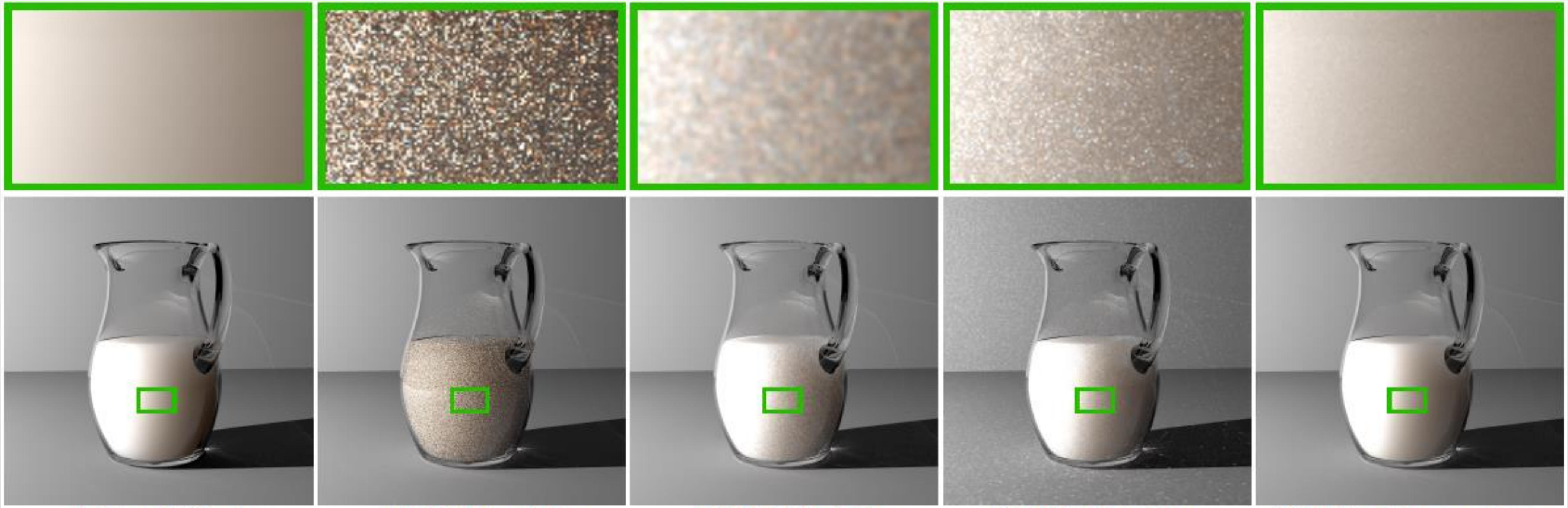
Bounced light is computed with surface samples. Accumulate all the radiance of surface samples, if light V_iP_k can be scattered into camera direction.

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

Result : Individual component analysis



Result - overall



(a) Our. 35.06 mins (b) BDPT, Equal Time (c) BRE, Equal Time (d) UPBP, Equal Time (e) UPBP, Reference. 6 hours

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.*

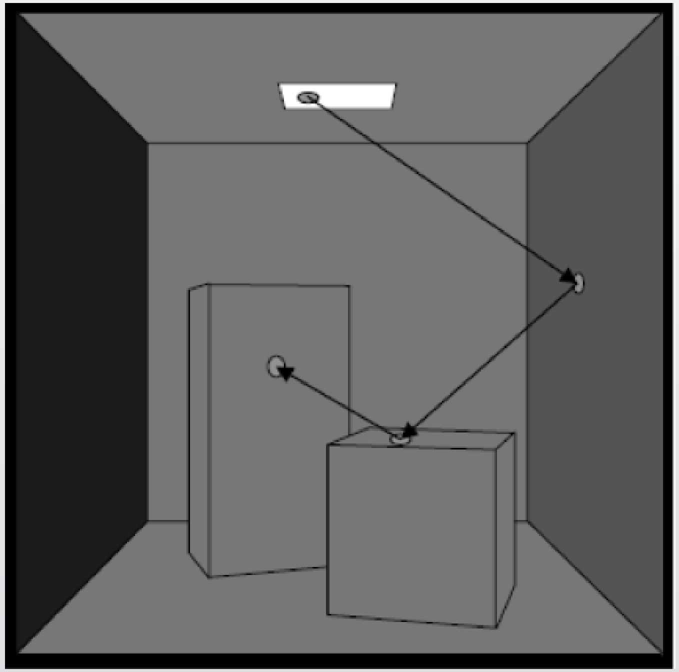
Beyond Points and Beams : Higher-Dimensional photon samples for volumetric light transport

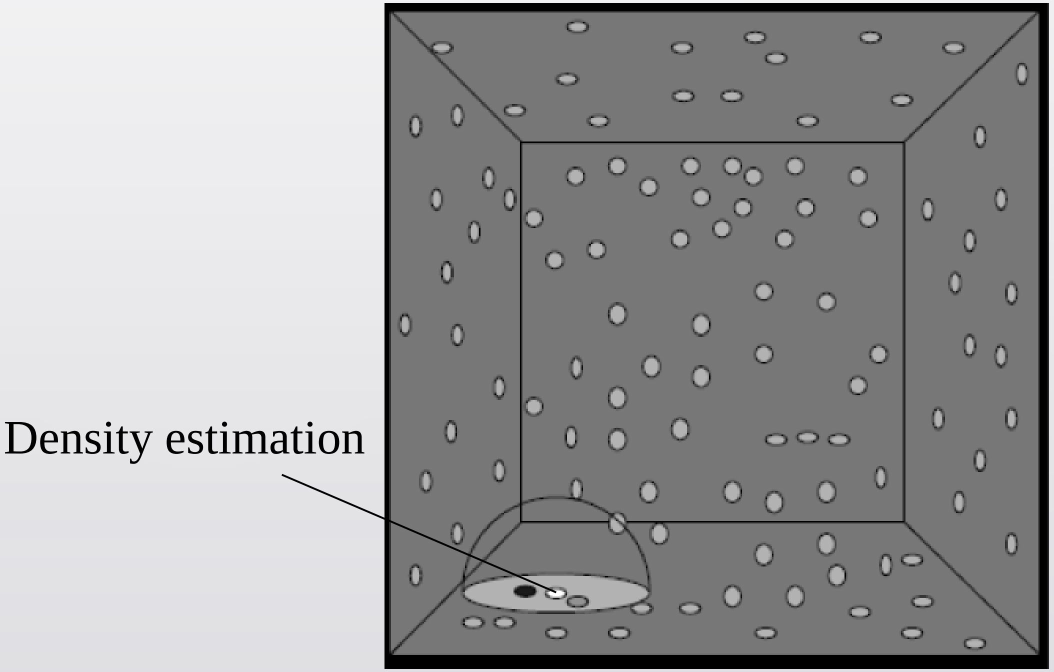
Beyond Points and Beams : Higher-Dimensional photon samples for volumetric light transport

- Generalized theory of density estimation
- Theoretical error analysis

Photon mapping

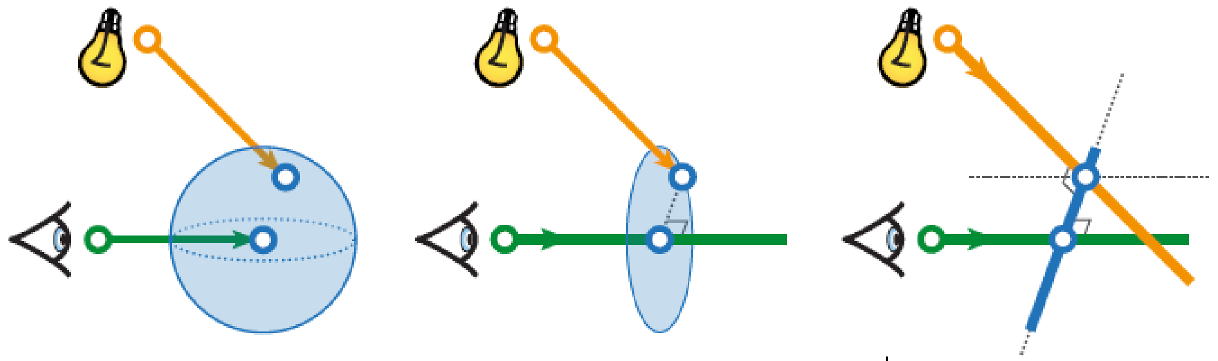
1. Shoot “photons” and record any hit-points
2. Shoot viewing rays and collect information from stored photons.





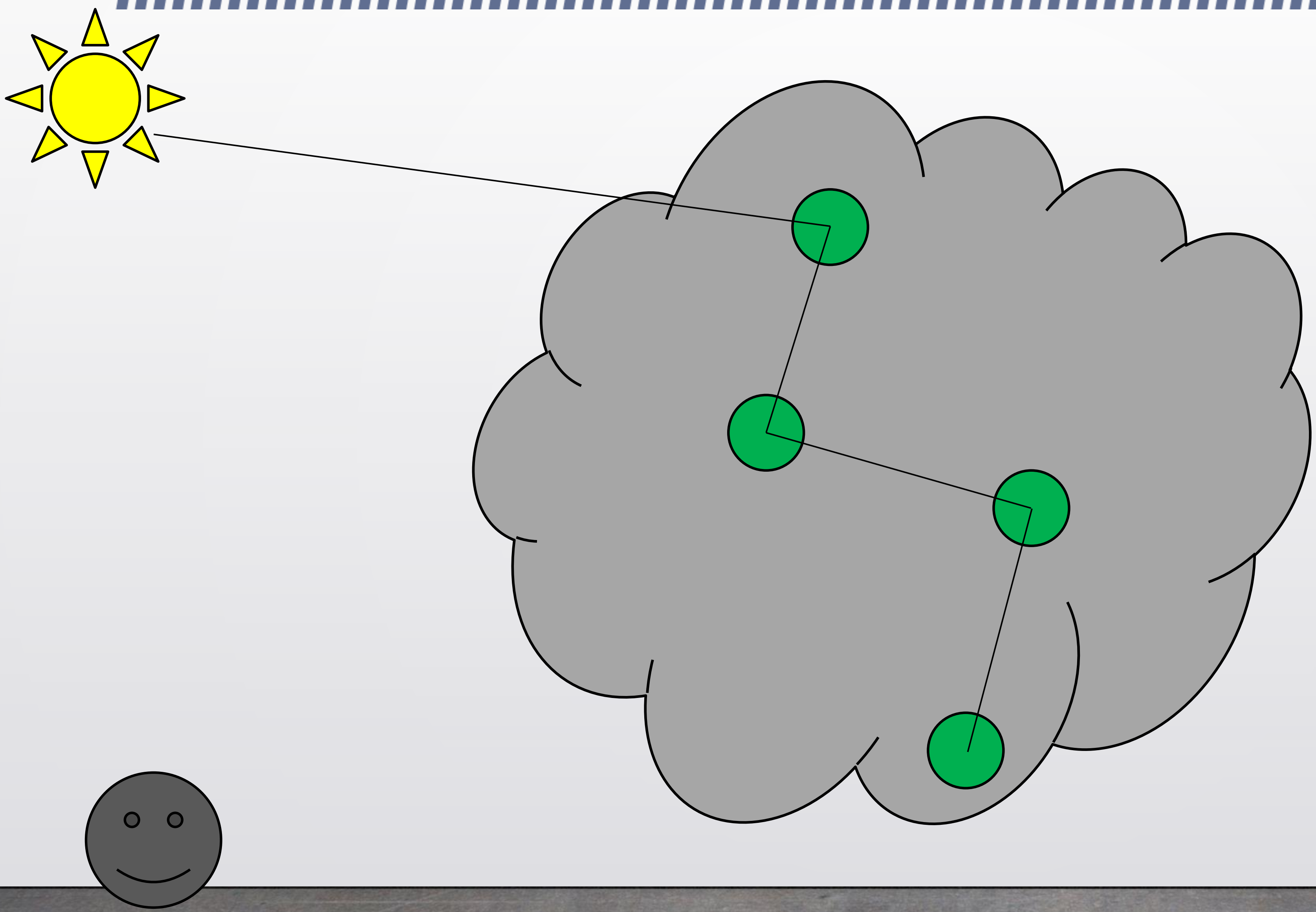
Density estimation?

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

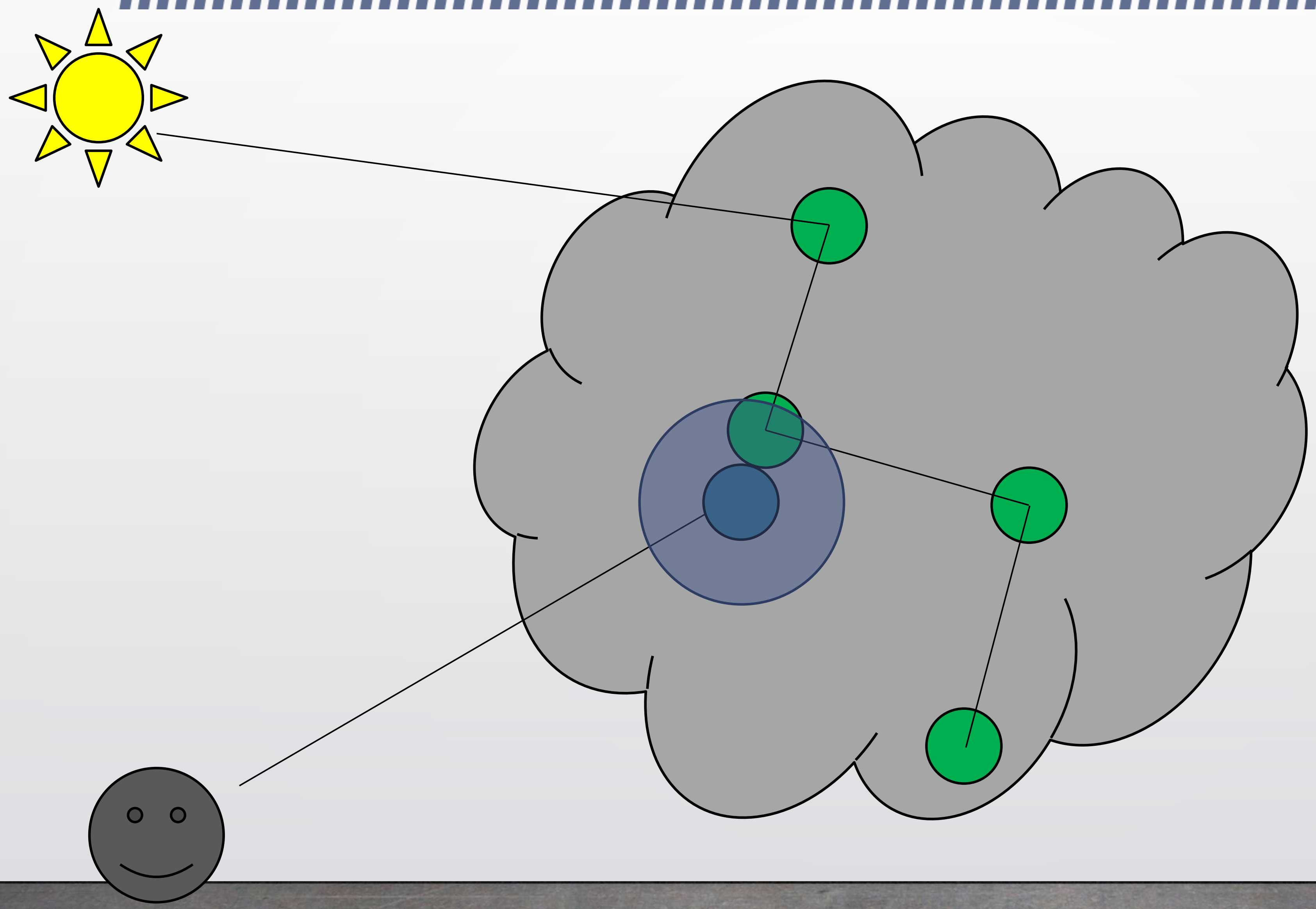


(a) Point-point 3D (b) Point-beam 2D (c) Beam-beam 1D

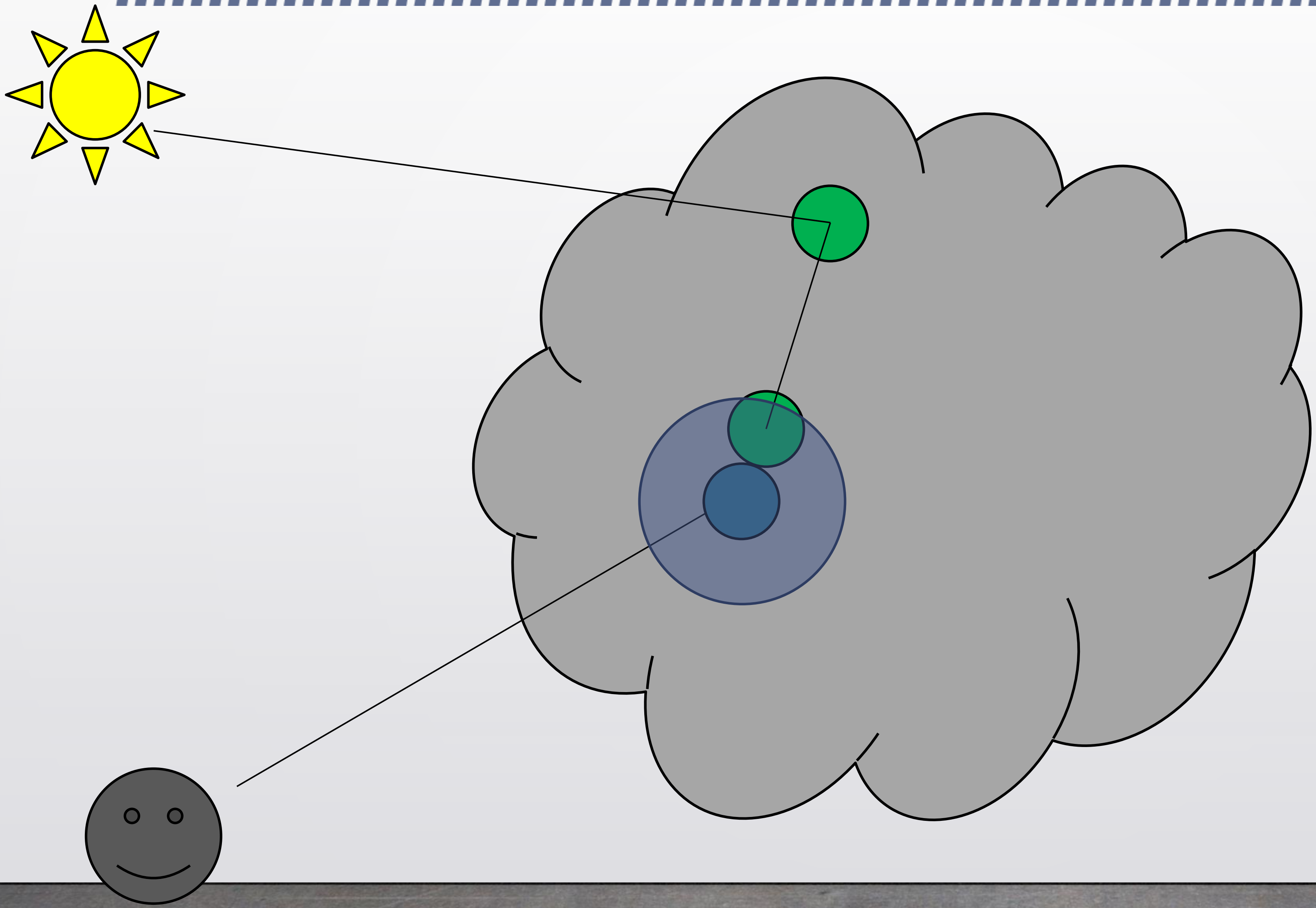
Figure 10: *Different volumetric photon density estimators and their corresponding kernel (i.e. blur) dimensionalities.*



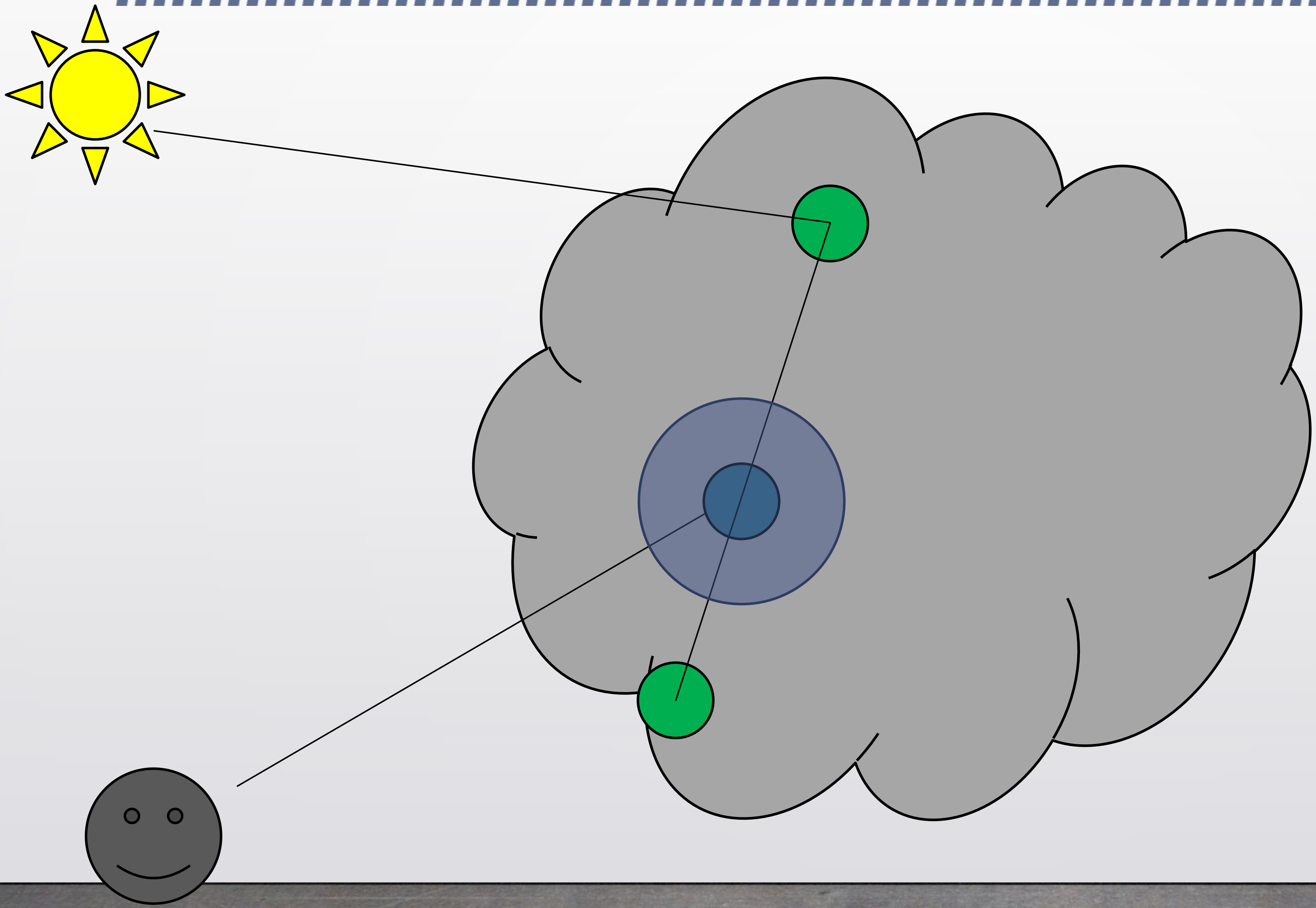
Shoot photon. Then it will scatter randomly with distance sampling.



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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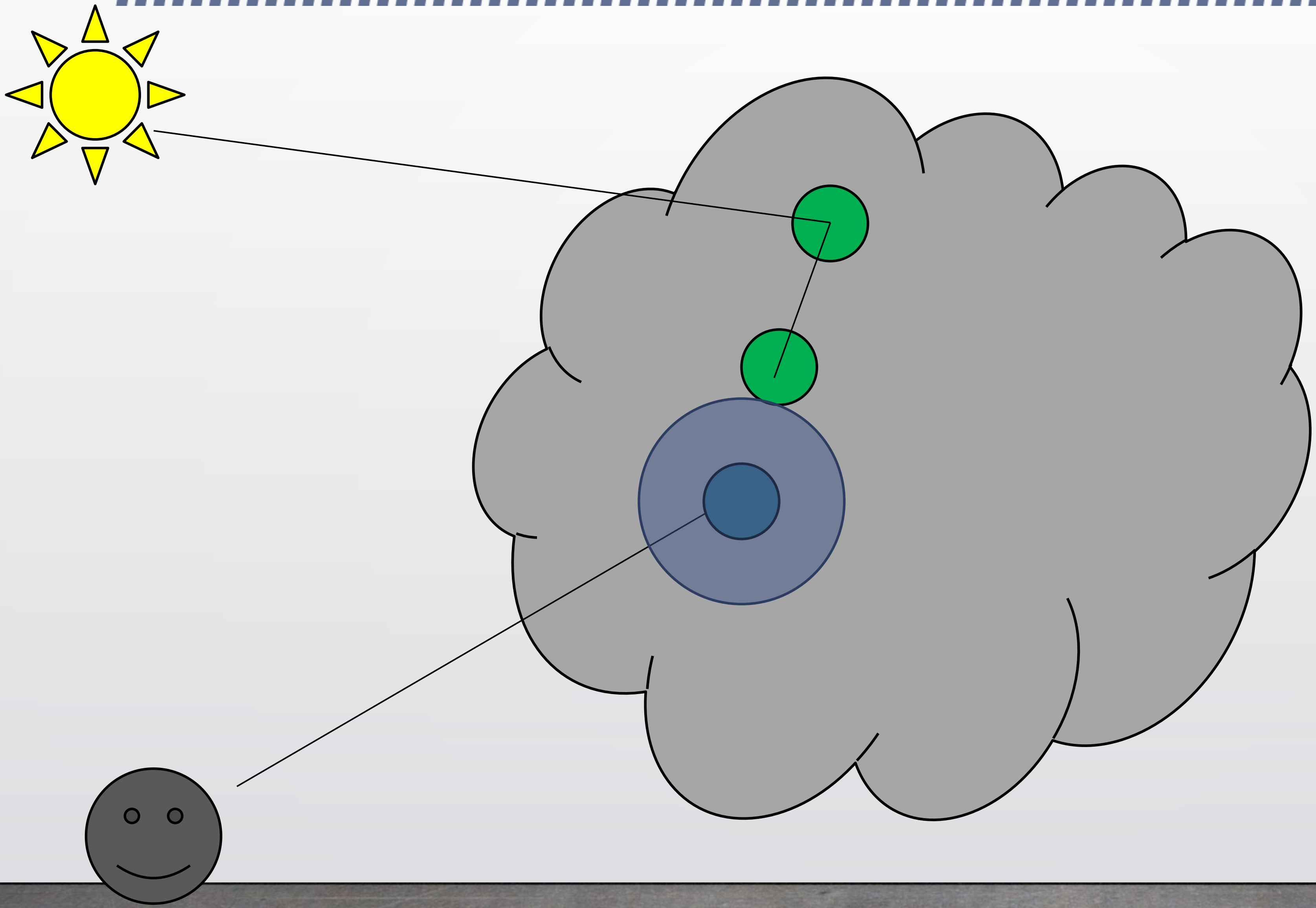

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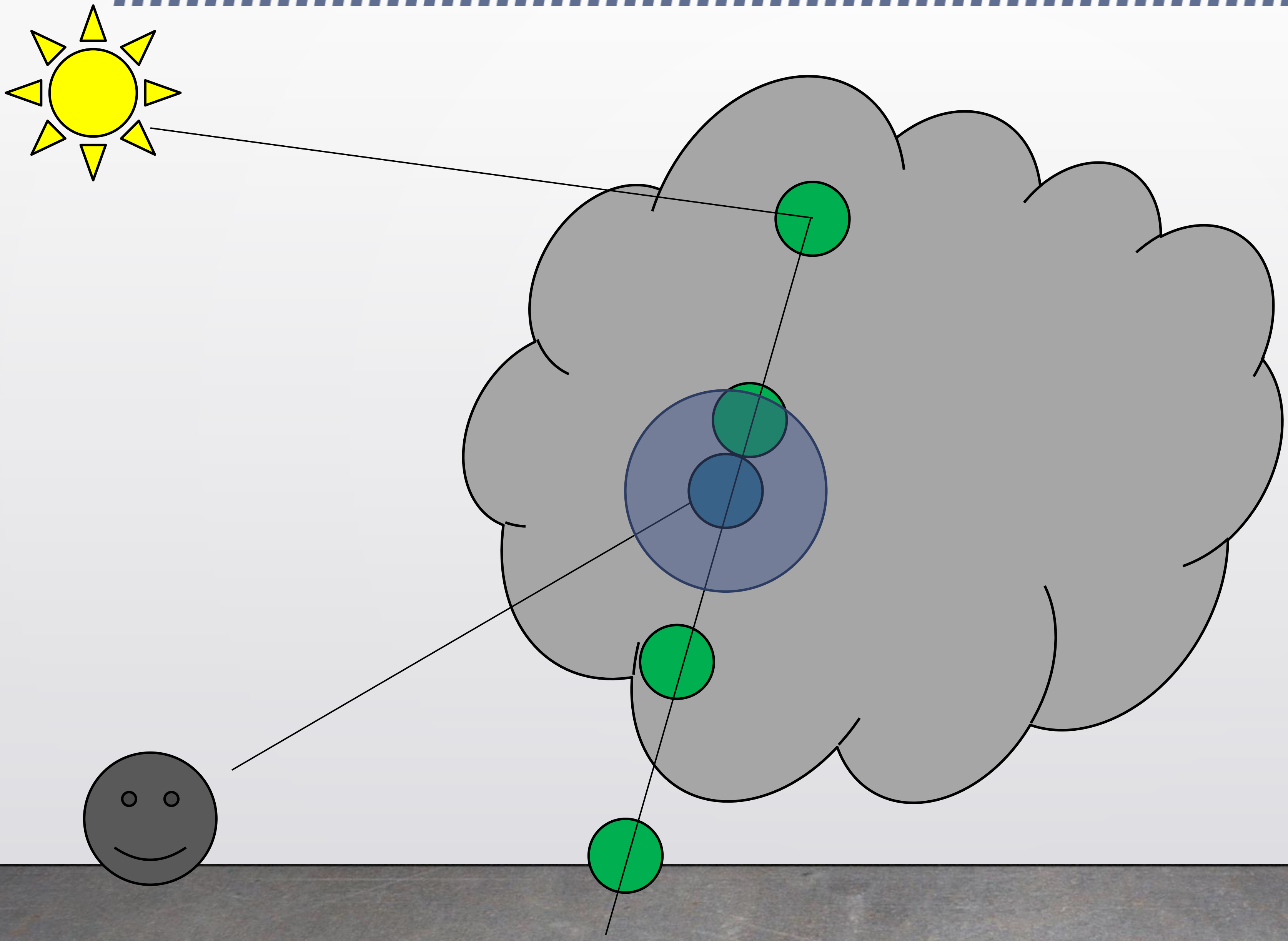
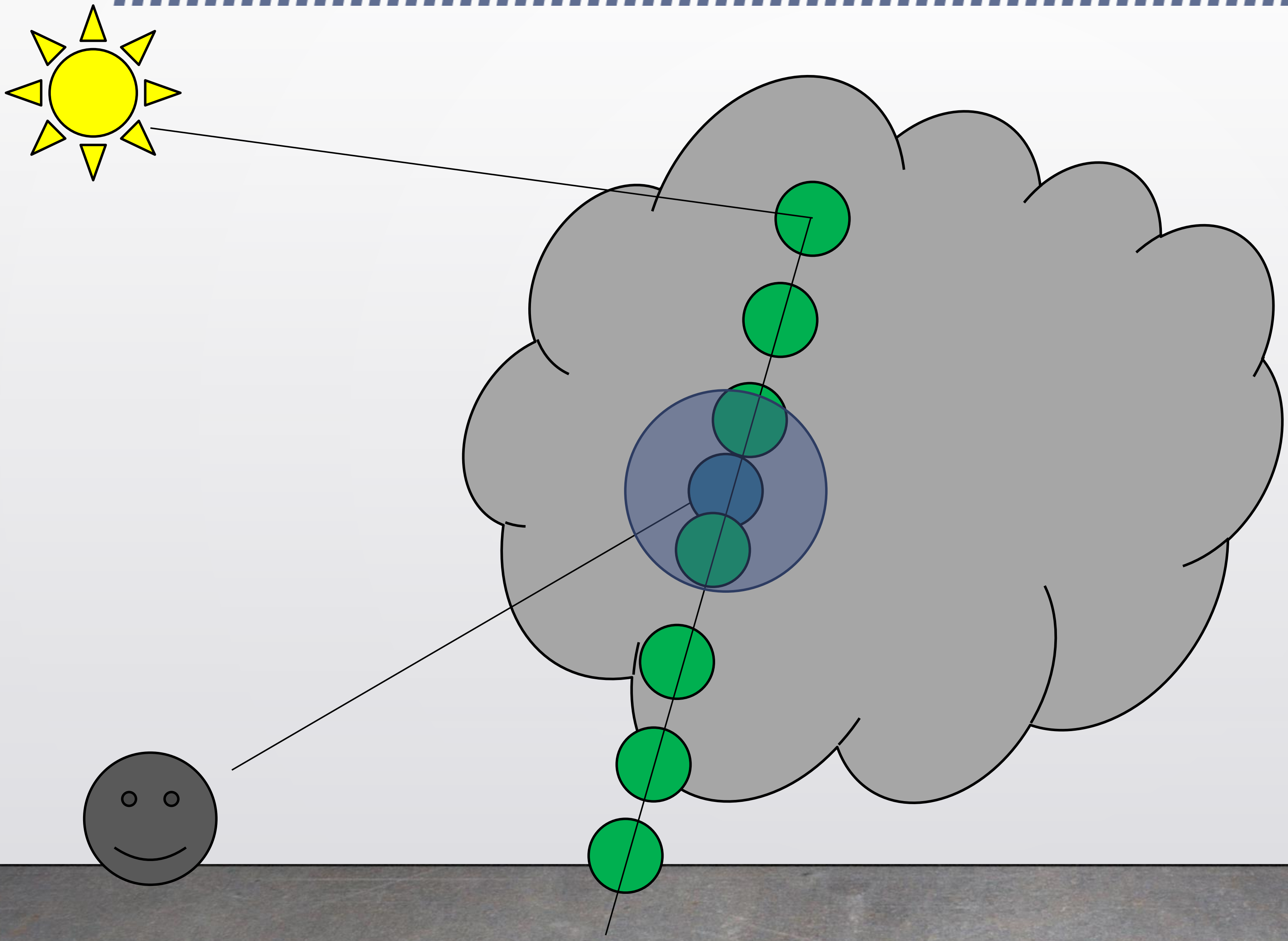


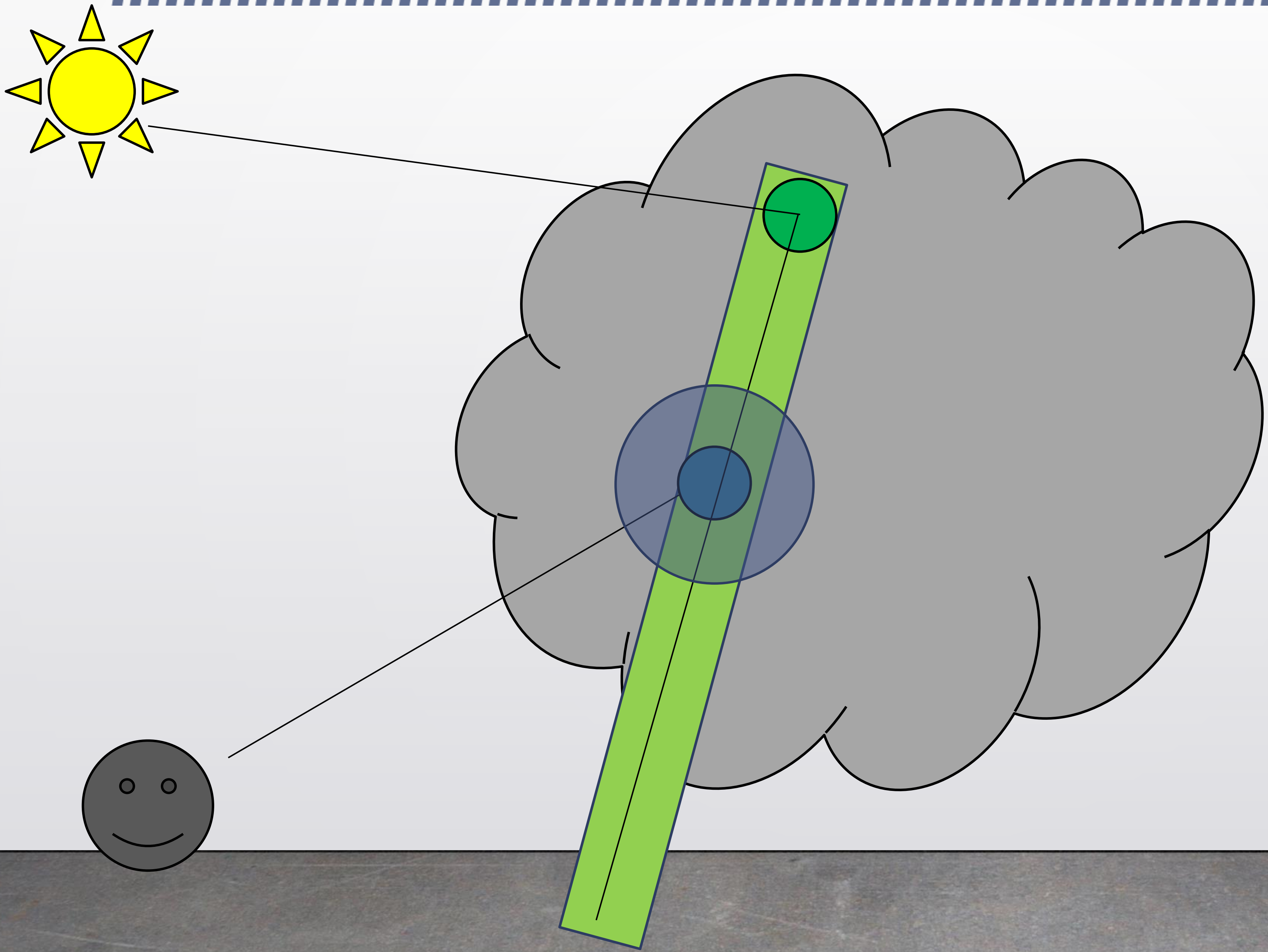
Let’s use method called “Marching”

Locate many photon samples to decrease the variance.



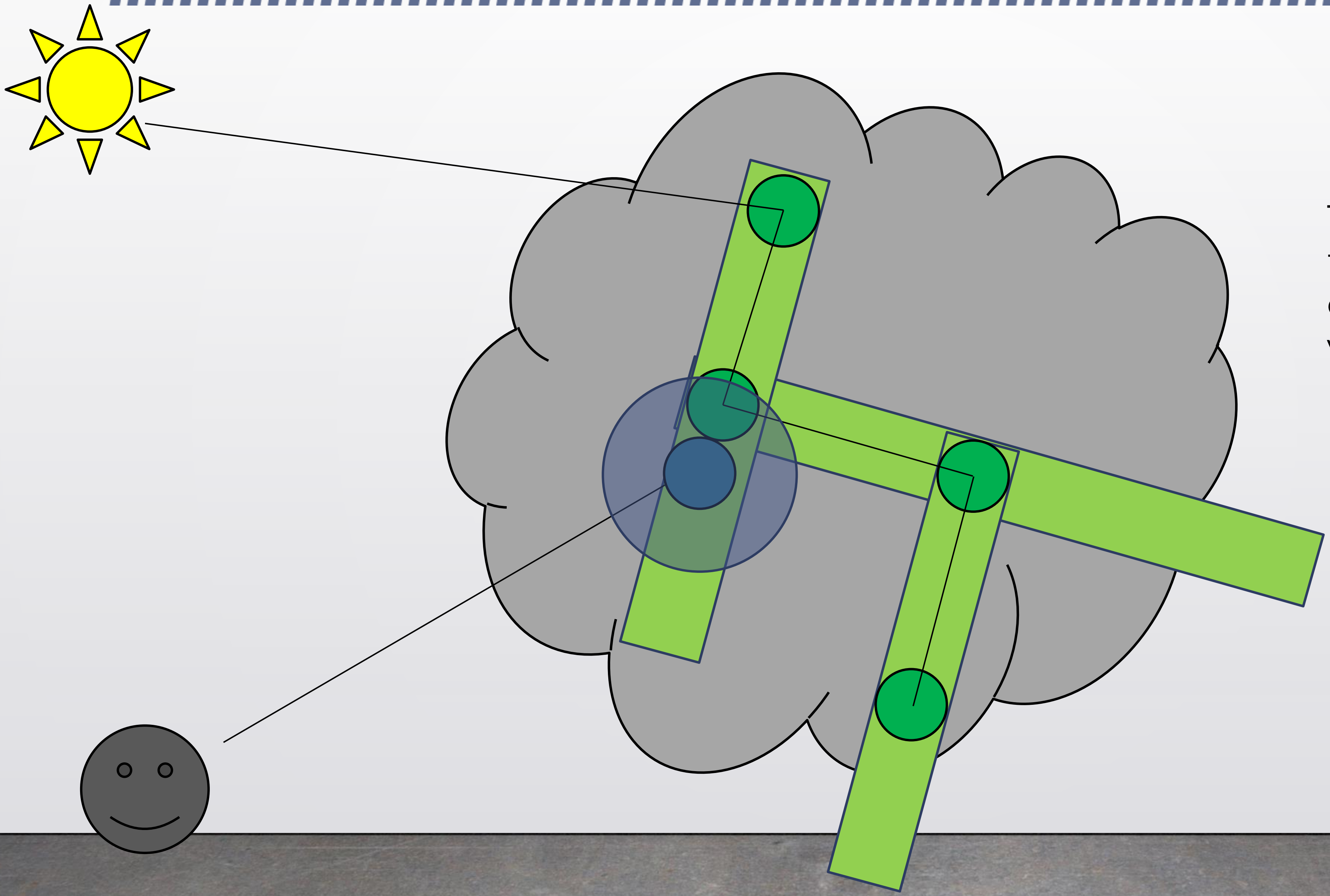
Sample more to further decrease the variance.

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



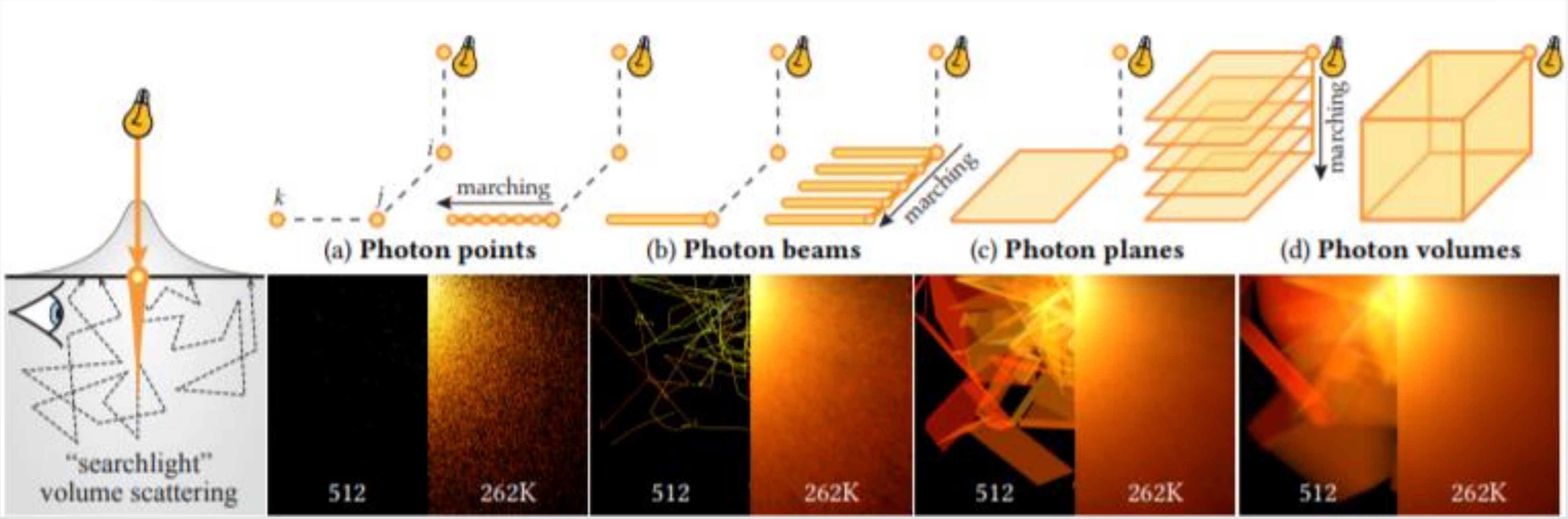
Sample more to further decrease the variance.

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

Beams
Planes, 0D Blur (Ours)
Variance: 0.41x
Planes, 1D Blur (Ours)
Variance: 0.09x
Beams
Planes, 0D Blur (Ours)
Variance: 0.27x
Planes, 1D Blur (Ours)
Variance: 0.07x

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).