Next Event Estimation++
Visibility Mapping for Efficient Light Transport Simulation

Jerry Guo, *Martin Eisemann & Elmar Eisemann

TU Delft, *TH Köln
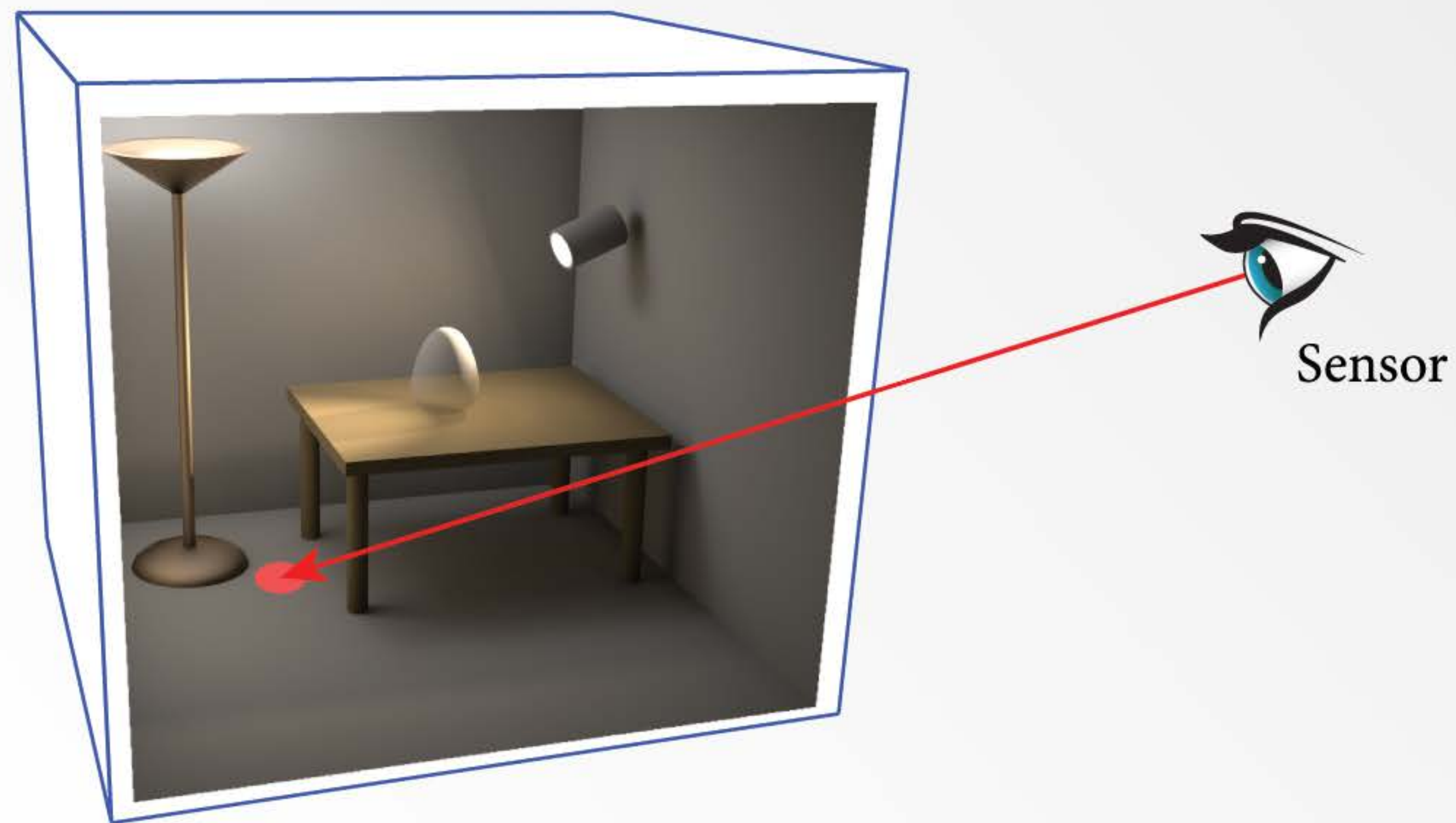
TUDelft

CGV

PG20+21
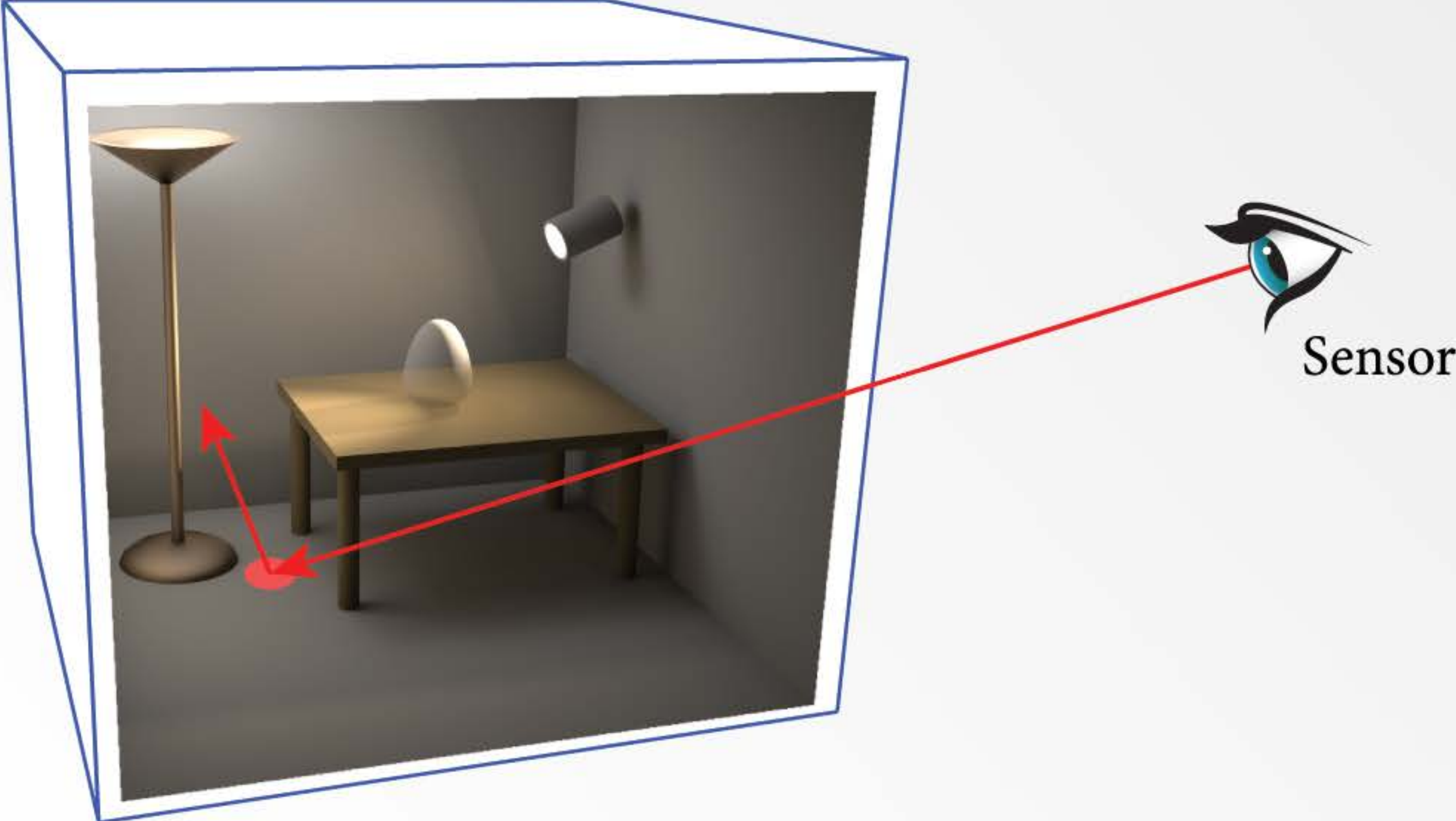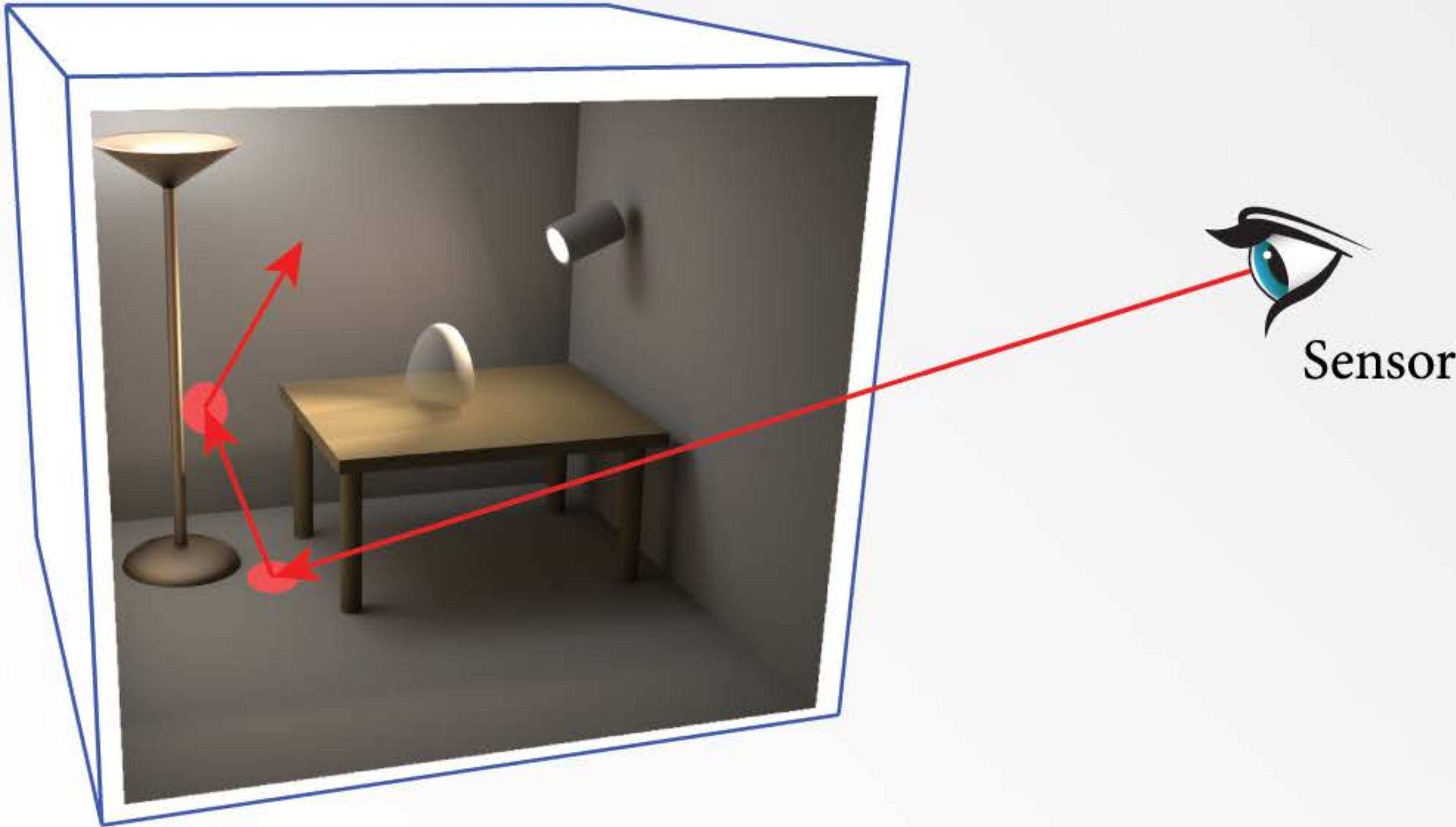WELLINGTON NZ

Uni-directional Path Tracing

Uni-directional Path Tracing

Sensor

Uni-directional Path Tracing

Sensor

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Sensor

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Uni-directional Path Tracing

$$L(\mathrm{x}, \omega_o) = L_e(\mathrm{x}, \omega_o) + \int_\Omega f_s(\mathrm{x}, \omega_i, \omega_o) L_i(\mathrm{x}, \omega_i) G(\mathrm{x}, \omega_i, \omega_o) \mathrm{d}\omega_i$$

Sensor

L_e Emitting luminance

f_s Bi-directional scatterding distribution function

L_i Incident luminance

G Geometry term
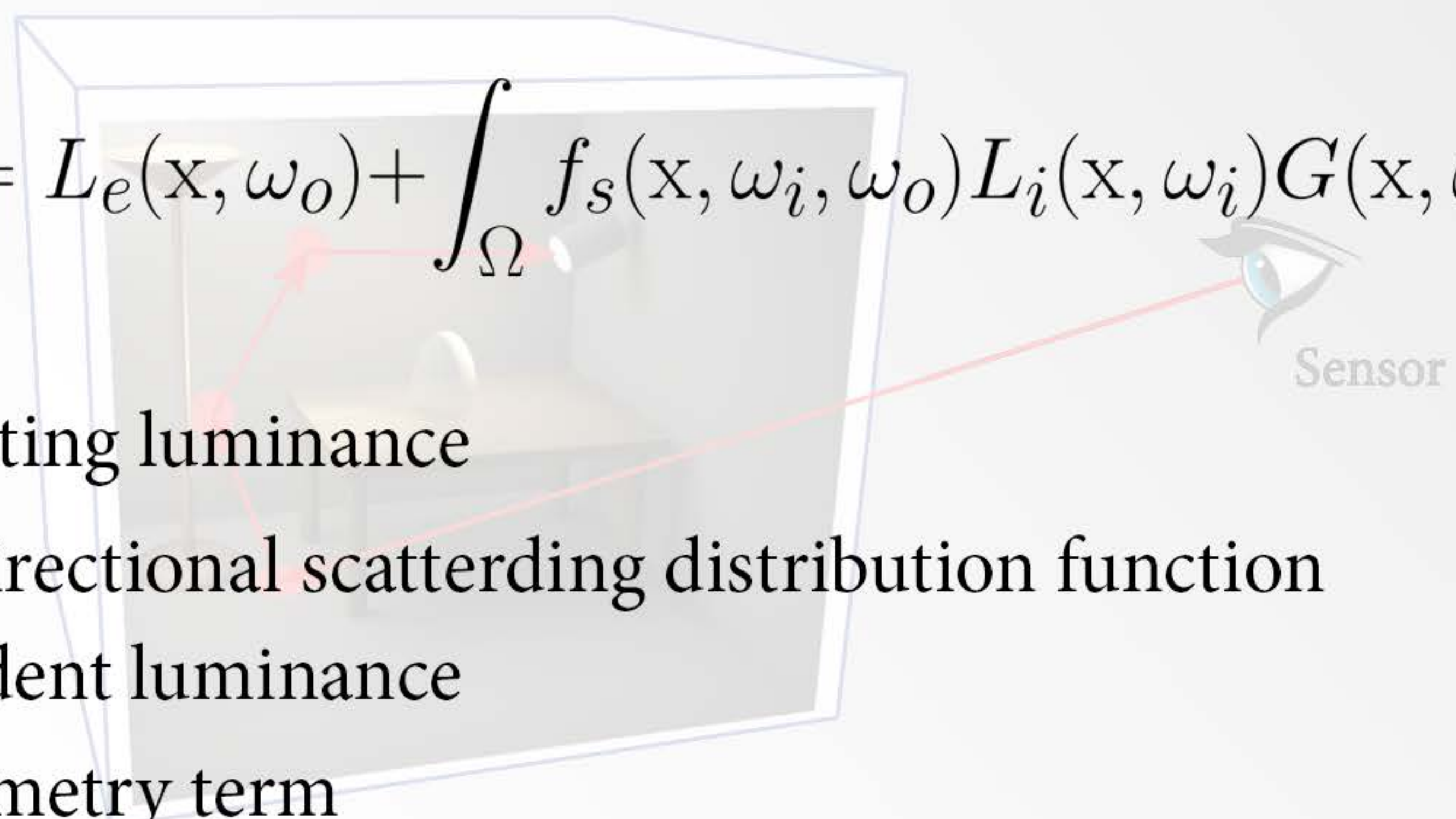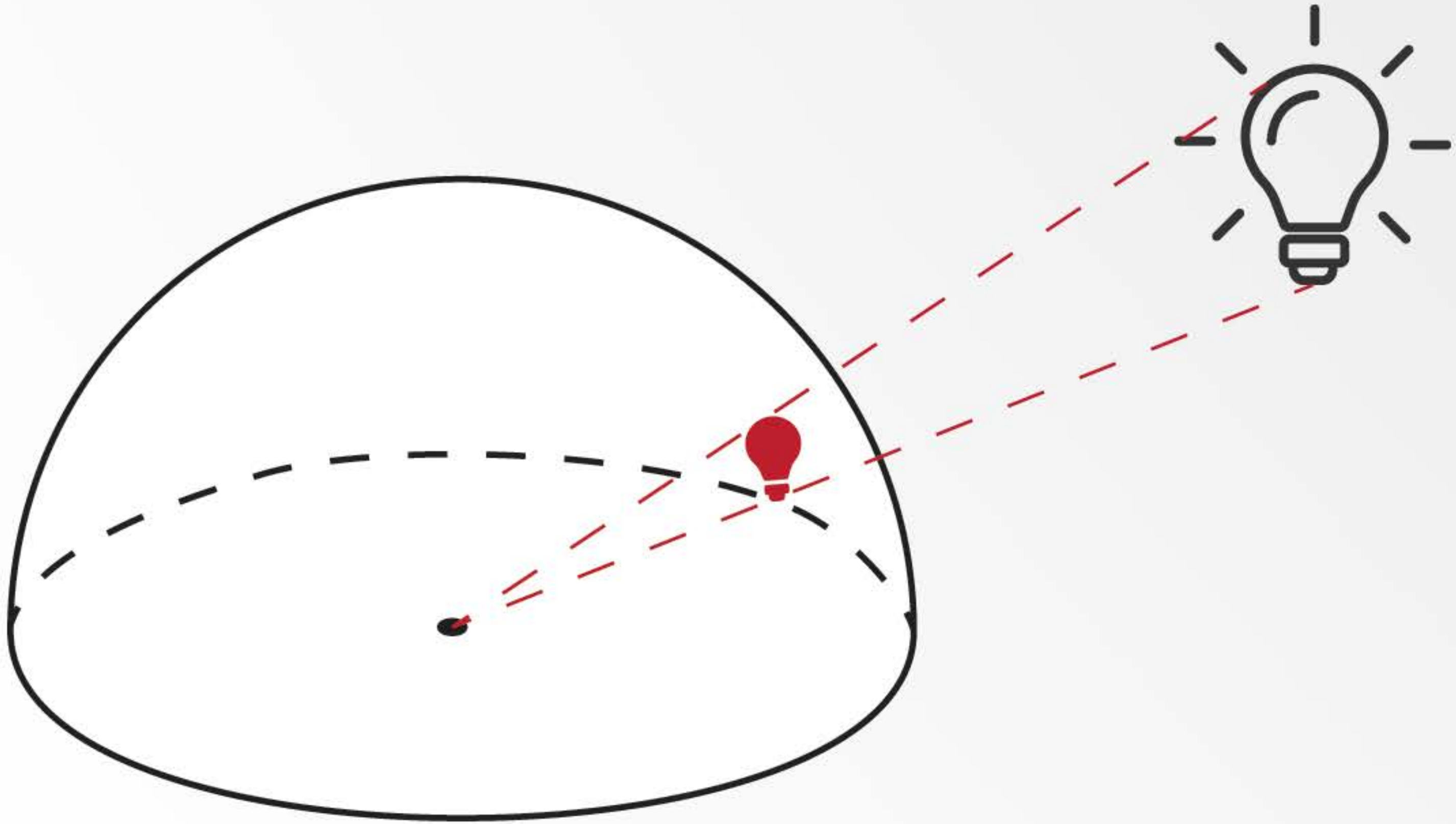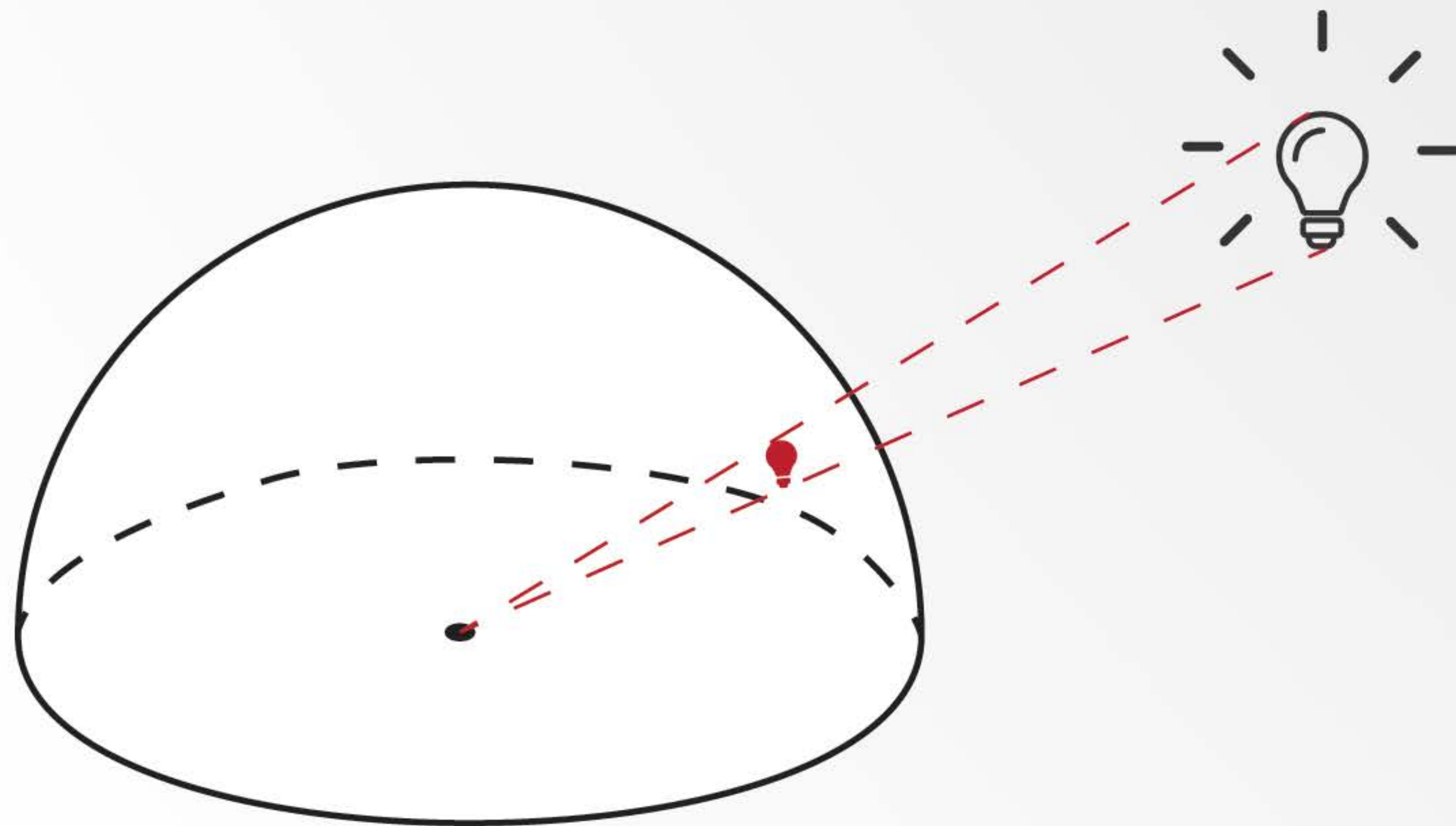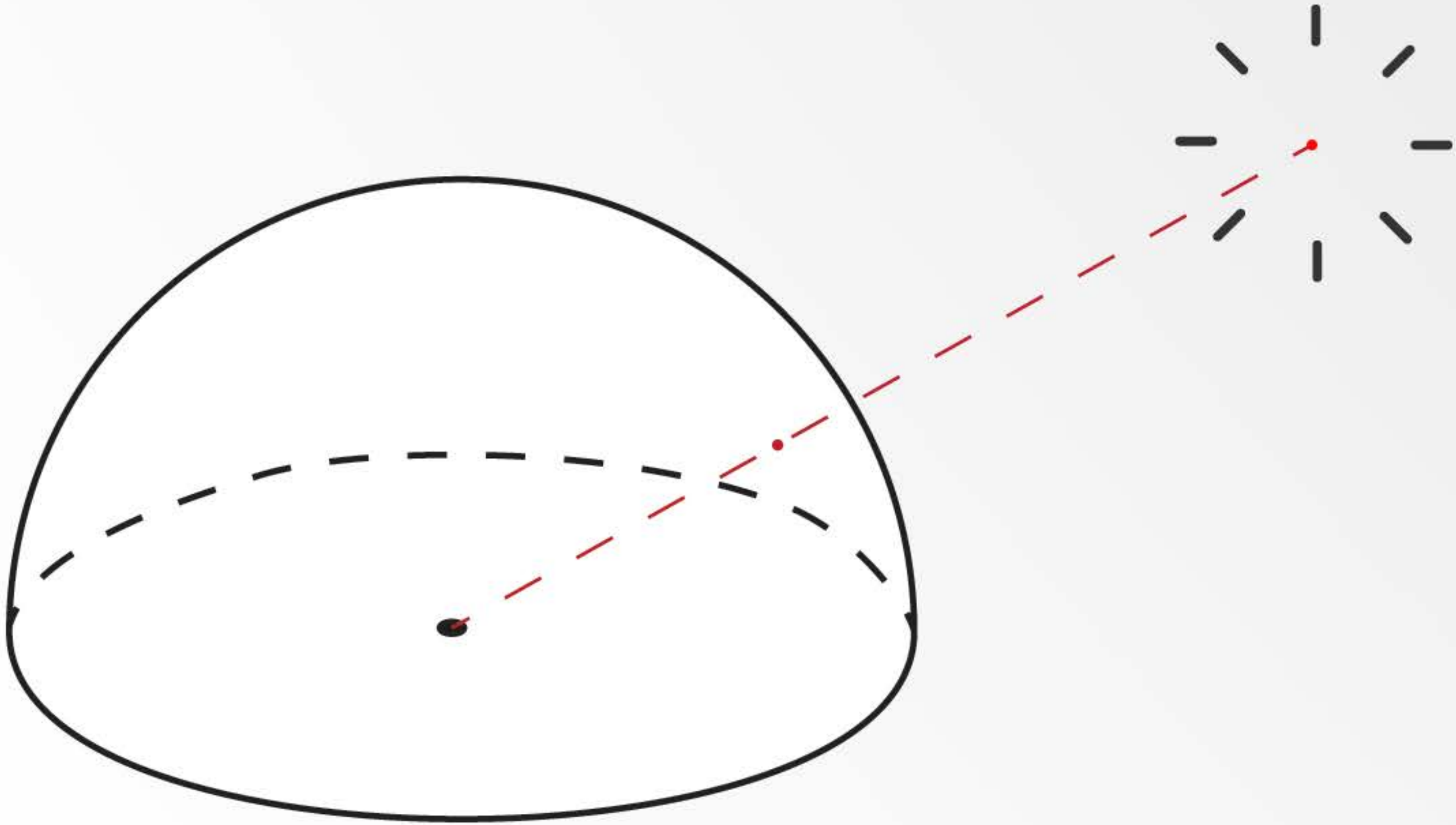
Uni-directional Path Tracing
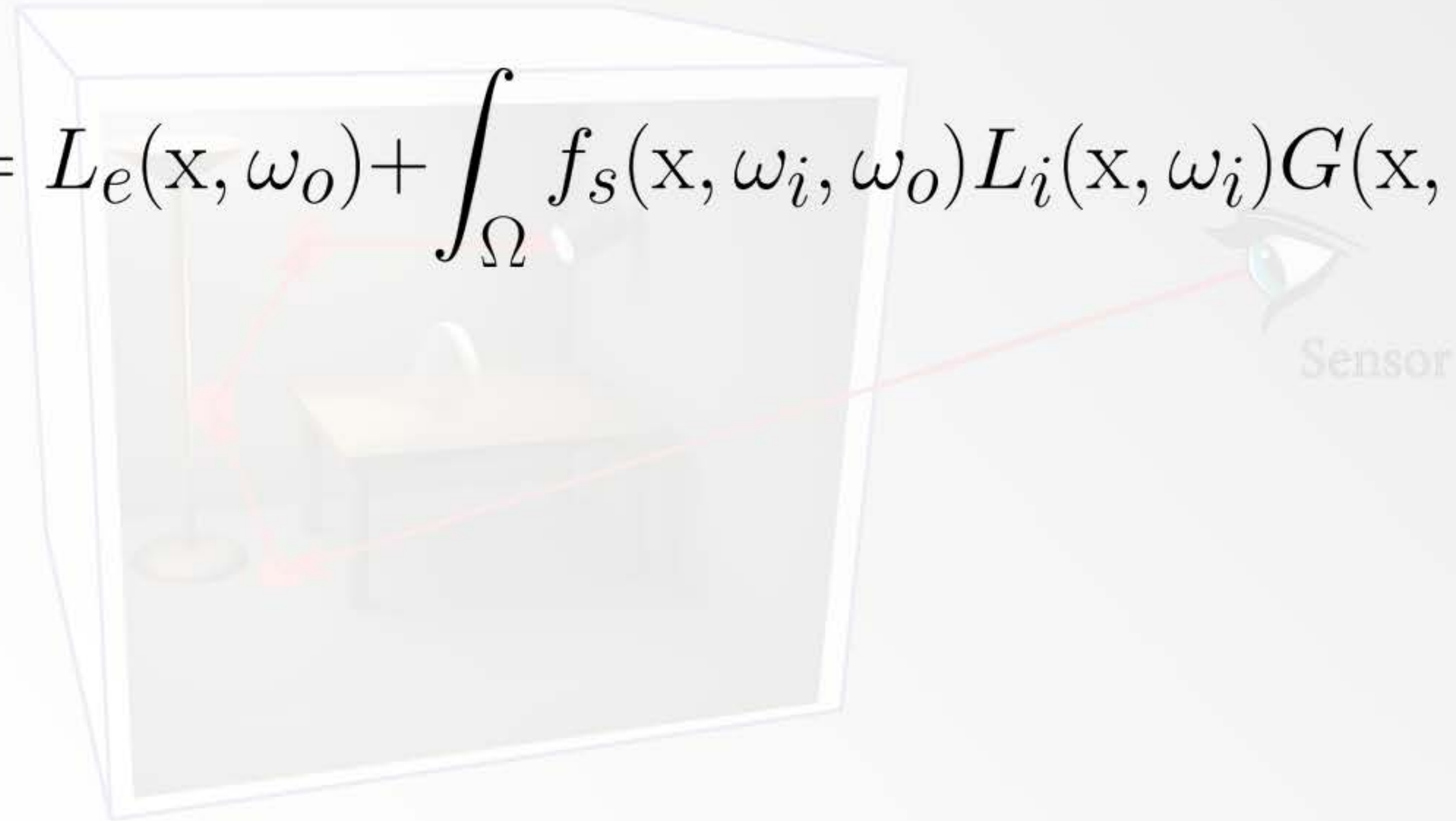
Uni-directional Path Tracing

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Uni-directional Path Tracing

$$L(\mathrm{x}, \omega_o) = L_e(\mathrm{x}, \omega_o) + \int_{\Omega} f_s(\mathrm{x}, \omega_i, \omega_o) L_i(\mathrm{x}, \omega_i) G(\mathrm{x}, \omega_i, \omega_o) \mathrm{d}\omega_i$$
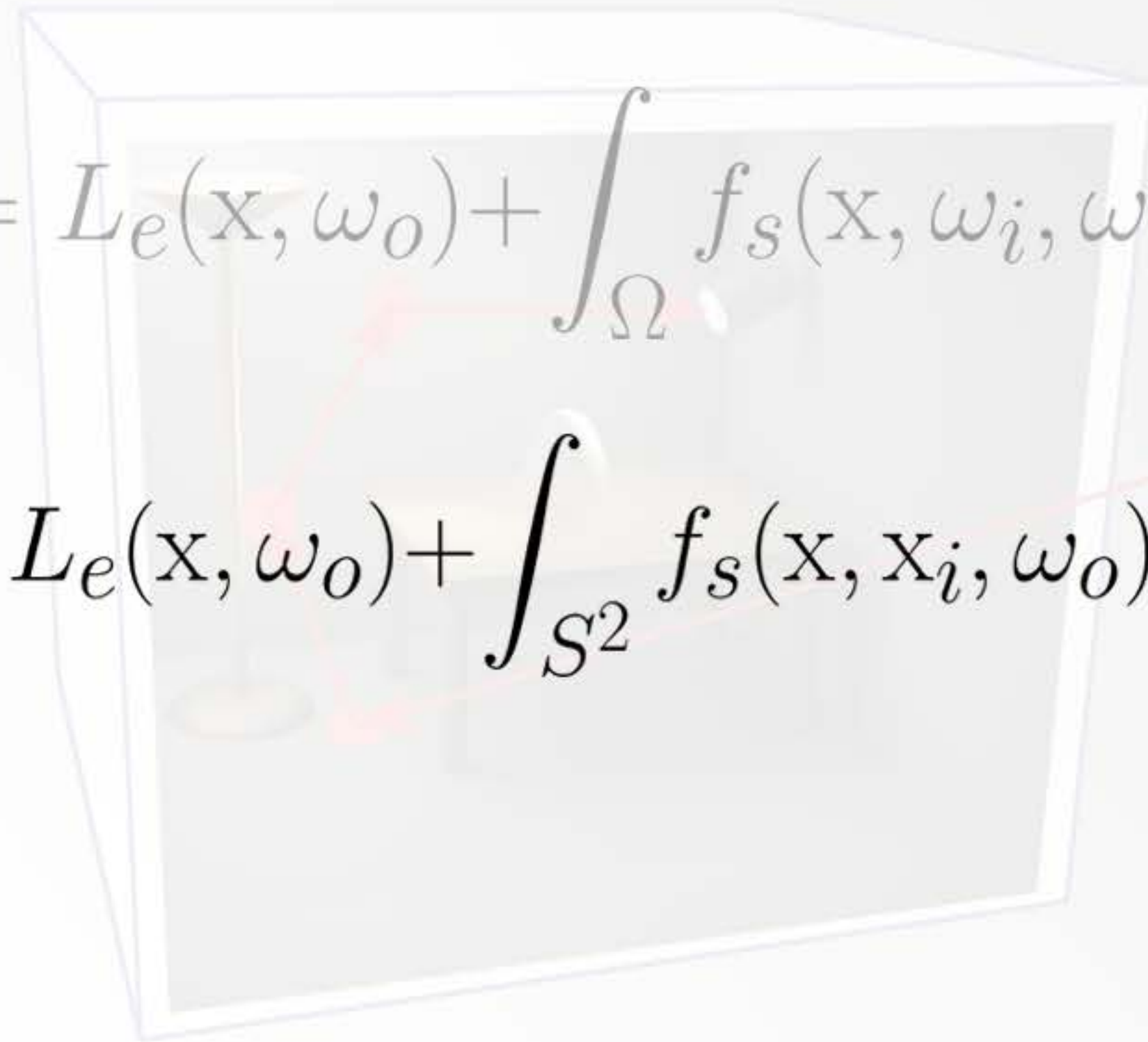
Sensor

Uni-directional Path Tracing

$$L(\mathrm{x}, \omega_o) = L_e(\mathrm{x}, \omega_o) + \int_\Omega f_s(\mathrm{x}, \omega_i, \omega_o) L_i(\mathrm{x}, \omega_i) G(\mathrm{x}, \omega_i, \omega_o) \mathrm{d}\omega_i$$

$$L(\mathrm{x}, \omega_o) = L_e(\mathrm{x}, \omega_o) + \int_{S^2} f_s(\mathrm{x}, \mathrm{x}_i, \omega_o) L_i(\mathrm{x}, \mathrm{x}_i) G(\mathrm{x}, \mathrm{x}_i) V(\mathrm{x}, \mathrm{x}_i) \mathrm{d}\mathrm{x}_i$$
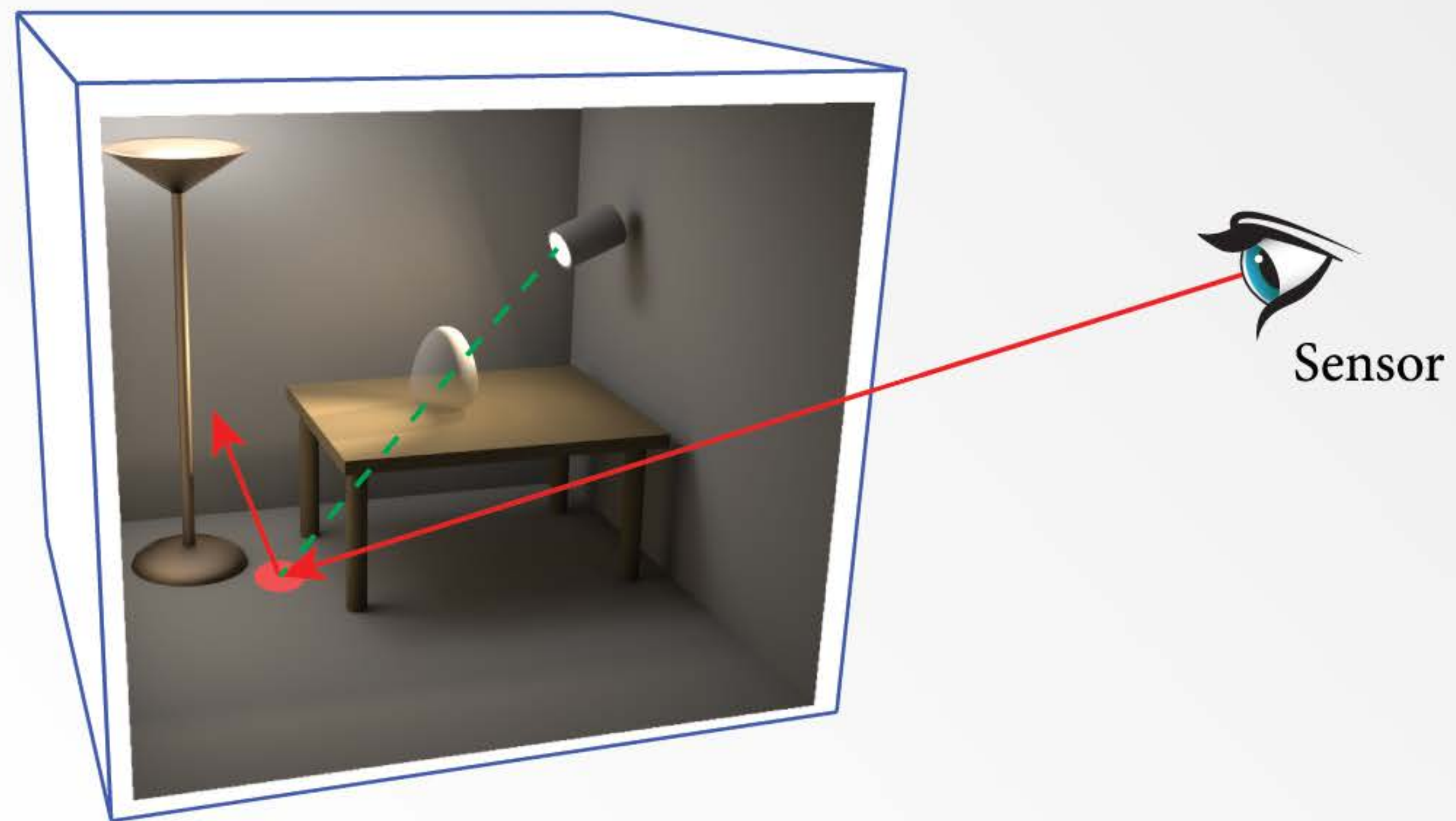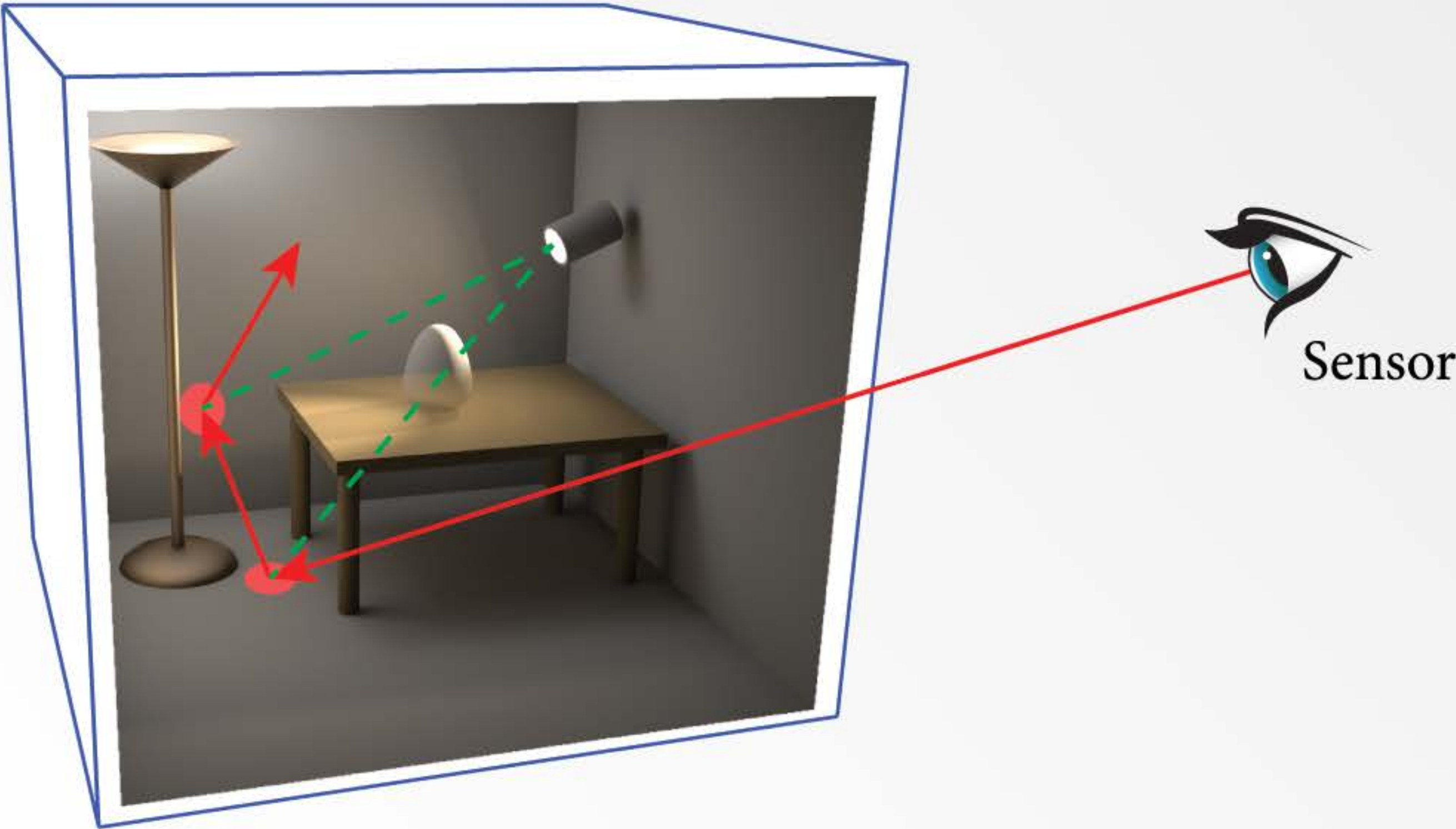
Sensor

Uni-directional Path Tracing

$$L(\mathrm{x}, \omega_o) = L_e(\mathrm{x}, \omega_o) + \int_{S^2} f_s(\mathrm{x}, \mathrm{x}_i, \omega_o) \textcolor{red}{L_i(\mathrm{x}, \mathrm{x}_i) G(\mathrm{x}, \mathrm{x}_i)} V(\mathrm{x}, \mathrm{x}_i) \mathrm{dx}_i$$

Uni-directional Path Tracing

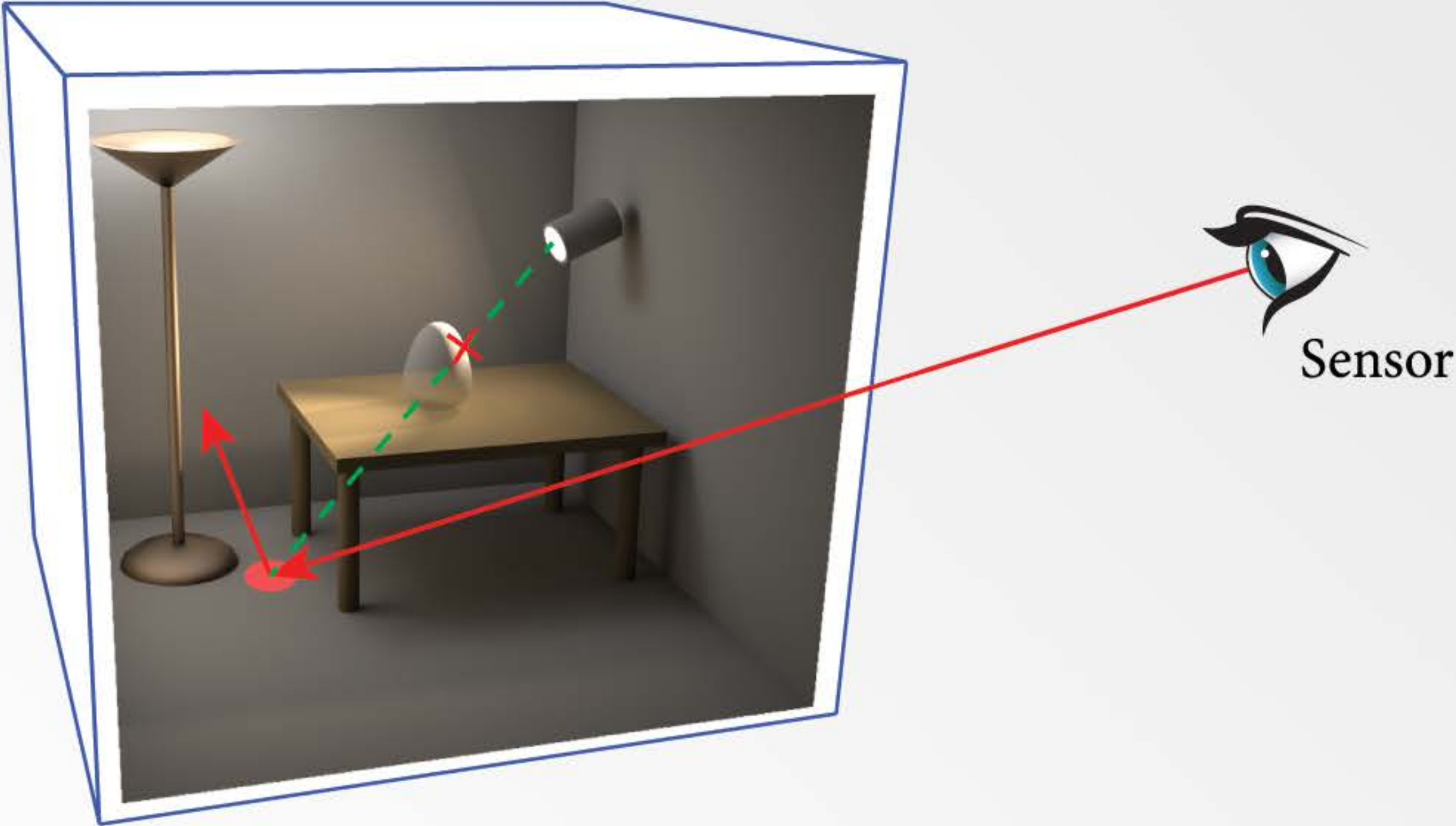# Uni-directional Path Tracing

Sensor

Uni-directional Path Tracing

$$L(\mathrm{x}, \omega_o) = L_e(\mathrm{x}, \omega_o) + \int_{S^2} f_s(\mathrm{x}, \mathrm{x}_i, \omega_o) L_i(\mathrm{x}, \mathrm{x}_i) G(\mathrm{x}, \mathrm{x}_i) \color{red}{V(\mathrm{x}, \mathrm{x}_i)} \color{black}{\mathrm{dx}_i}$$
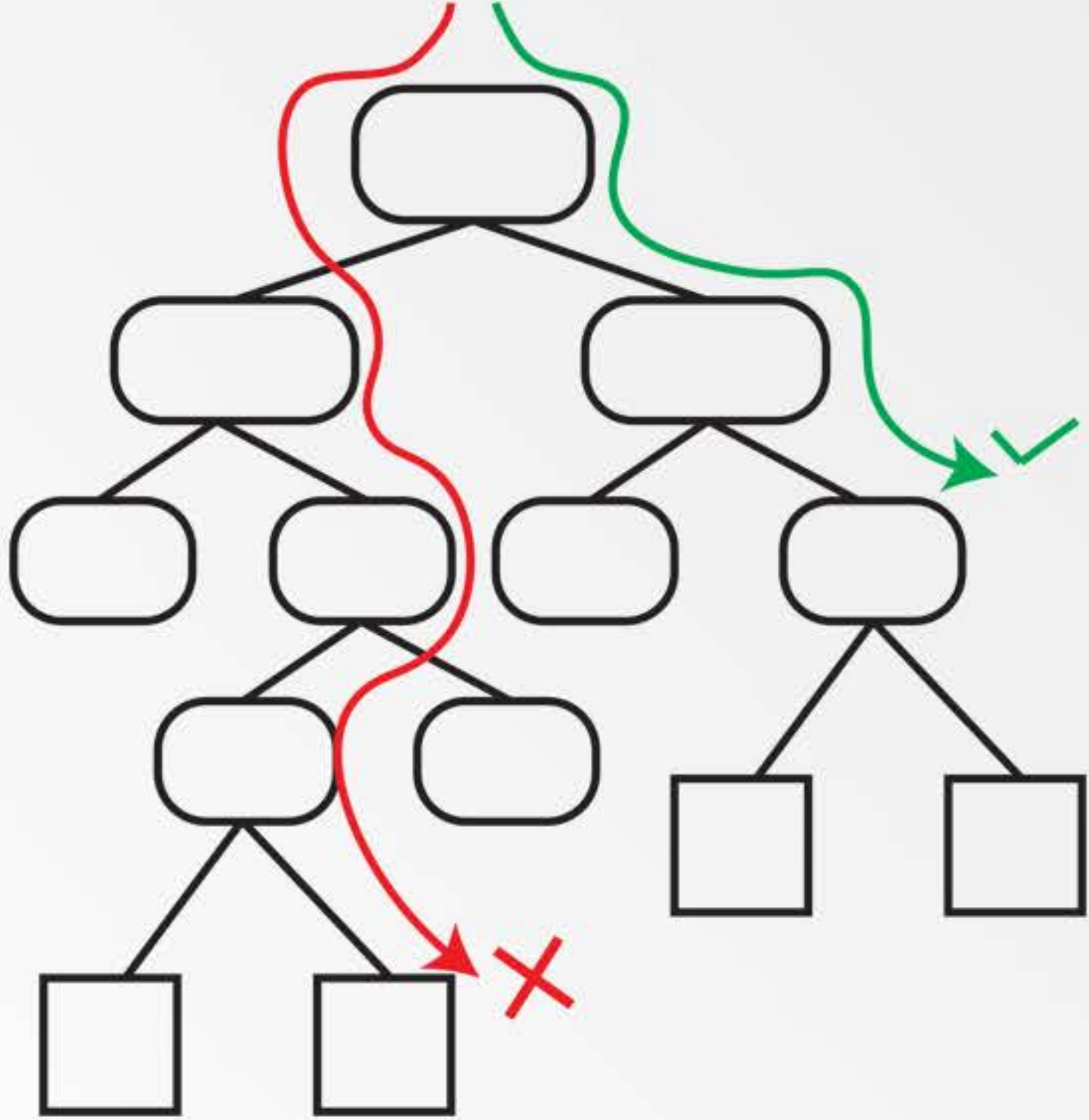
Uni-directional Path Tracing
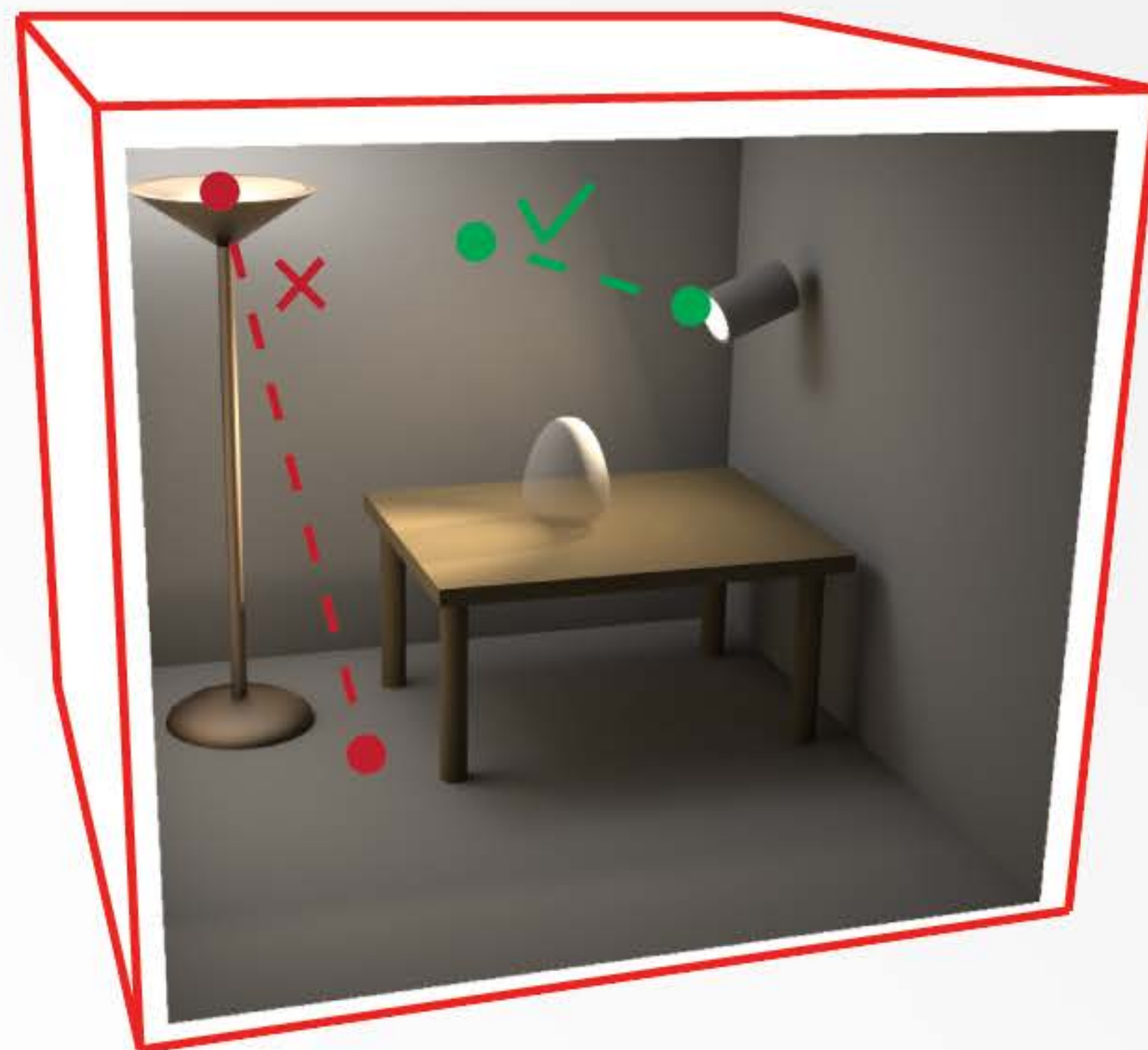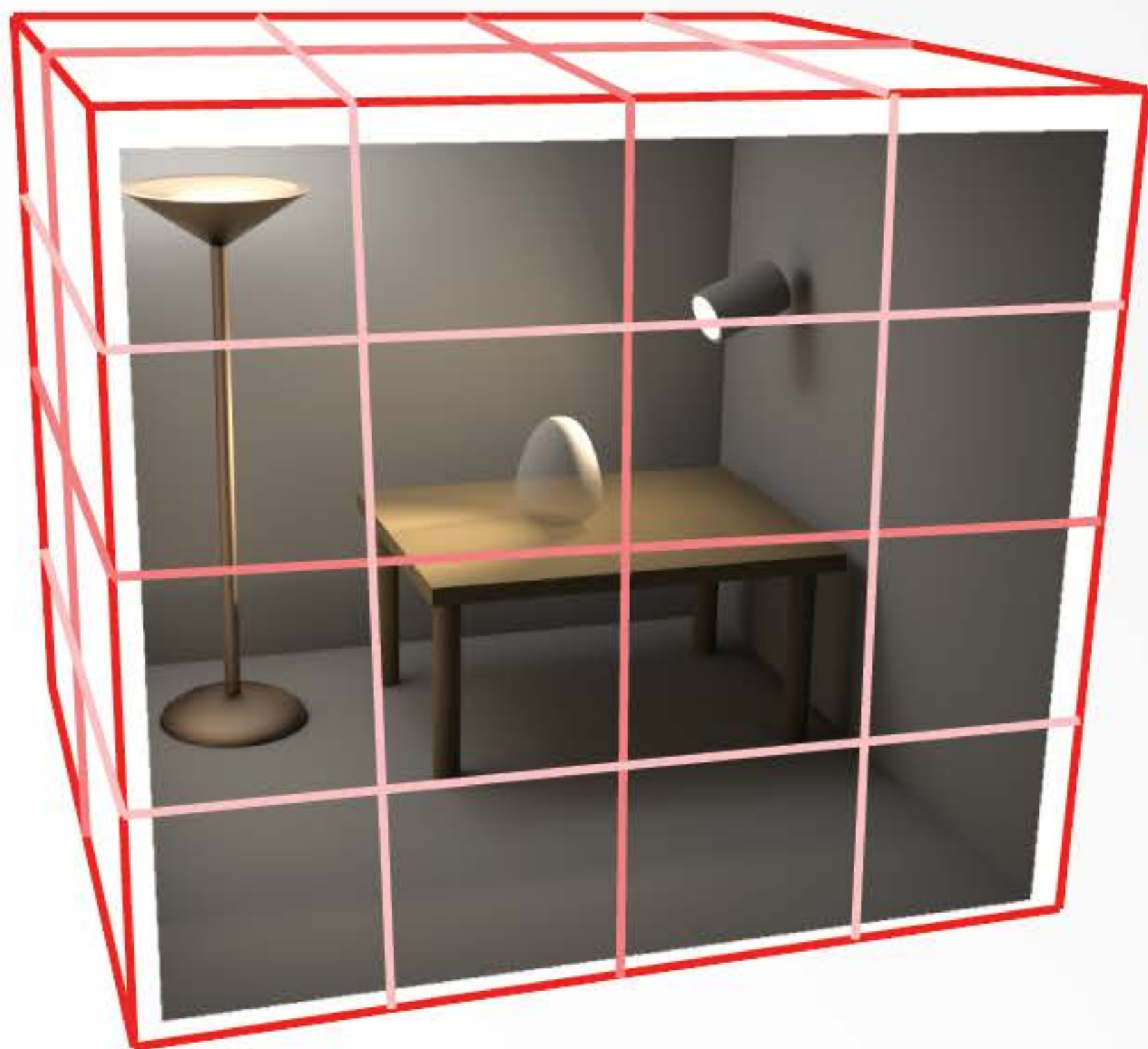

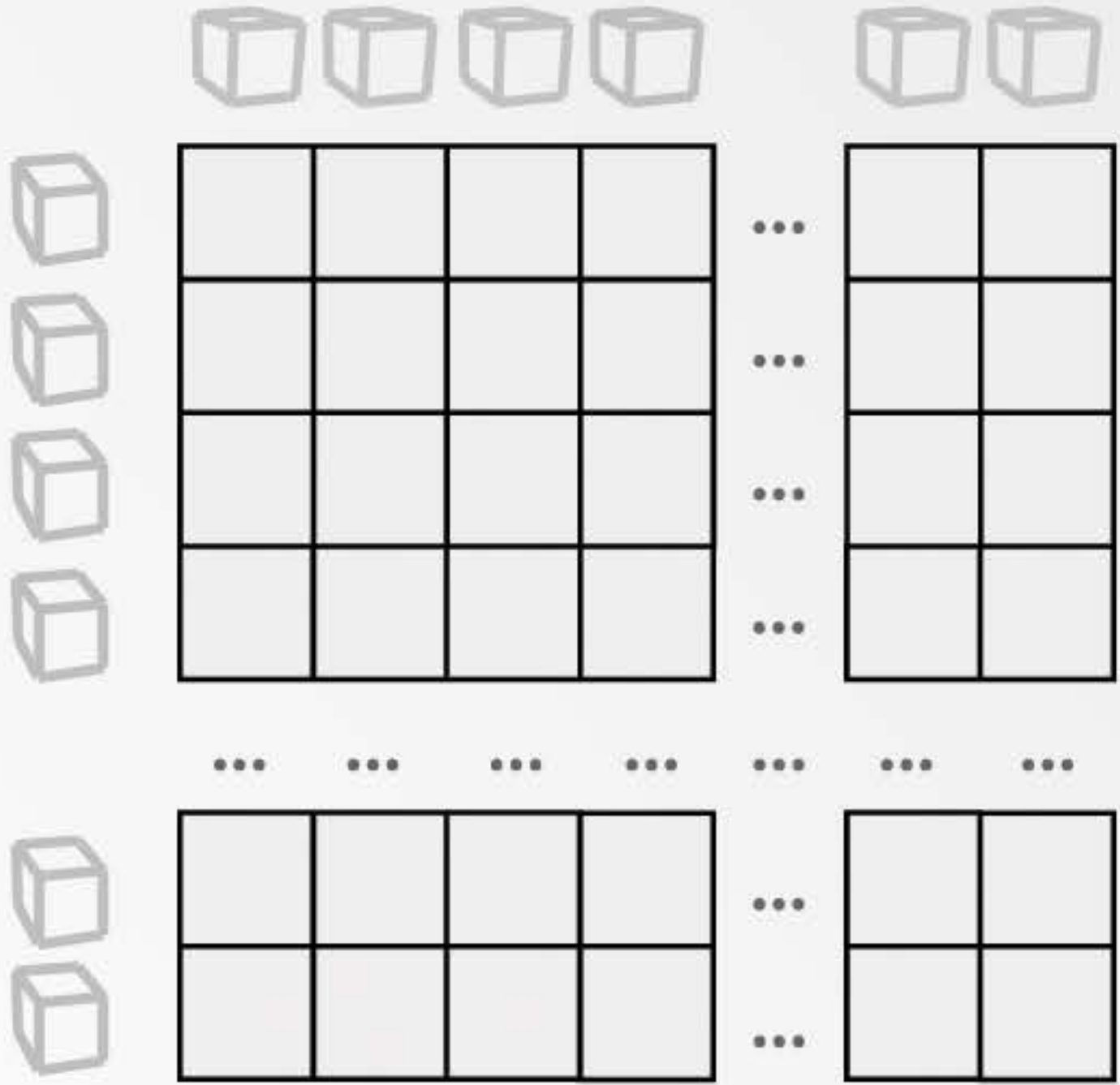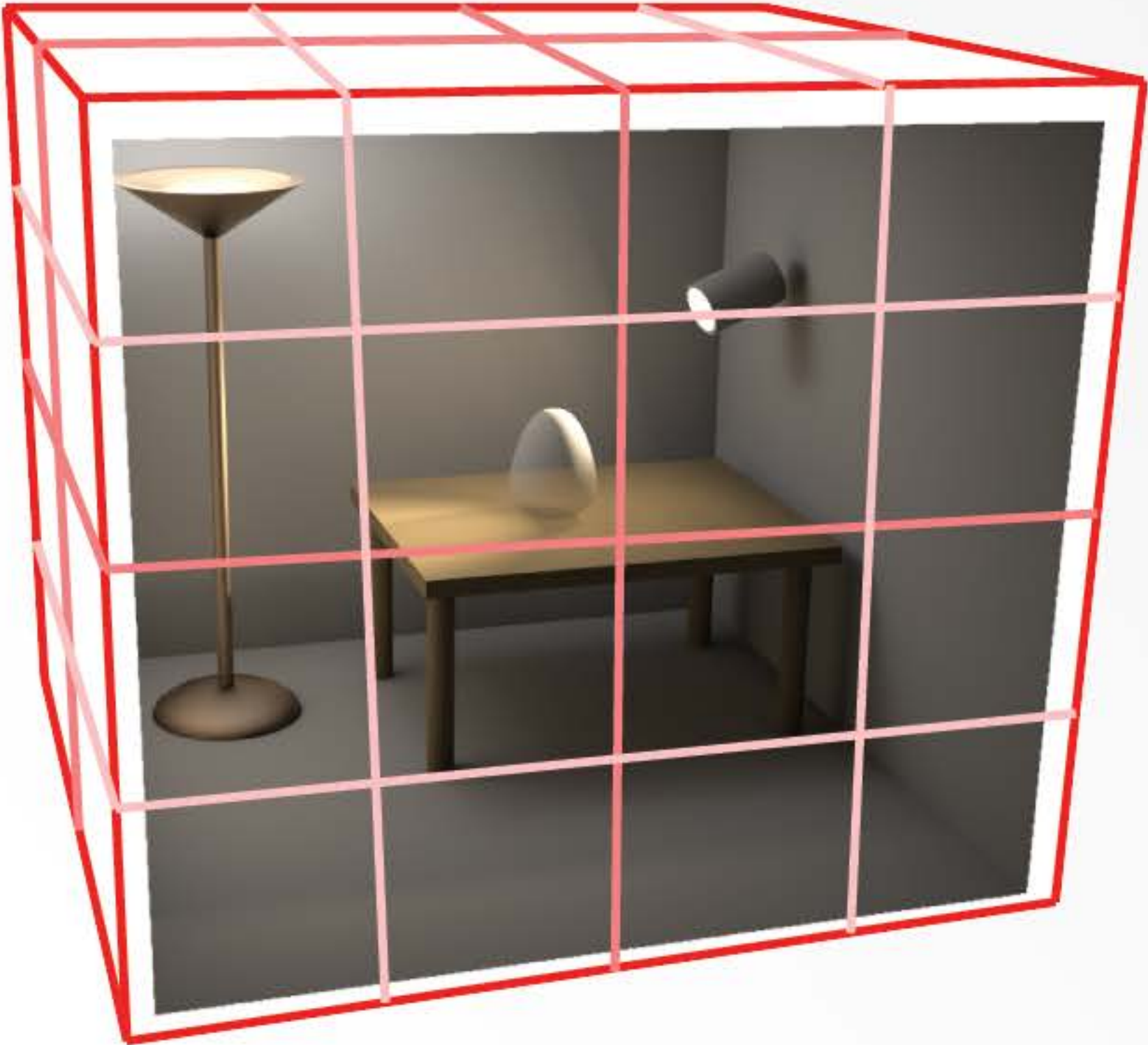Light sample occuluded

Sensor

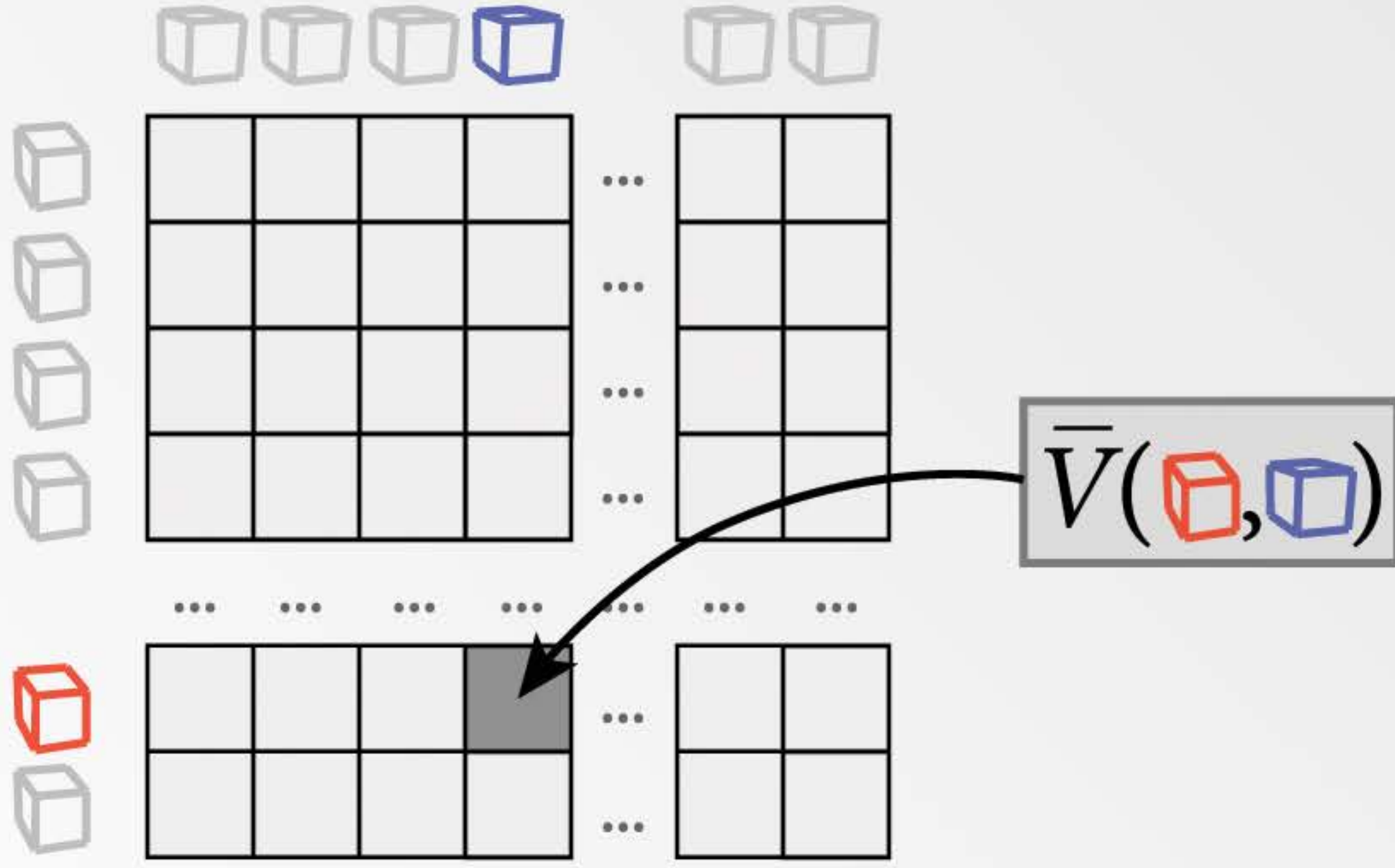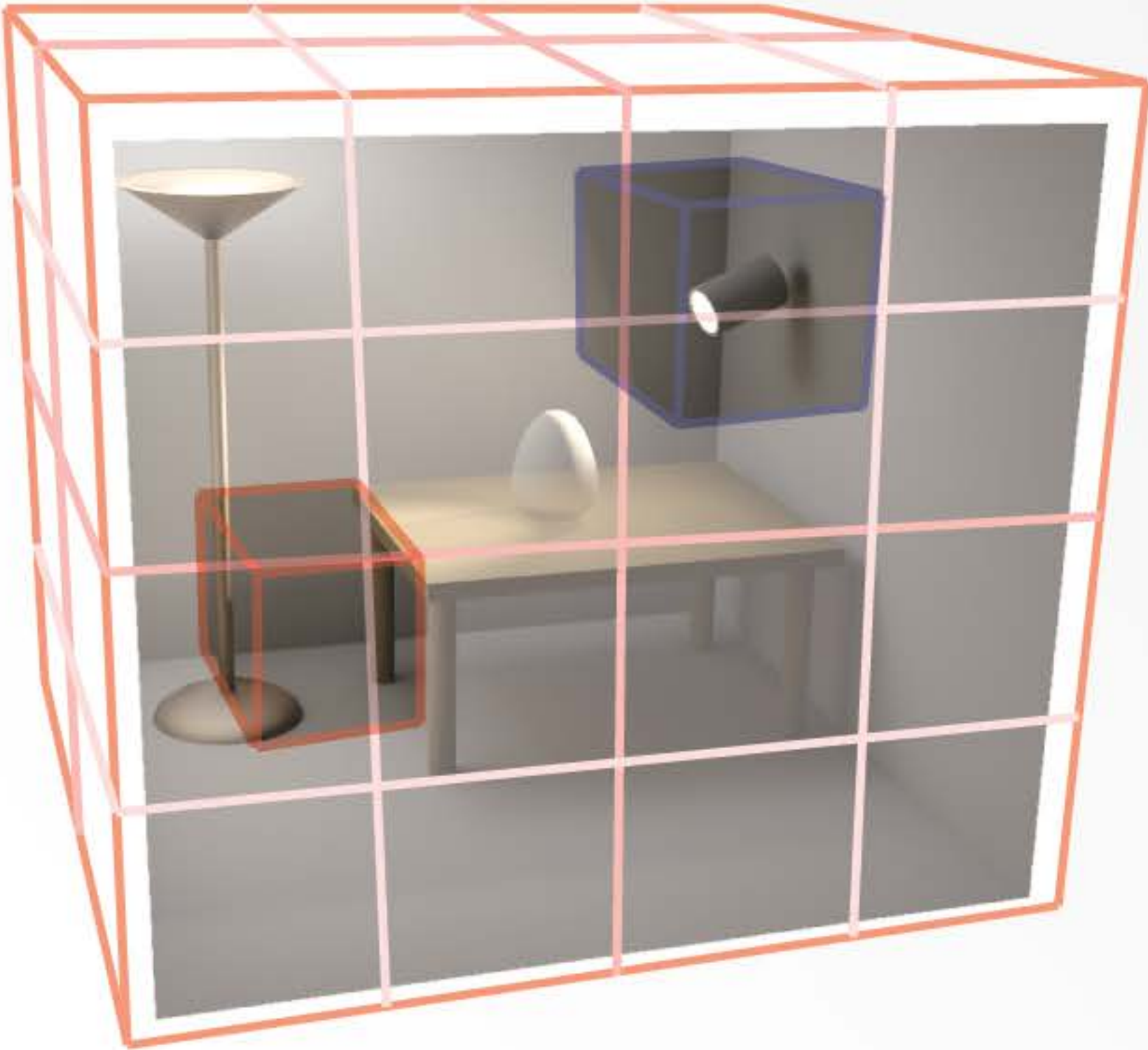# Uni-directional Path Tracing

BVH traversal

Caching Visibility in a Map

Caching Visibility in a Map
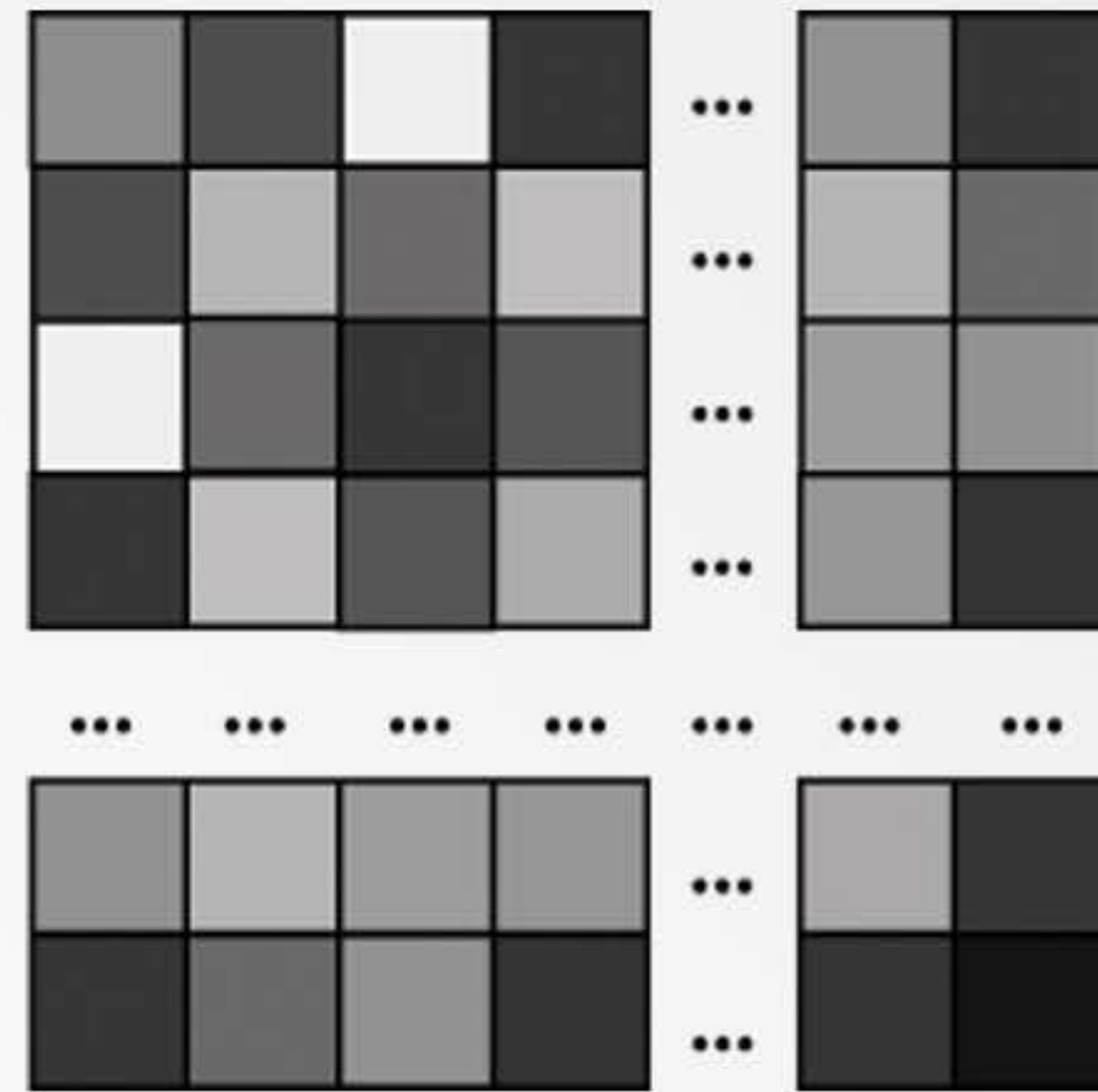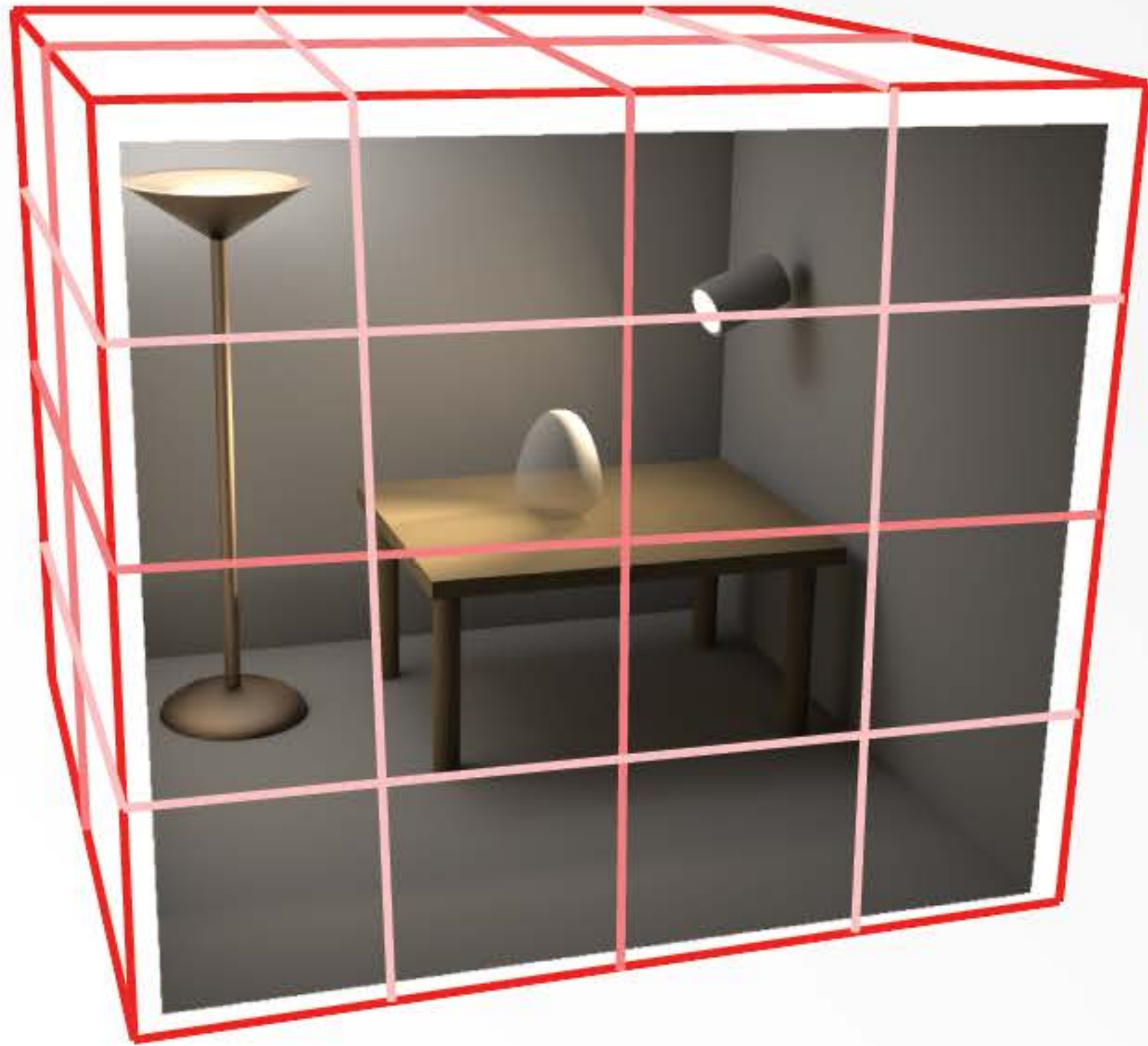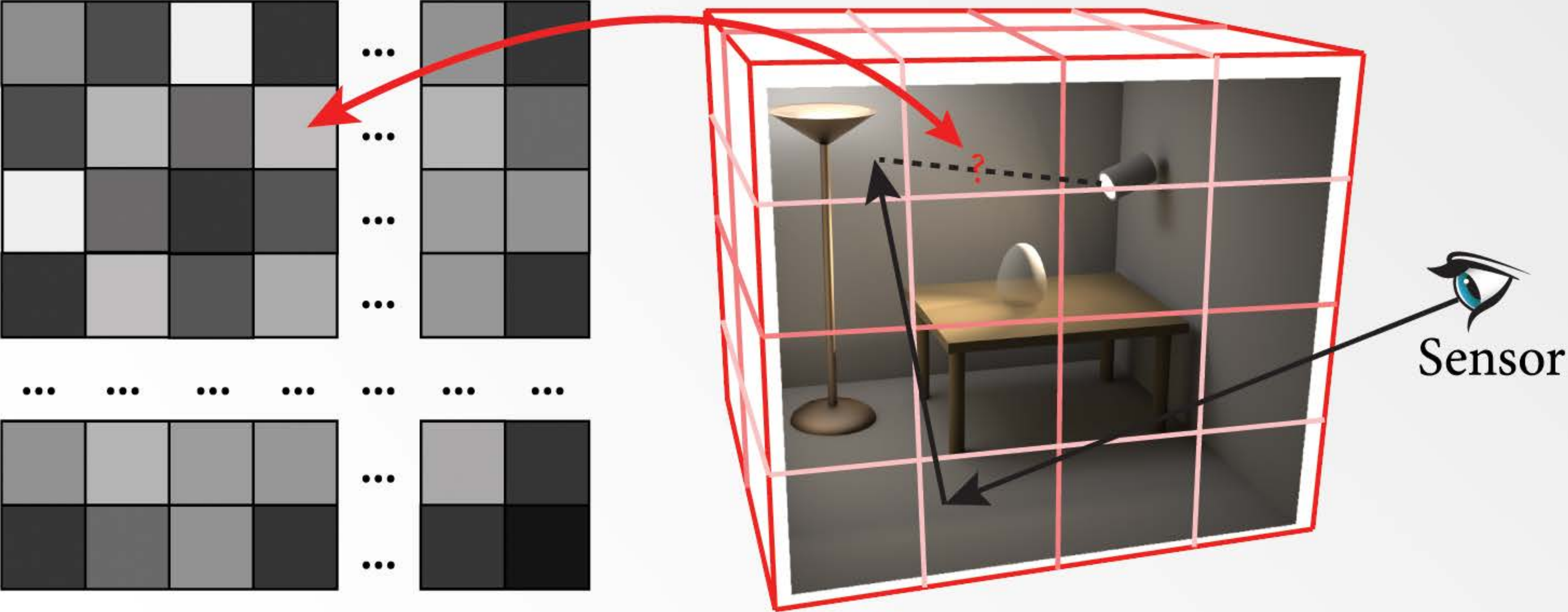
Caching Visibility in a Map

Caching Visibility in a Map

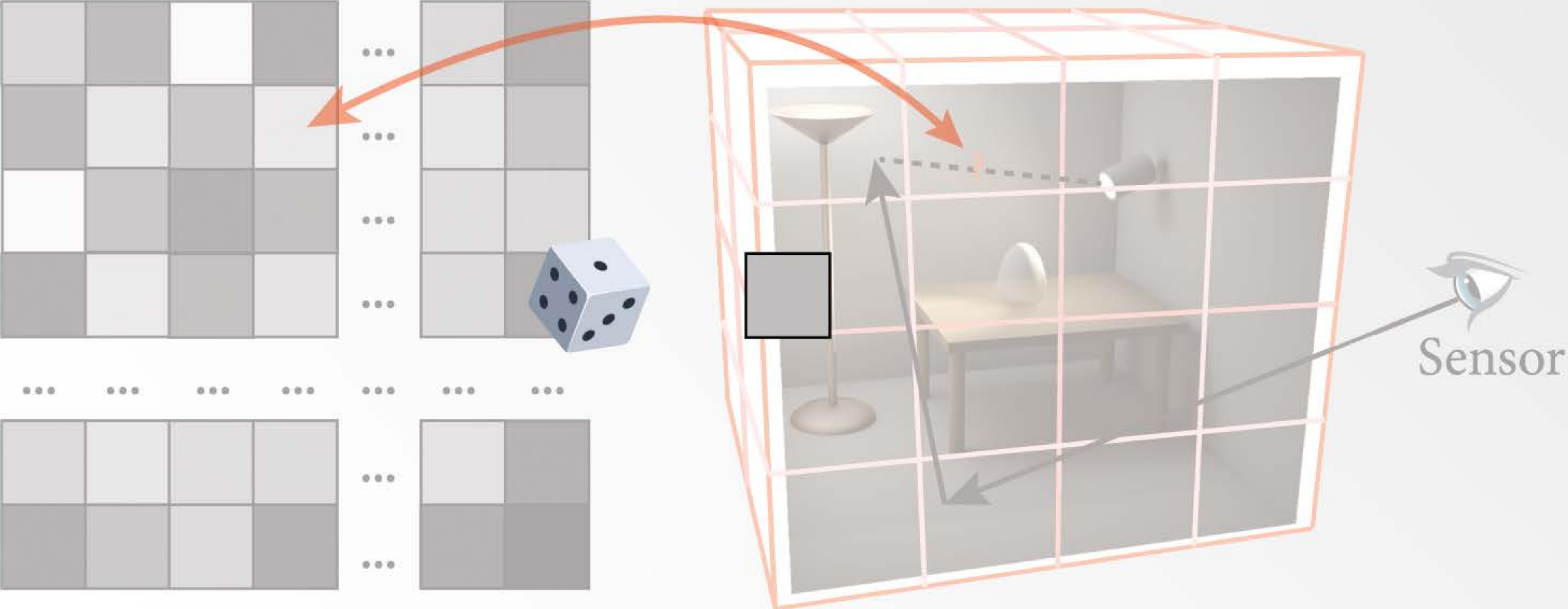$$\bar{V}(\textcolor{red}{\blacksquare}, \textcolor{blue}{\blacksquare})$$

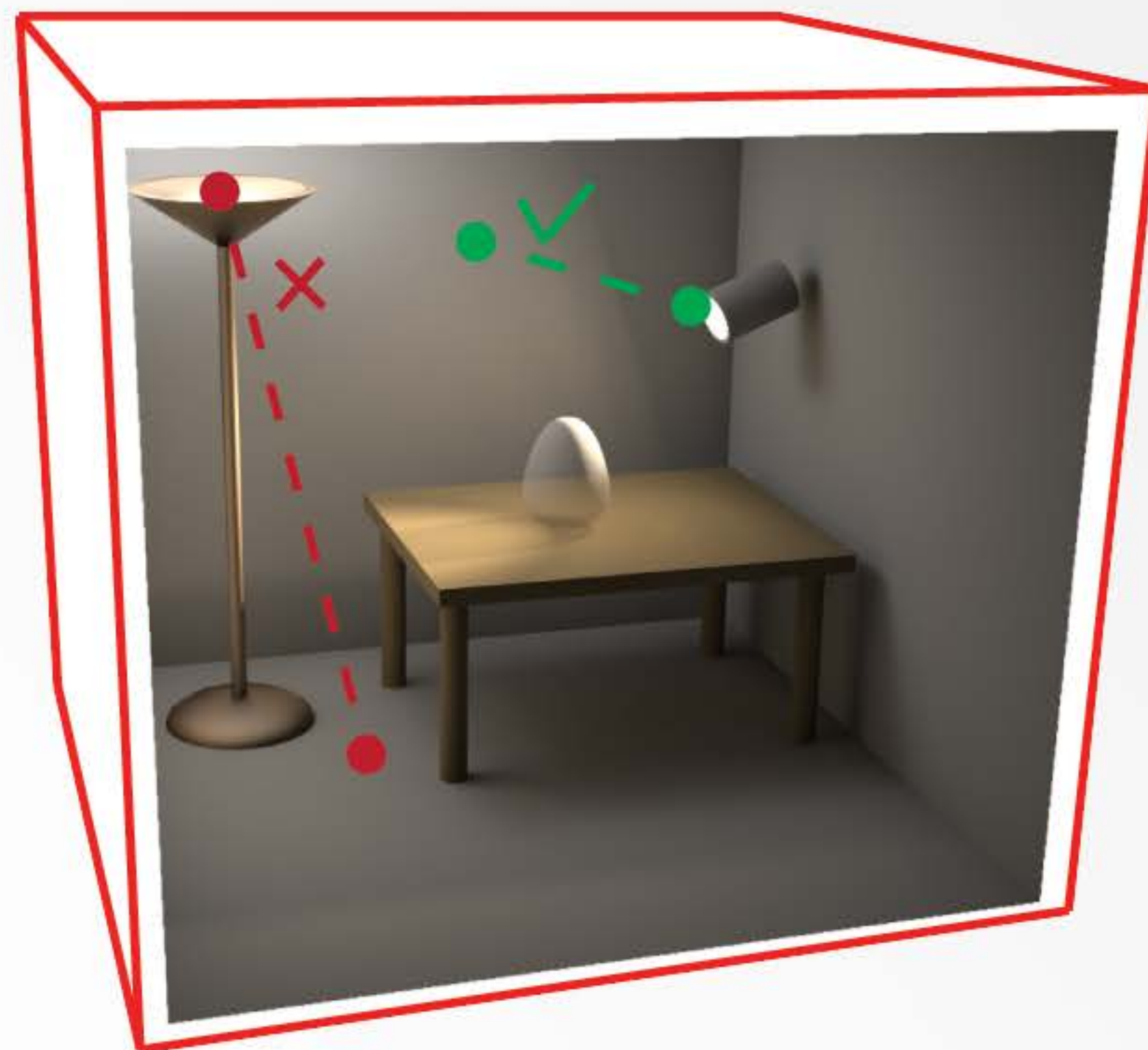# Rendering with Visibility Map

Visibility Based Rejection Sampling

Visibility Based Rejection Sampling

Visibility Based Rejection Sampling

Visibility Based Rejection Sampling

$$\hat{L}_{rr} = L_e + \begin{cases} \frac{f_s LGV(x'',x')}{\tilde{V}(x'',x')p(x'')} & \xi < \tilde{V}(x'',x') \\ 0 & else \end{cases} , \xi \sim U[0,1]$$

Visibility Based Rejection Sampling

$$\hat{L}_{rr} = L_e + \begin{cases} \frac{f_s LGV(x'',x')}{\tilde{V}(x'',x')p(x'')} & \xi < \tilde{V}(x'',x') \\ 0 & else \end{cases}, \xi \sim U[0,1]$$

$$E[\hat{L}_{rr}] = L_e + \tilde{V}(x'',x') \times E[\frac{f_s LGV(x'',x')}{\tilde{V}(x'',x')p(x'')}] + (1 - \tilde{V}(x'',x')) \times 0$$

Visibility Based Rejection Sampling

$$\hat{L}_{rr} = L_e + \begin{cases} \frac{f_s LGV(x'',x')}{\tilde{V}(x'',x')p(x'')} & \xi < \tilde{V}(x'',x') \\ 0 & else \end{cases}, \xi \sim U[0,1]$$

$$E[\hat{L}_{rr}] = L_e + \tilde{V}(x'',x') \times E[\frac{f_s LGV(x'',x')}{\tilde{V}(x'',x')p(x'')}] + (1 - \tilde{V}(x'',x')) \times 0$$

$$= L_e + E[f_s LGV] = L.$$

Visibility Based Rejection Sampling

$$\hat{L}_{rr} = L_e + \begin{cases} \frac{f_s LGV(x'',x')}{\tilde{V}(x'',x')p(x'')} & \xi < \tilde{V}(x'',x') \\ 0 & else \end{cases}, \xi \sim U[0,1]$$

Visibility Based Rejection Sampling

Visibility Based Rejection Sampling

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Visibility Based Rejection Sampling

	rMSE		
	4 SPP	64 SPP	1024 SPP
NEE	5.82e$-$2	3.24e$-$2	2.12e$-$2
NEE++	5.91e$-$2	3.33e$-$2	2.18e$-$2
Ratio	1.01	1.03	1.03

Visibility Based Rejection Sampling

	Shadowrays		
	4 SPP	64 SPP	1024 SPP
NEE	5.45e+6	8.72e+7	1.40e+9
NEE++	1.19e+6	1.92e+7	3.07e+8
Ratio	0.22	0.21	0.22

Visibility Based Rejection Sampling

	Runtime Visibility Tests		
	4 SPP	64 SPP	1024 SPP
NEE	1.26s	5.47s	82.4s
NEE++	0.43s	1.54s	24.9s
Ratio	0.34	0.28	0.30

Visibility Based Light Sampling

$$L(\mathrm{x}, \omega_o) = L_e(\mathrm{x}, \omega_o) + \int_{S^2} f_s(\mathrm{x}, \mathrm{x}_i, \omega_o) \textcolor{red}{L_i(\mathrm{x}, \mathrm{x}_i) G(\mathrm{x}, \mathrm{x}_i)} V(\mathrm{x}, \mathrm{x}_i) \mathrm{d}\mathrm{x}_i$$

Visibility Based Light Sampling

$$L(\mathrm{x}, \omega_o) = L_e(\mathrm{x}, \omega_o) + \int_{S^2} f_s(\mathrm{x}, \mathrm{x}_i, \omega_o) L_i(\mathrm{x}, \mathrm{x}_i) G(\mathrm{x}, \mathrm{x}_i) V(\mathrm{x}, \mathrm{x}_i) \mathrm{d}\mathrm{x}_i$$

Visibility Based Light Sampling

Sample light based on visibility

Visibility Based Light Sampling

Sample light based on visibility

    Each physical light source links to a list of voxels

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    Each physical light source links to a list of voxels

    Build light distribution according to scattering voxel

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Visibility Based Light Sampling

Sample light based on visibility

- Each physical light source links to a list of voxels
- Build light distribution according to scattering voxel
- Sample light distribution

Other sampling strategies

Visibility Based Light Sampling

Sample light based on visibility

- Each physical light source links to a list of voxels

- Build light distribution according to scattering voxel

- Sample light distribution

Other sampling strategies

- Uniform

Visibility Based Light Sampling

Sample light based on visibility

    Each physical light source links to a list of voxels

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Other sampling strategies

    Uniform

    Power

Visibility Based Light Sampling

Sample light based on visibility

- Each physical light source links to a list of voxels
- Build light distribution according to scattering voxel
- Sample light distribution

Other sampling strategies

- Uniform
- Power
- Spatial

Visibility Based Light Sampling
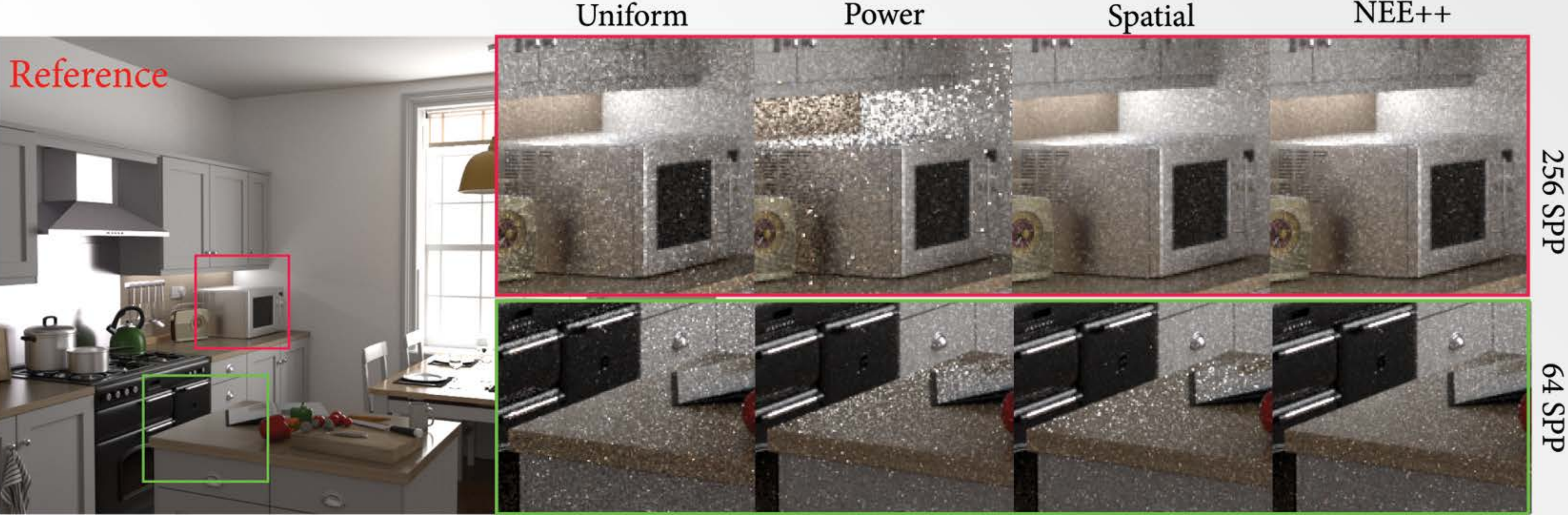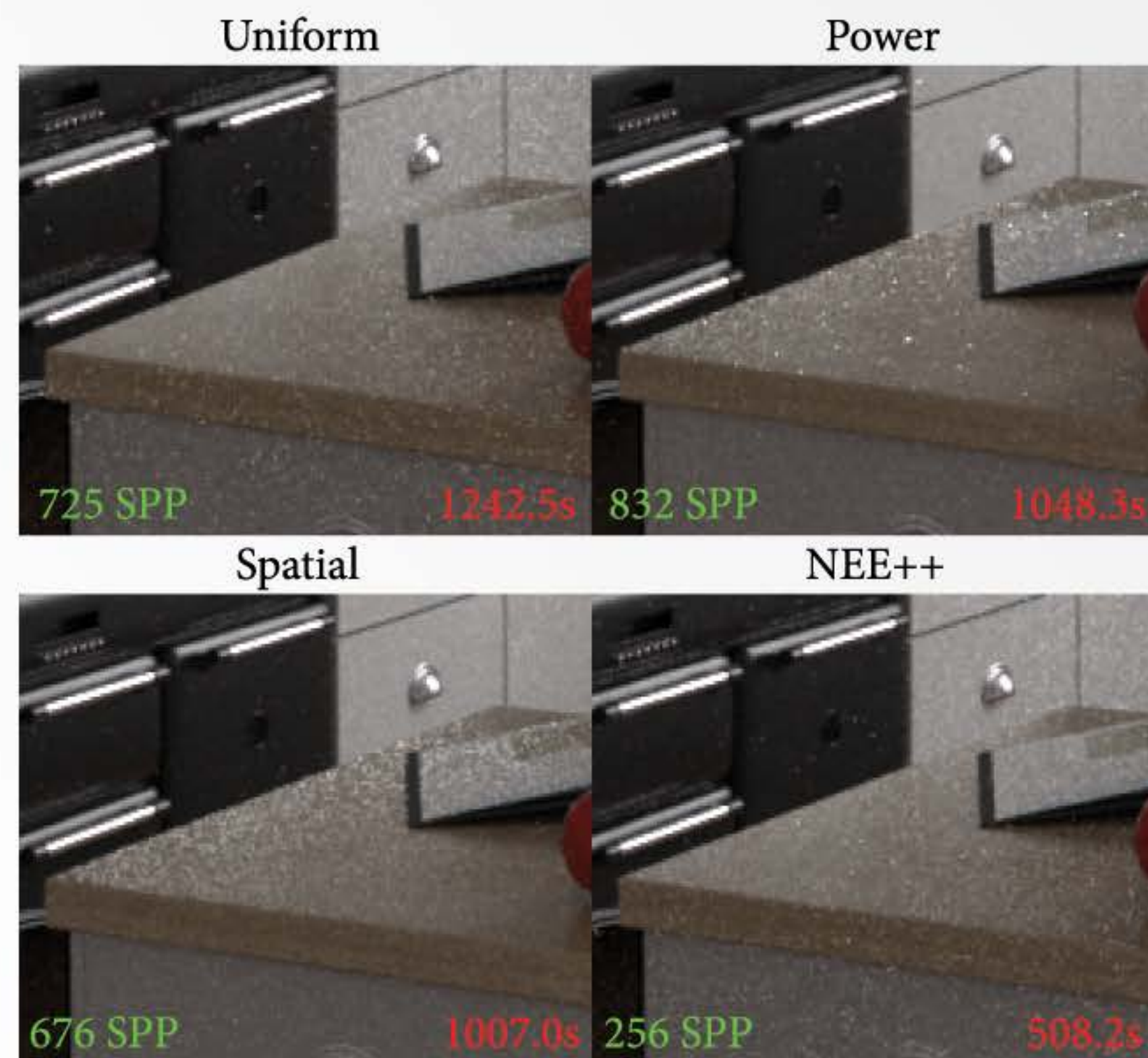
Visibility Based Light Sampling

Visibility Based Light Sampling
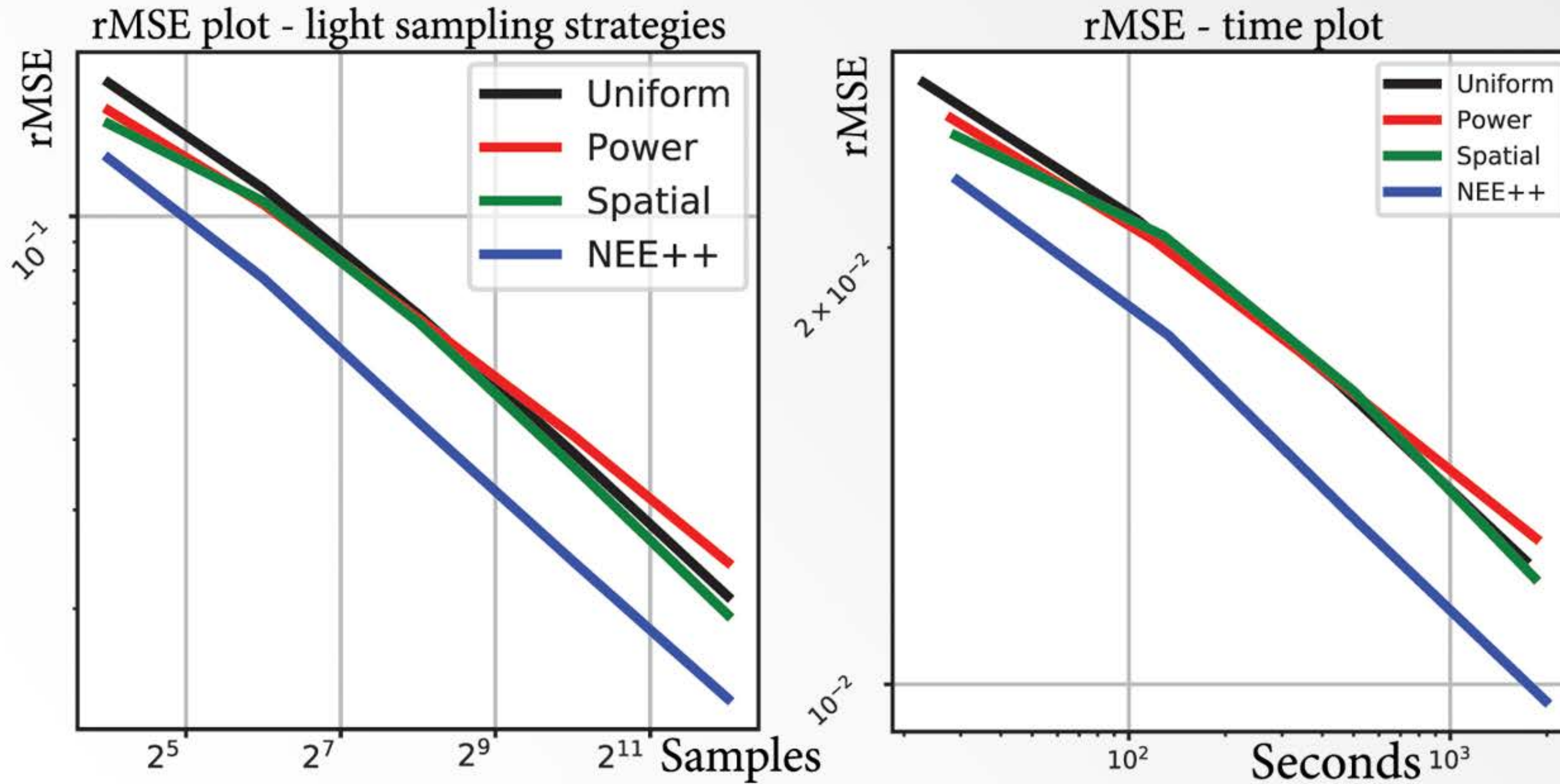
Visibility Based Light Sampling
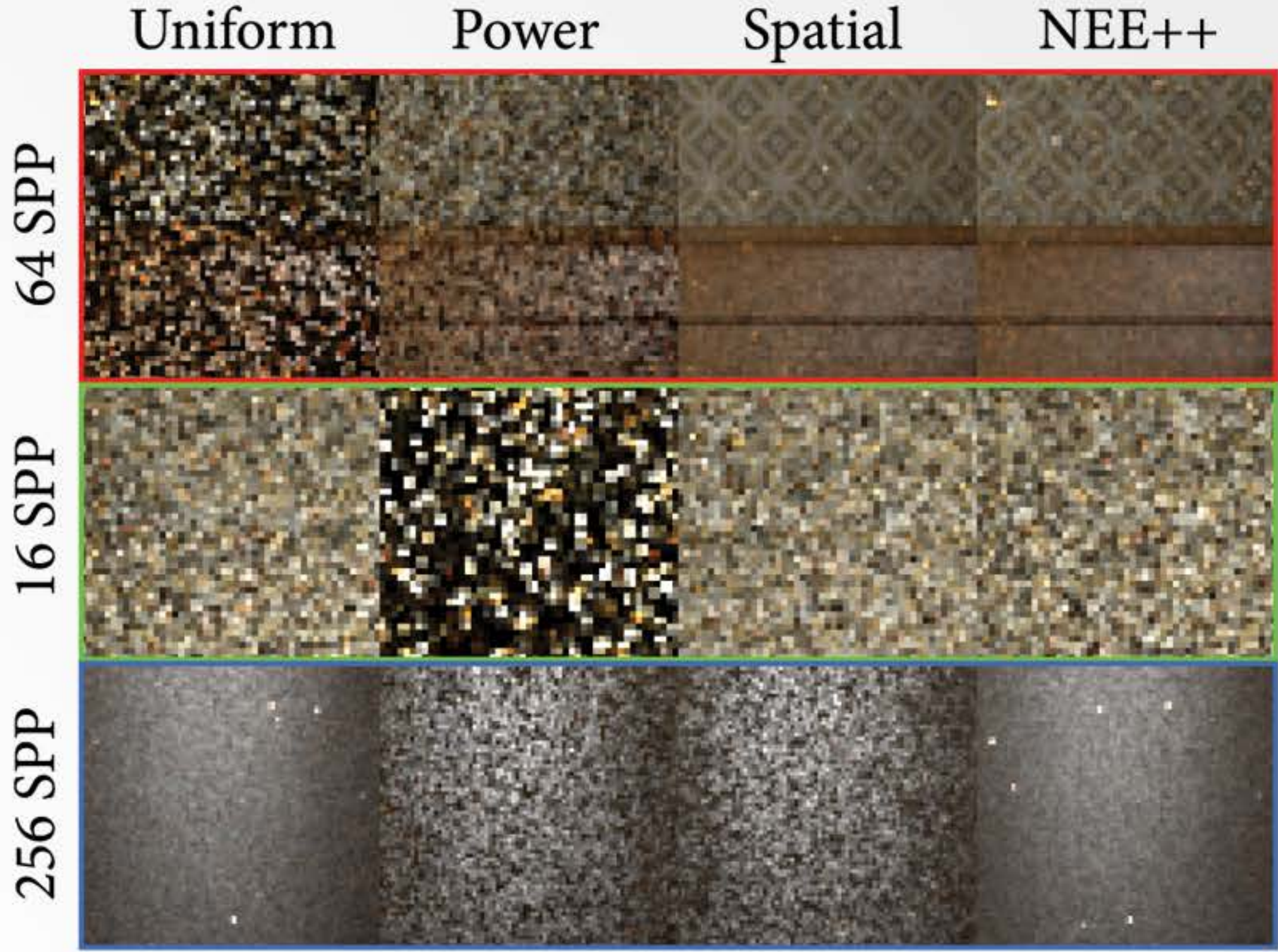
Visibility Based Light Sampling

Light Subpath Sampling for BDPT

Light Subpath Sampling for BDPT

Sensor
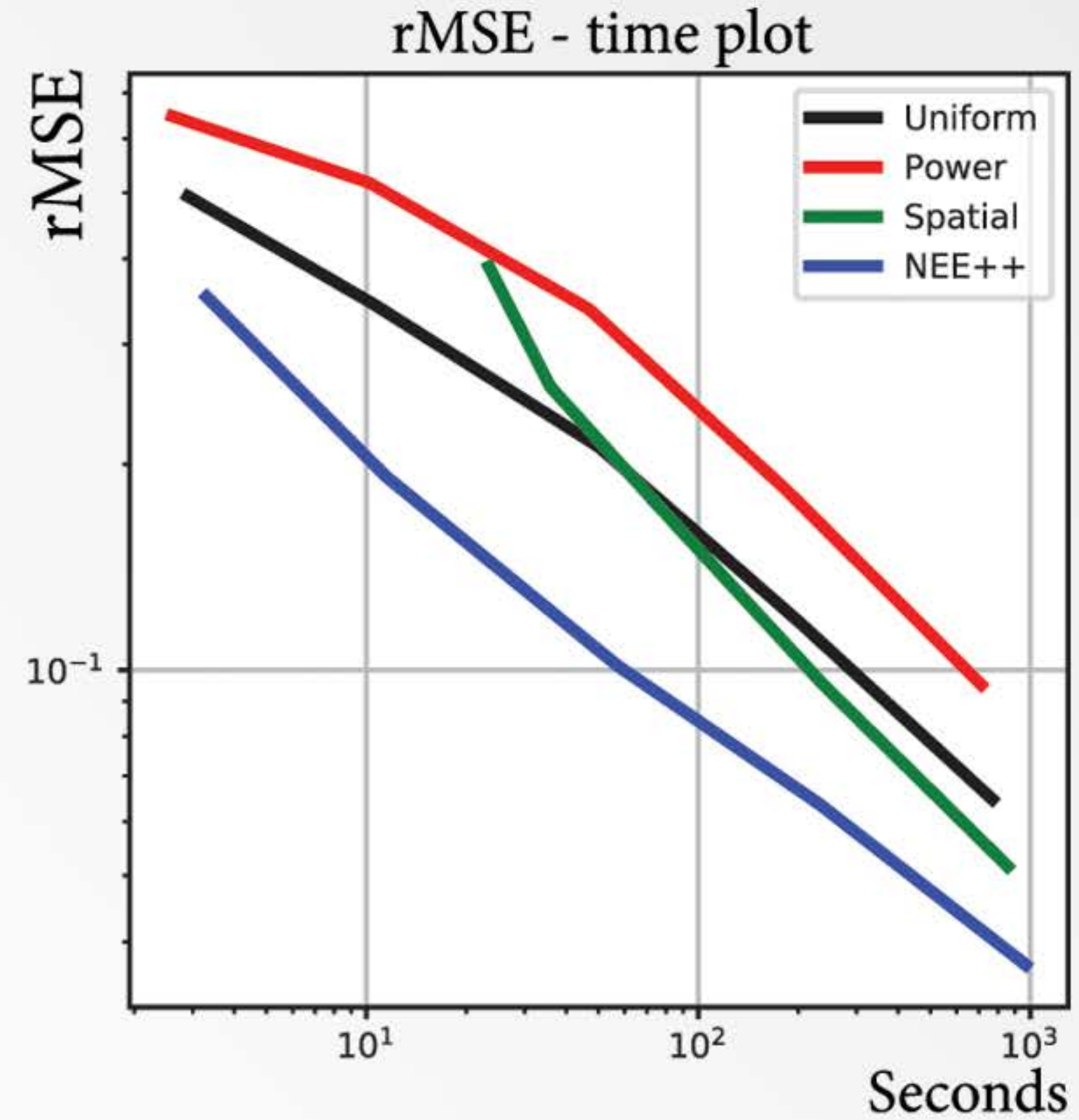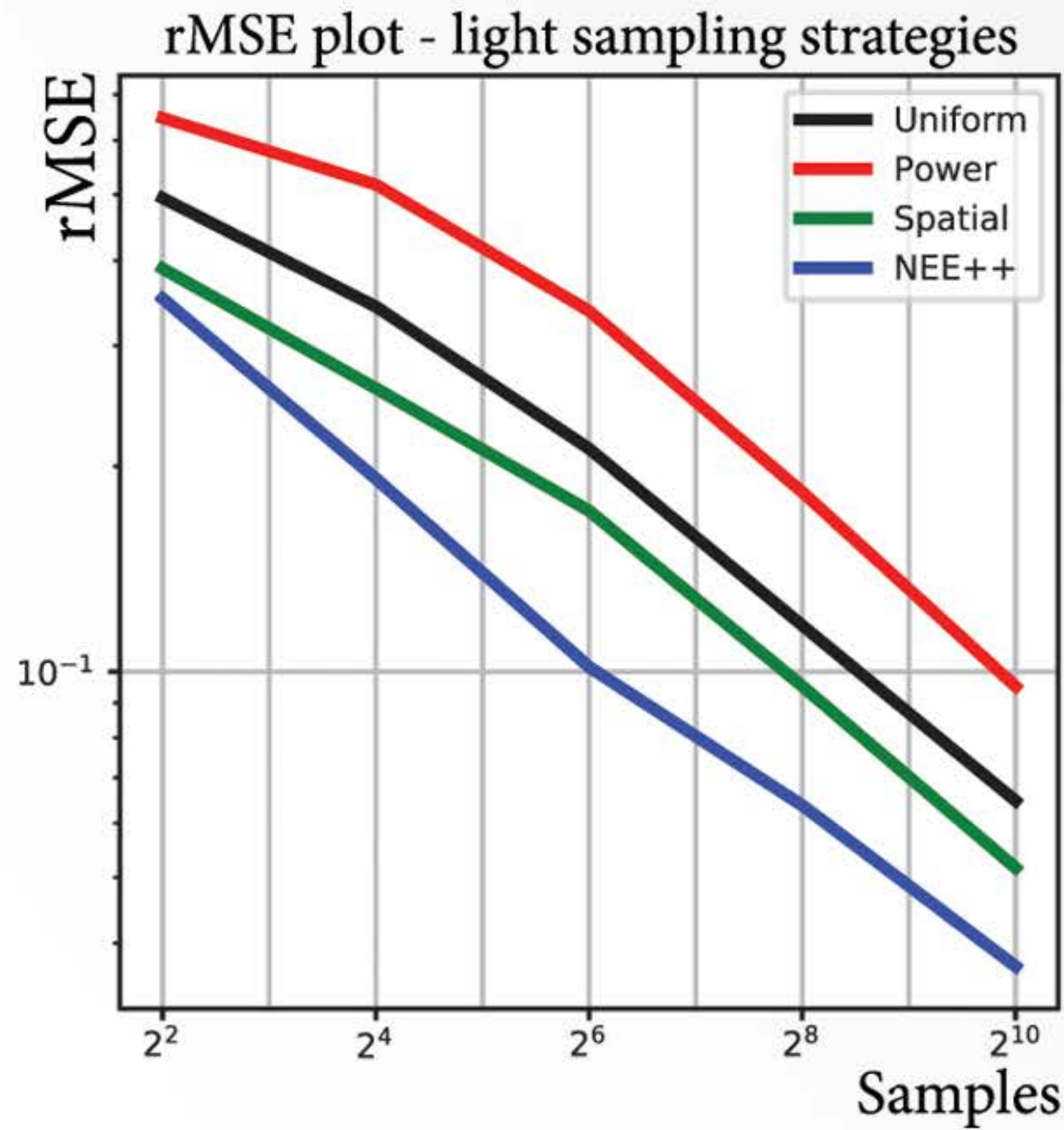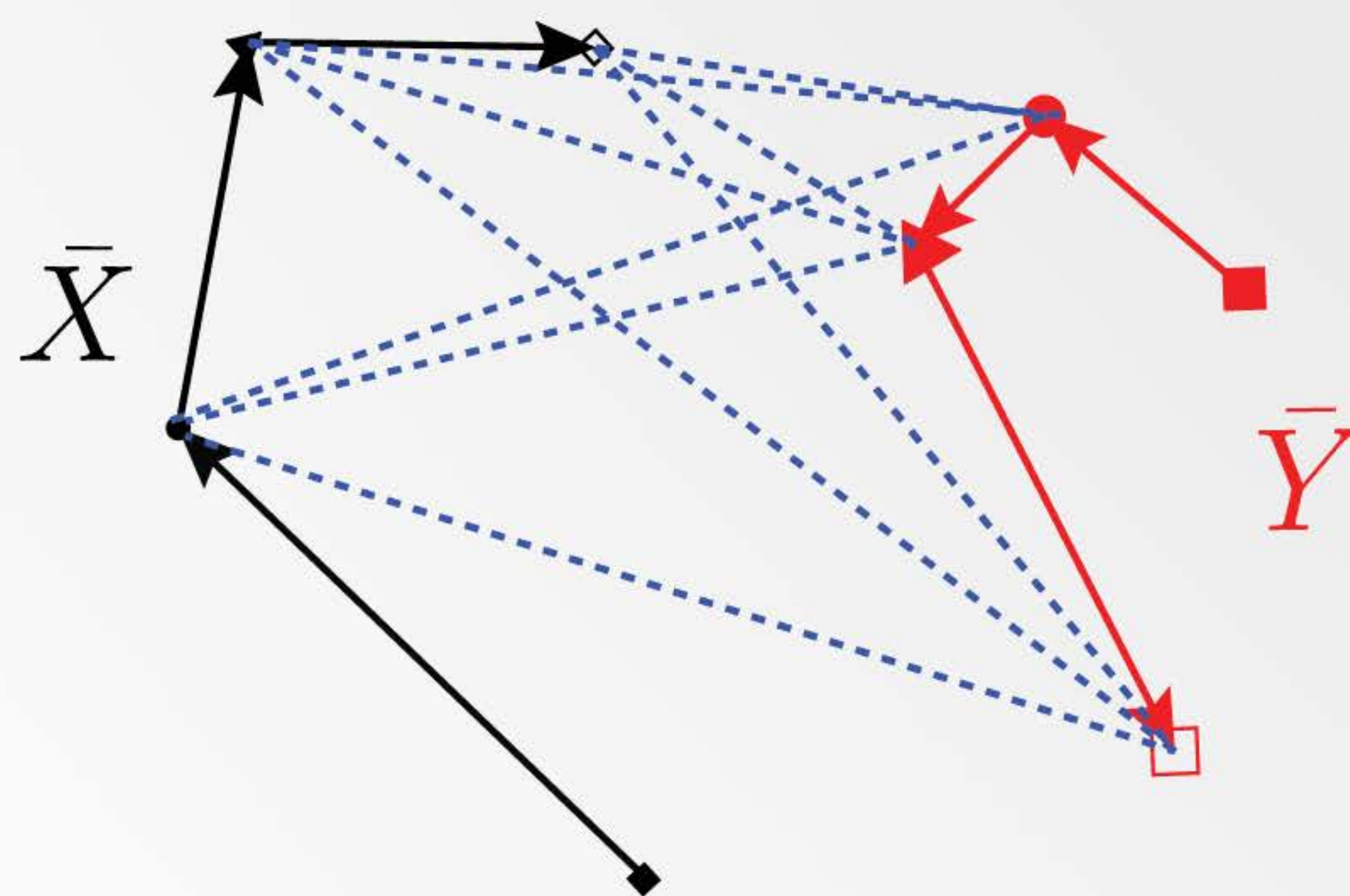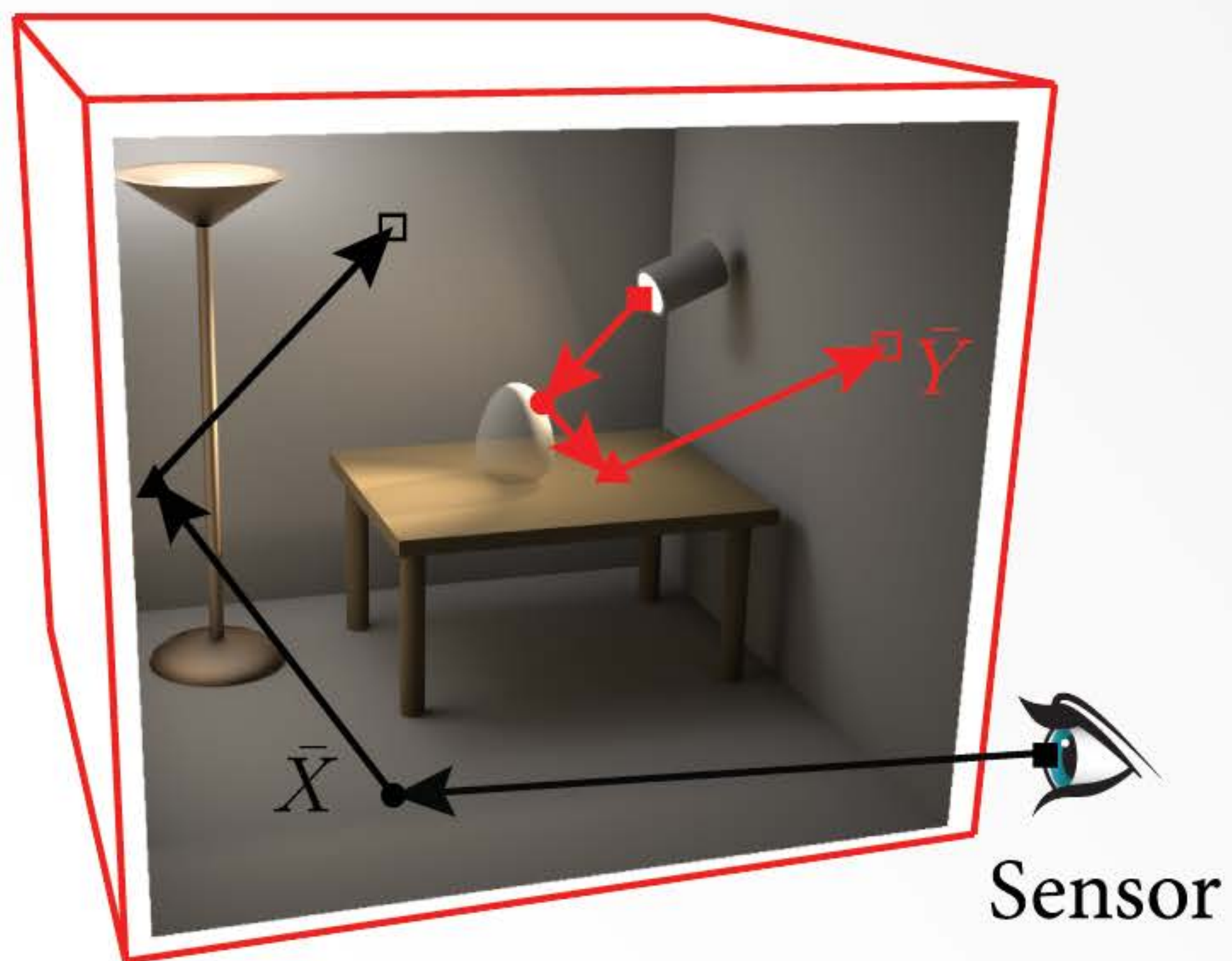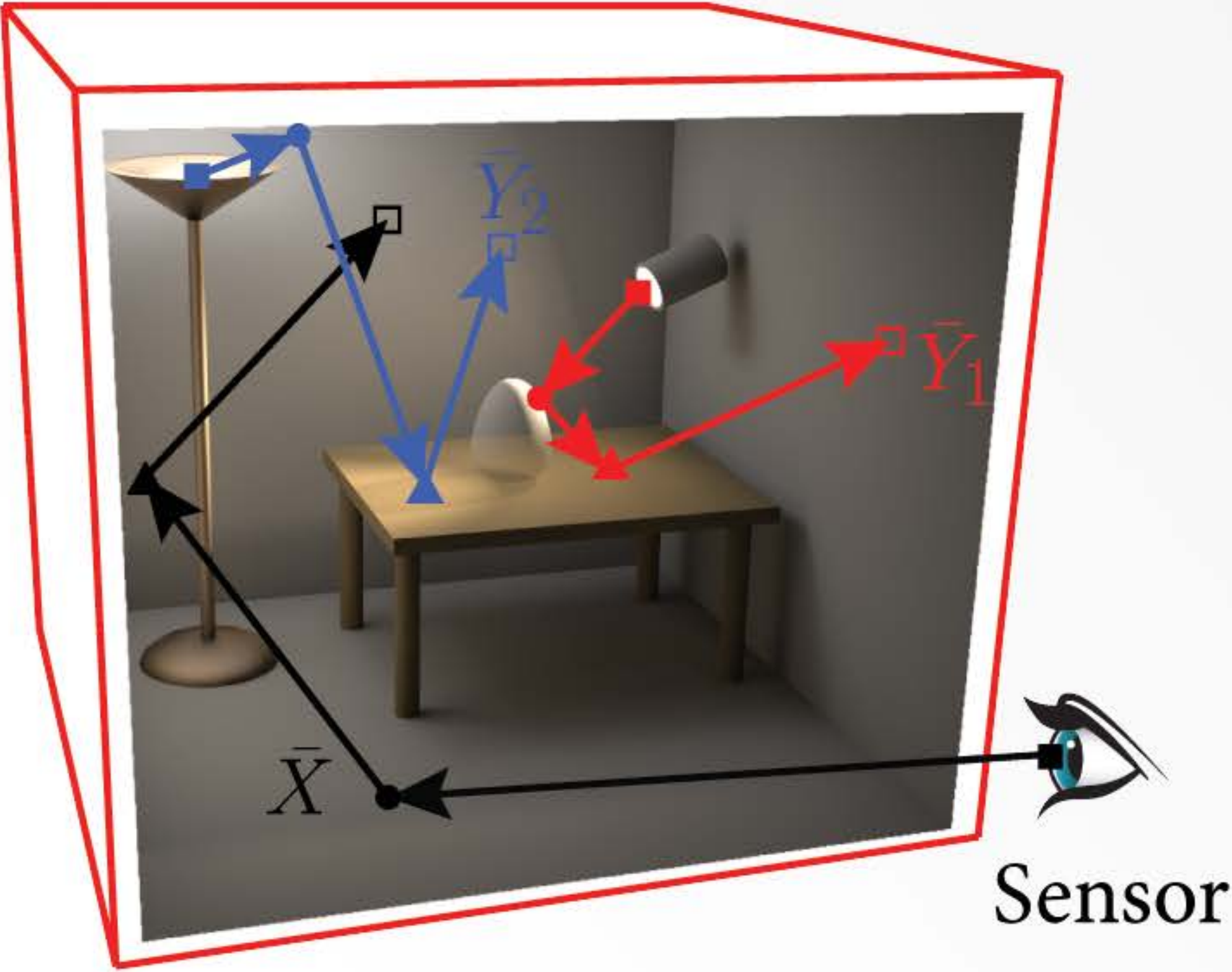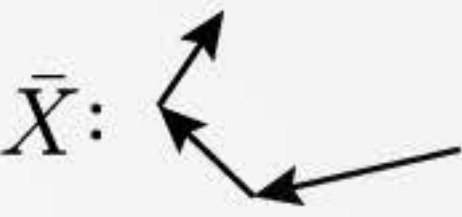
Camera subpath	Light subpaths
$\bar{X}$:	$\bar{Y}_1$:
	$\bar{Y}_2$:
	...

Light Subpath Sampling for BDPT
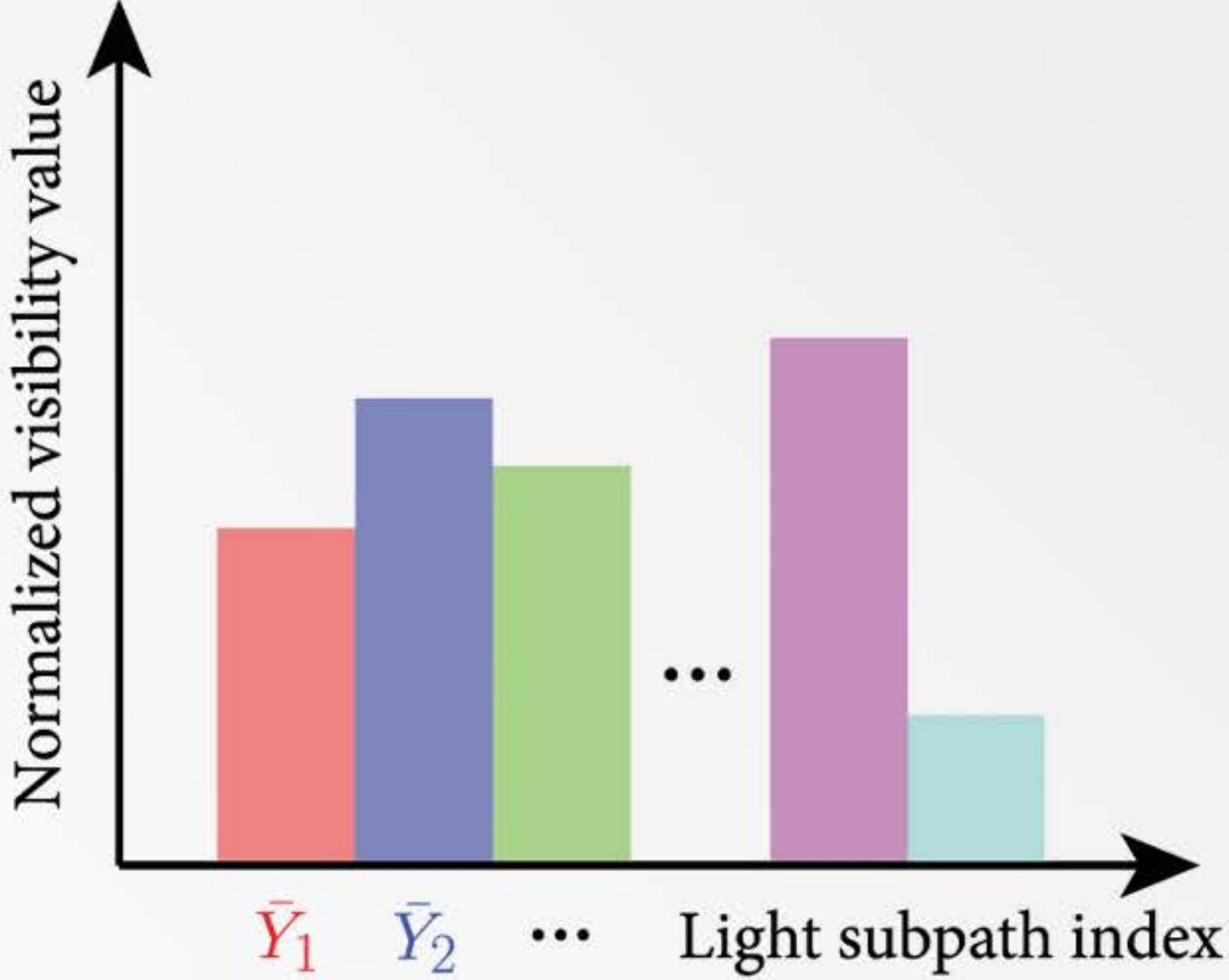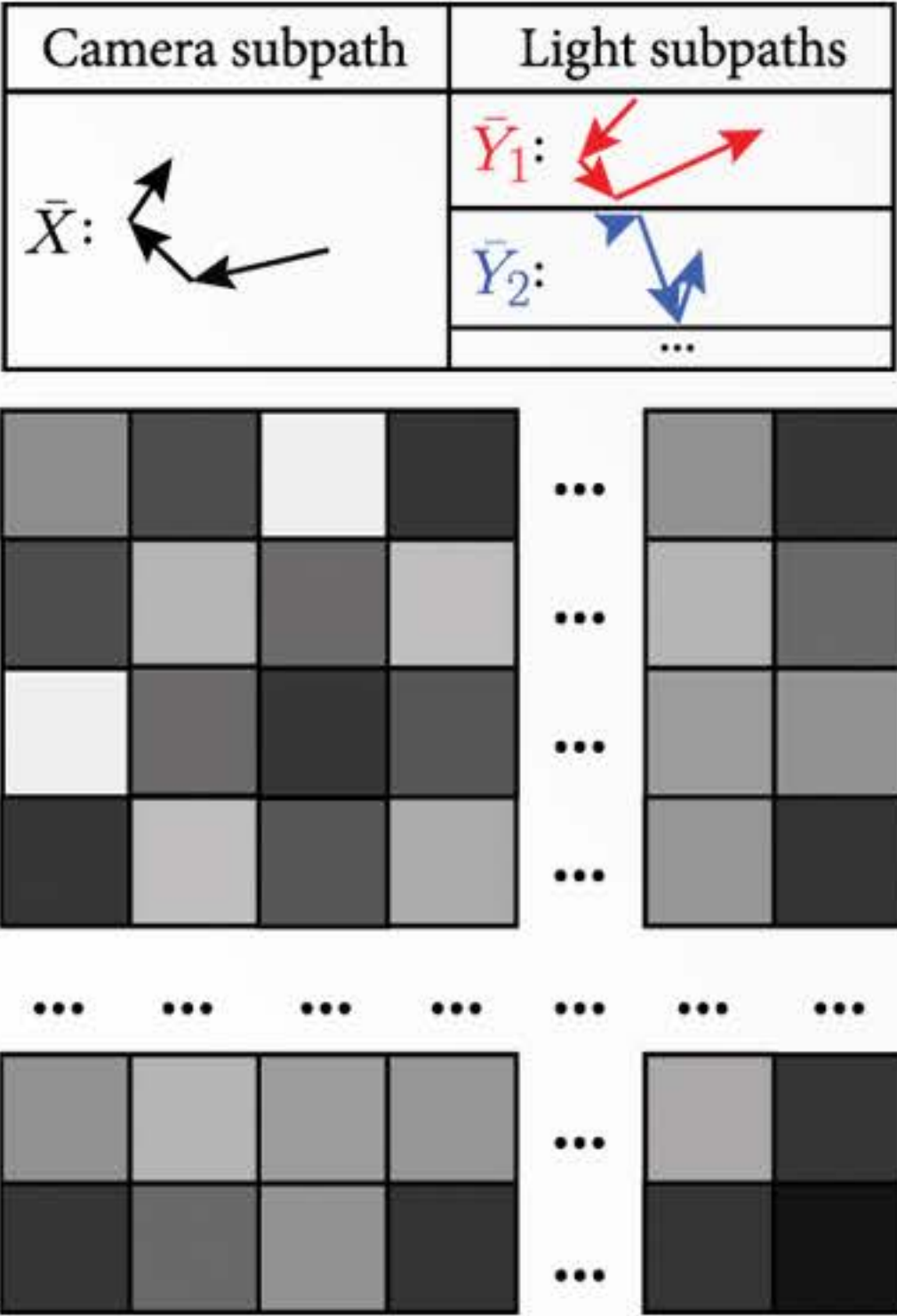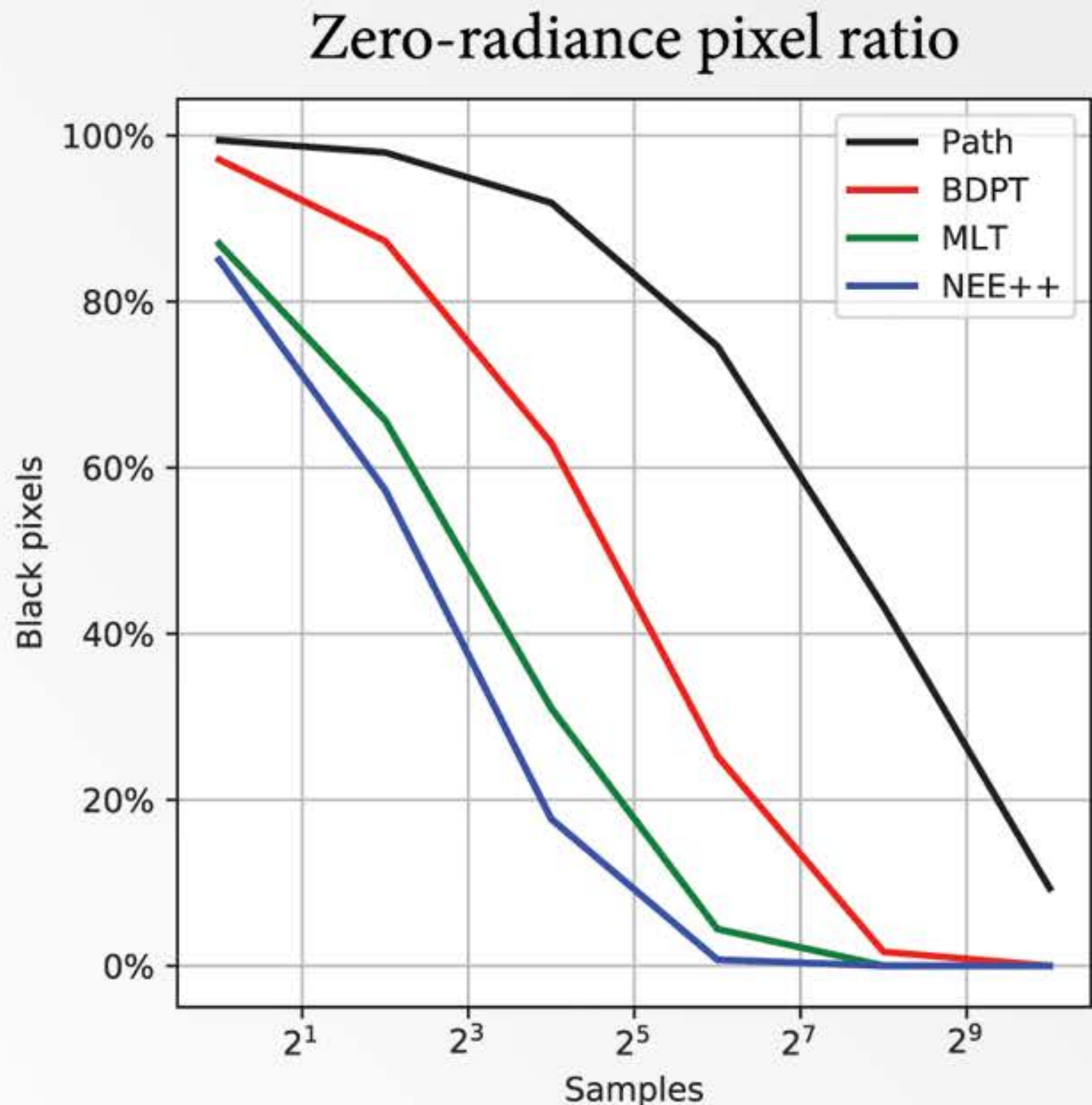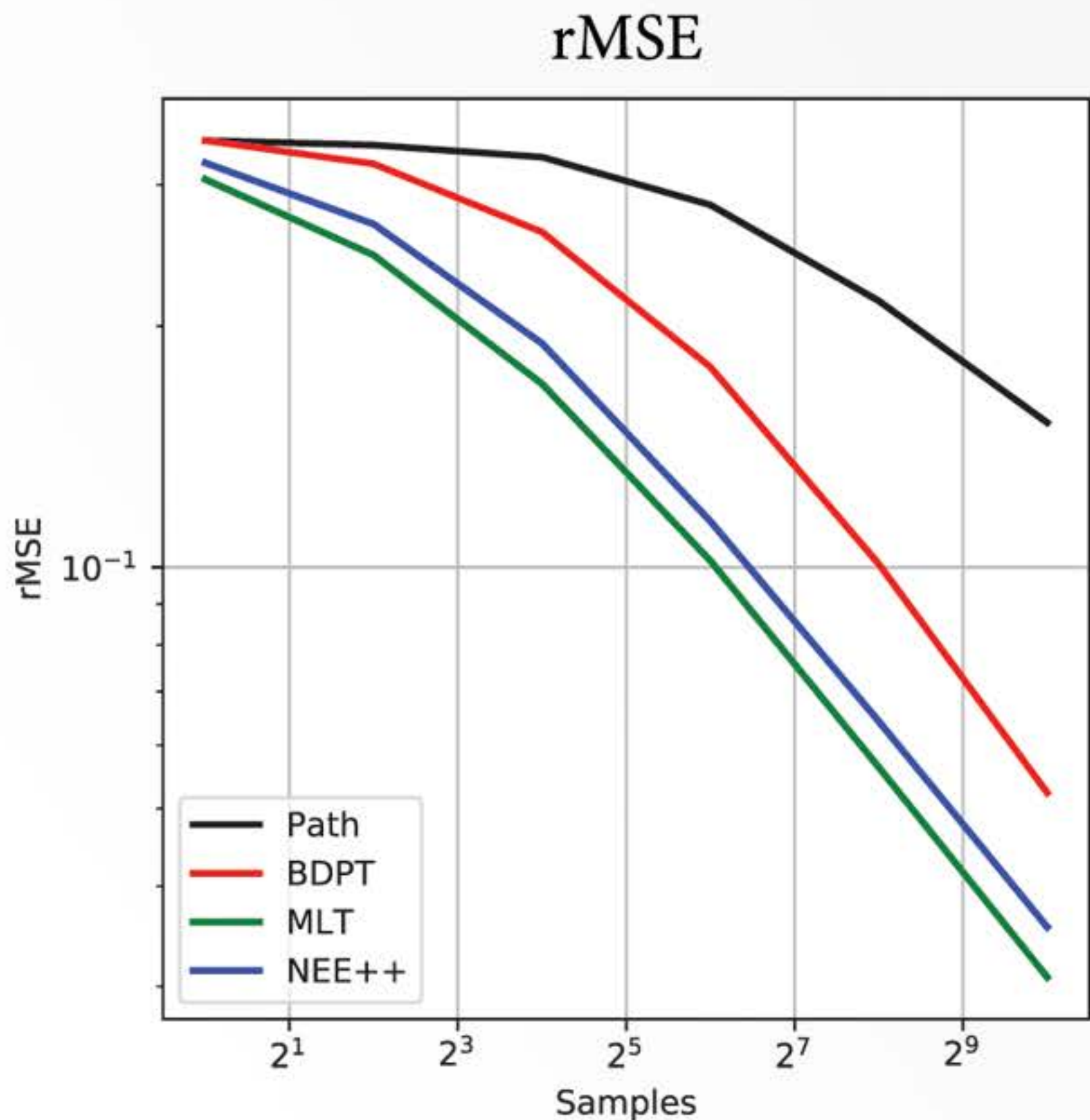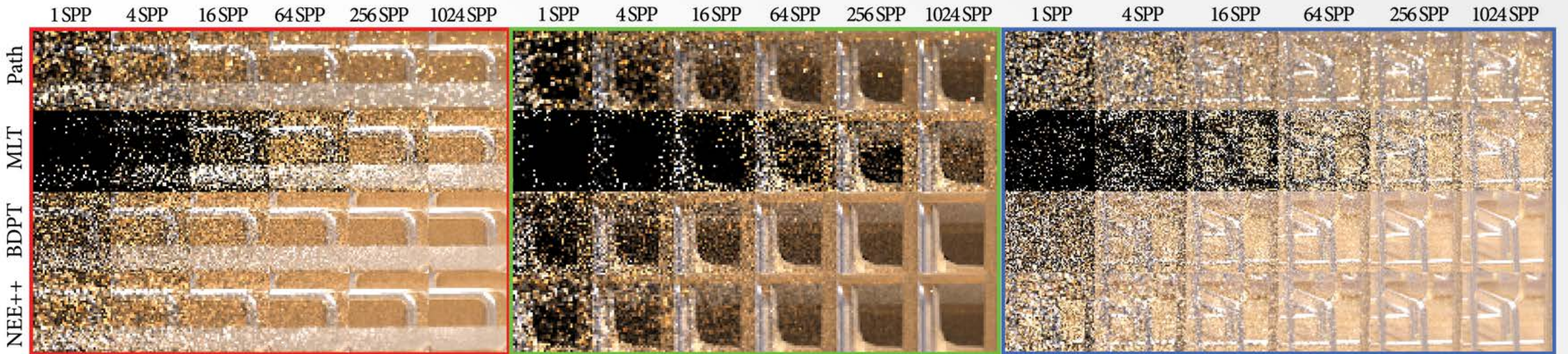
Light Subpath Sampling for BDPT

$$\hat{I}_{\bar{X}} = \frac{\text{CONNECT}(\bar{X}, \bar{Y}_i)}{p_{\bar{Y}_i}}$$
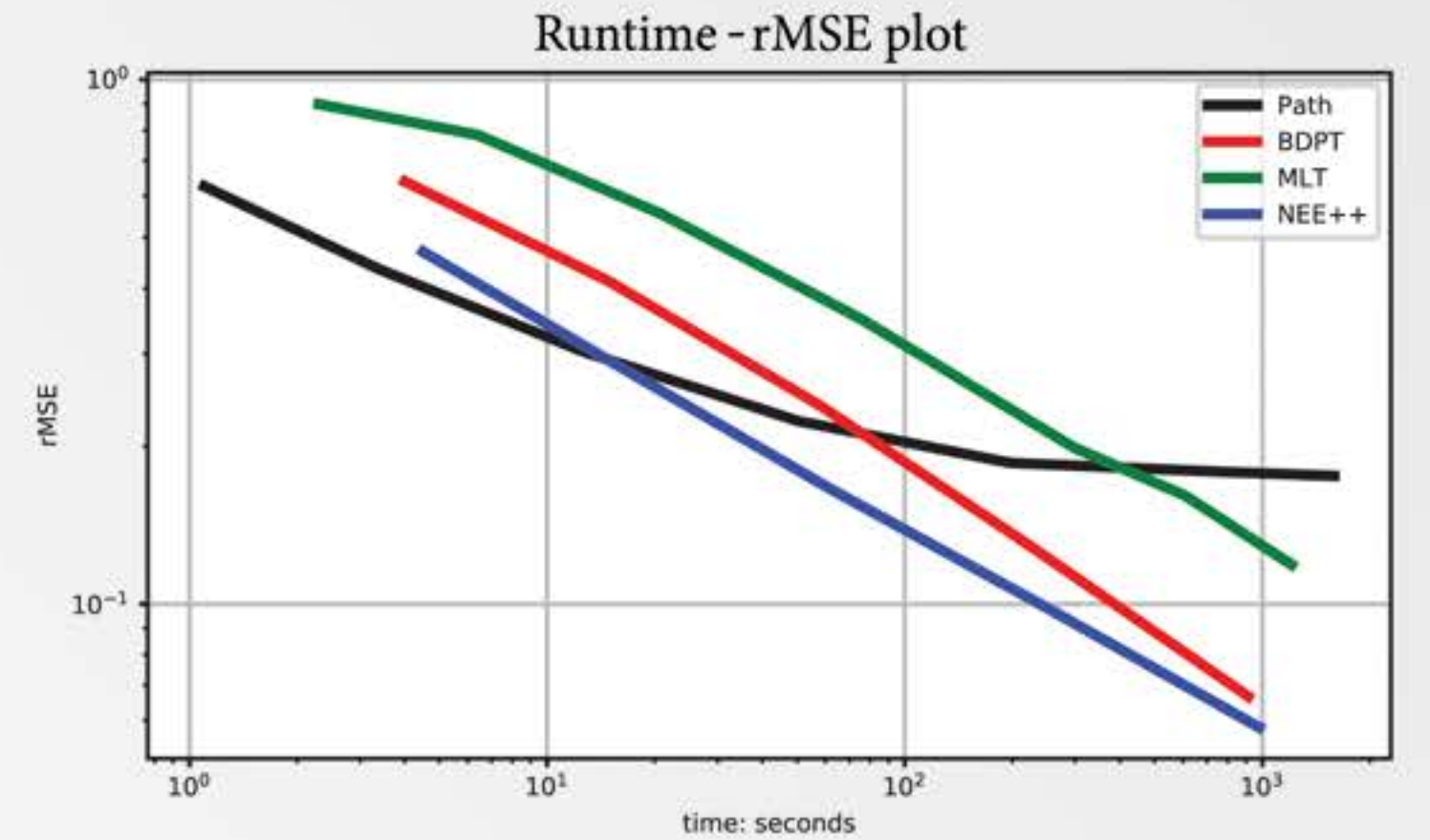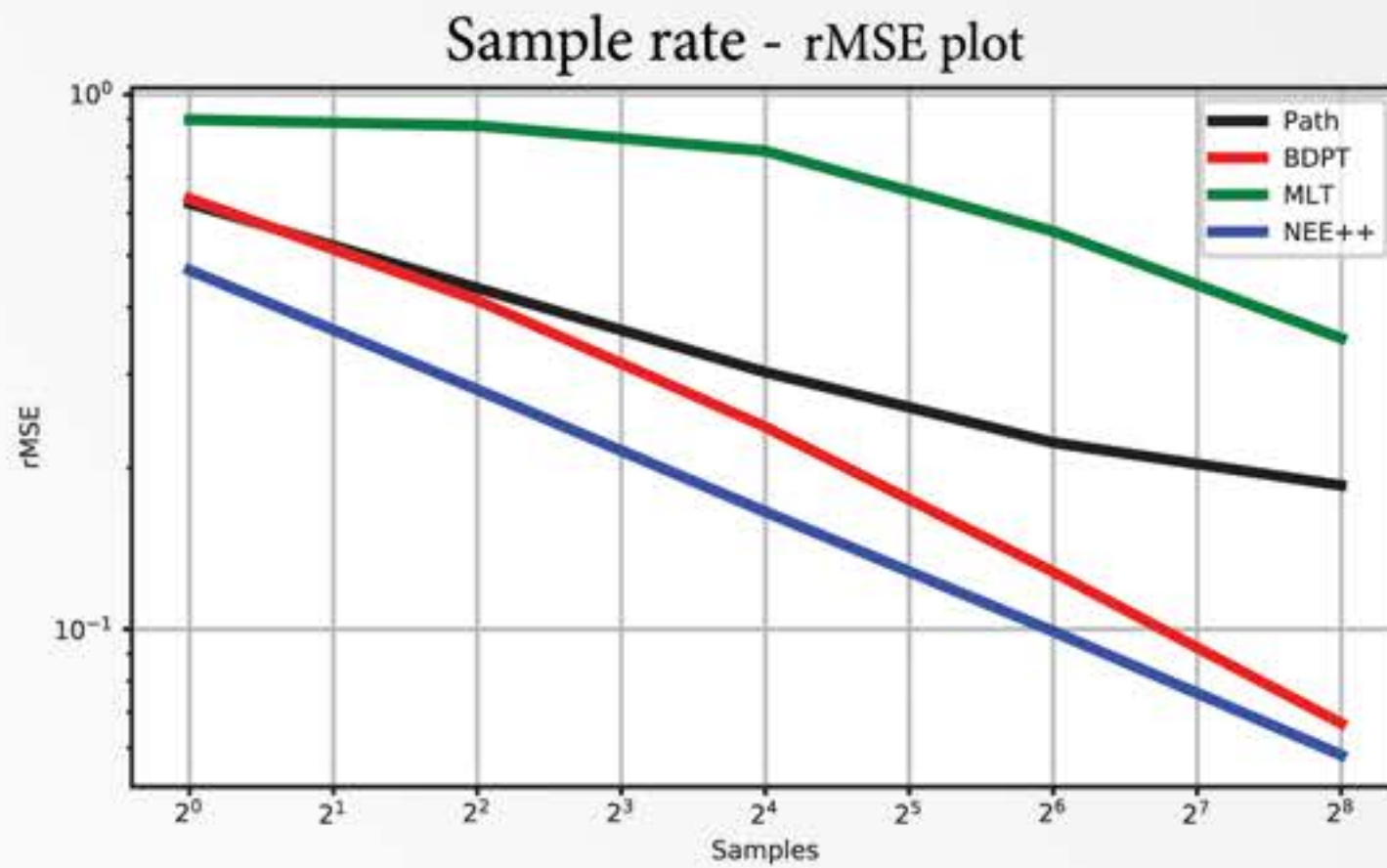
Light Subpath Sampling for BDPT
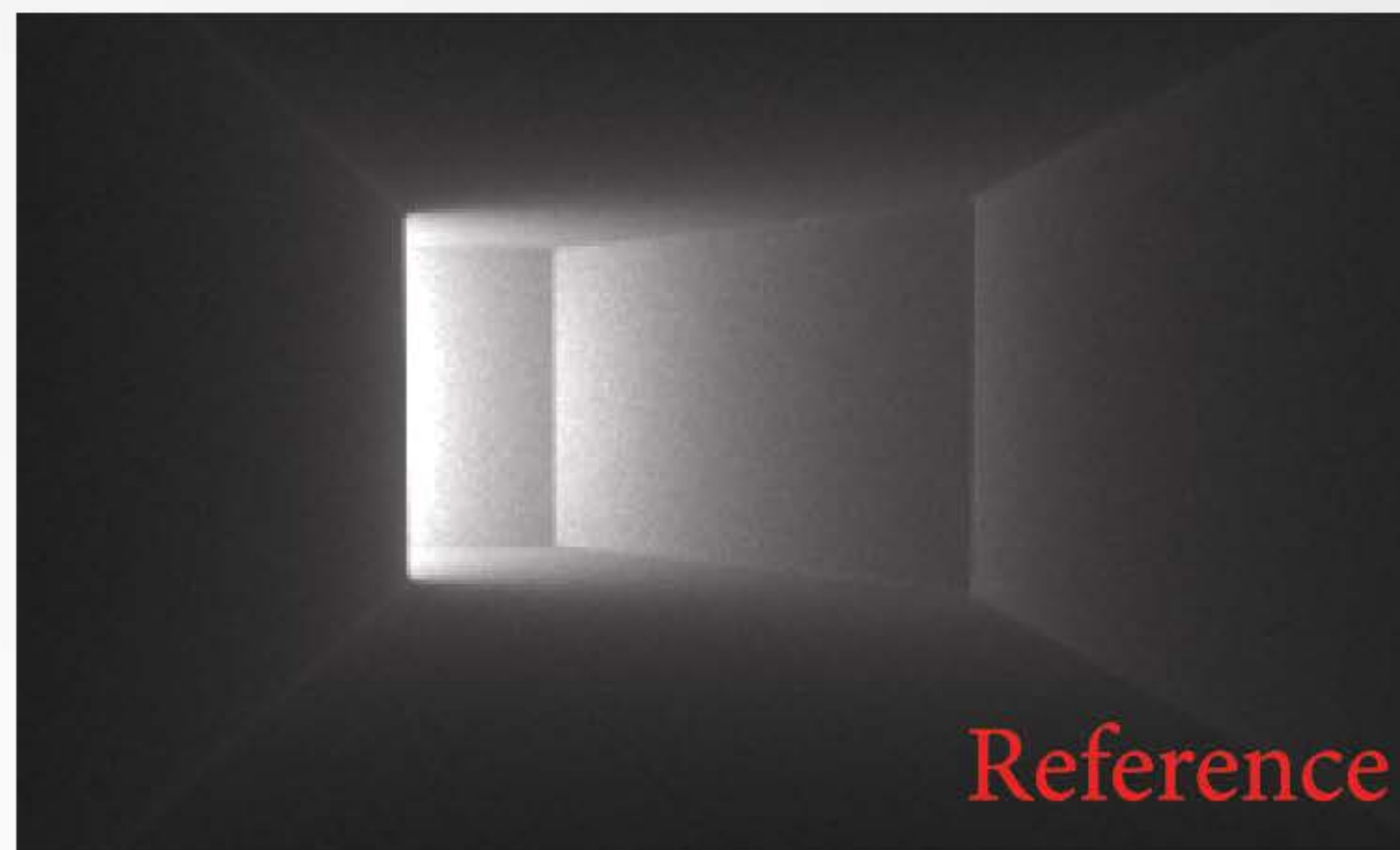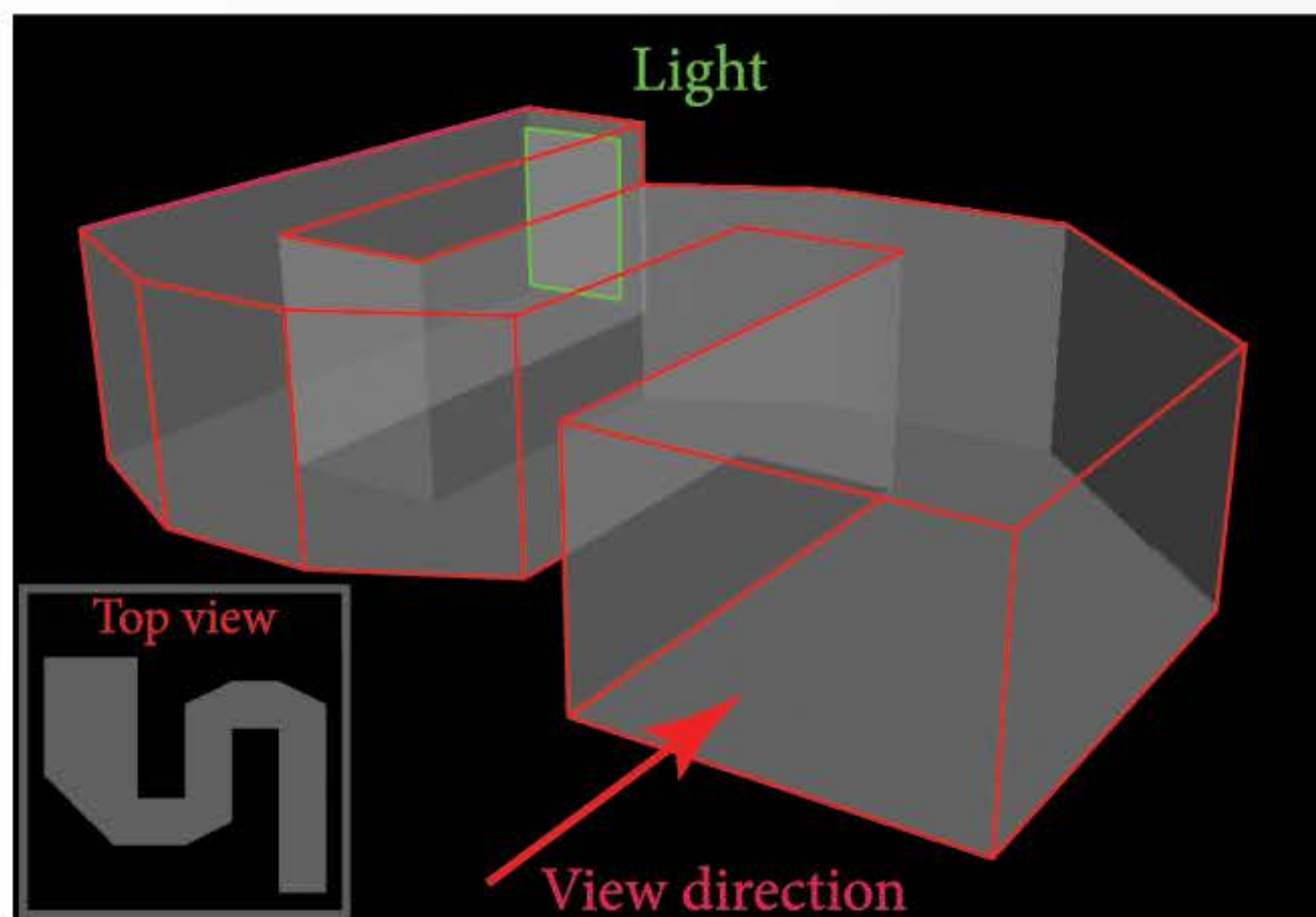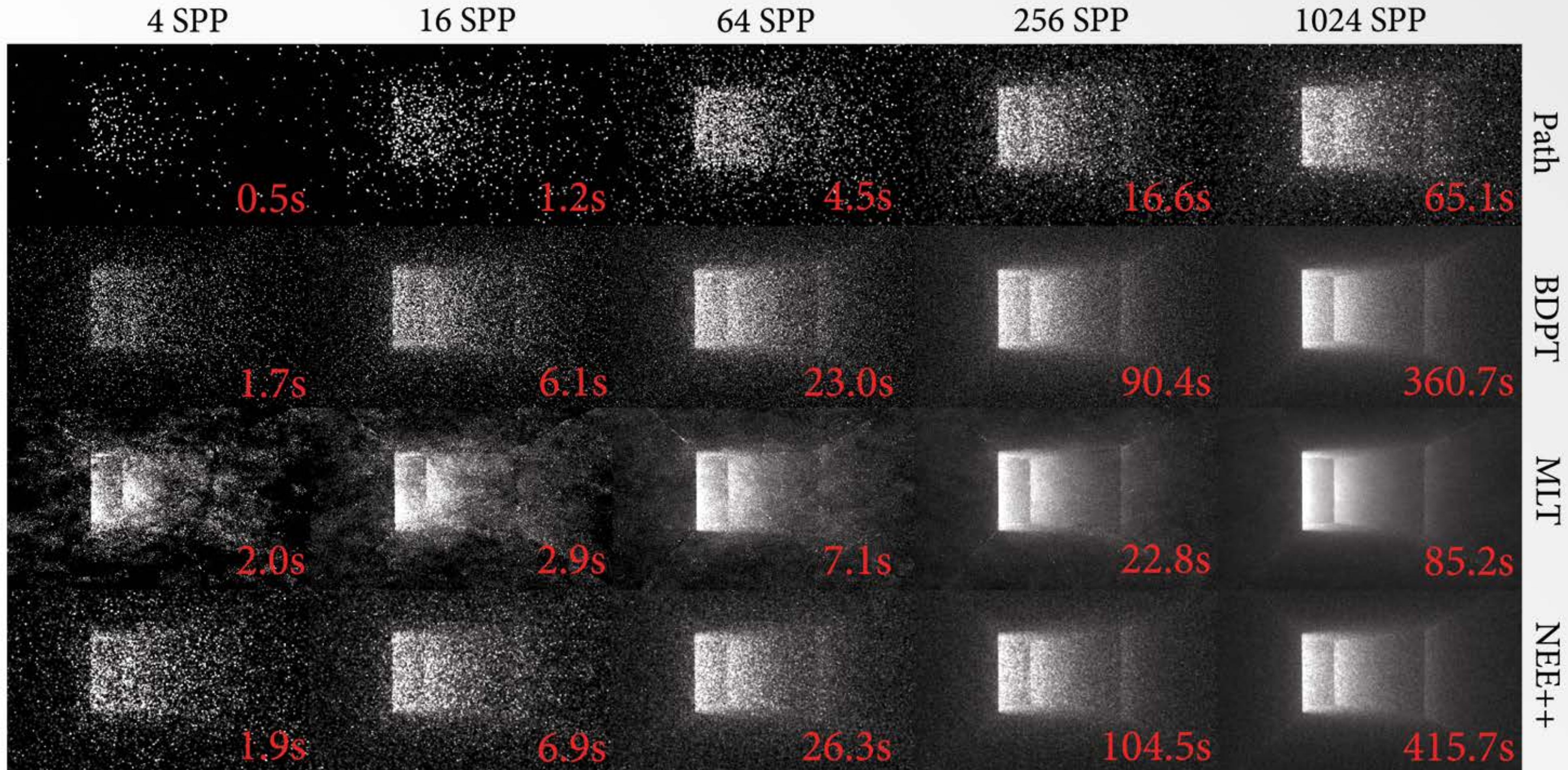
Light Subpath Sampling for BDPT

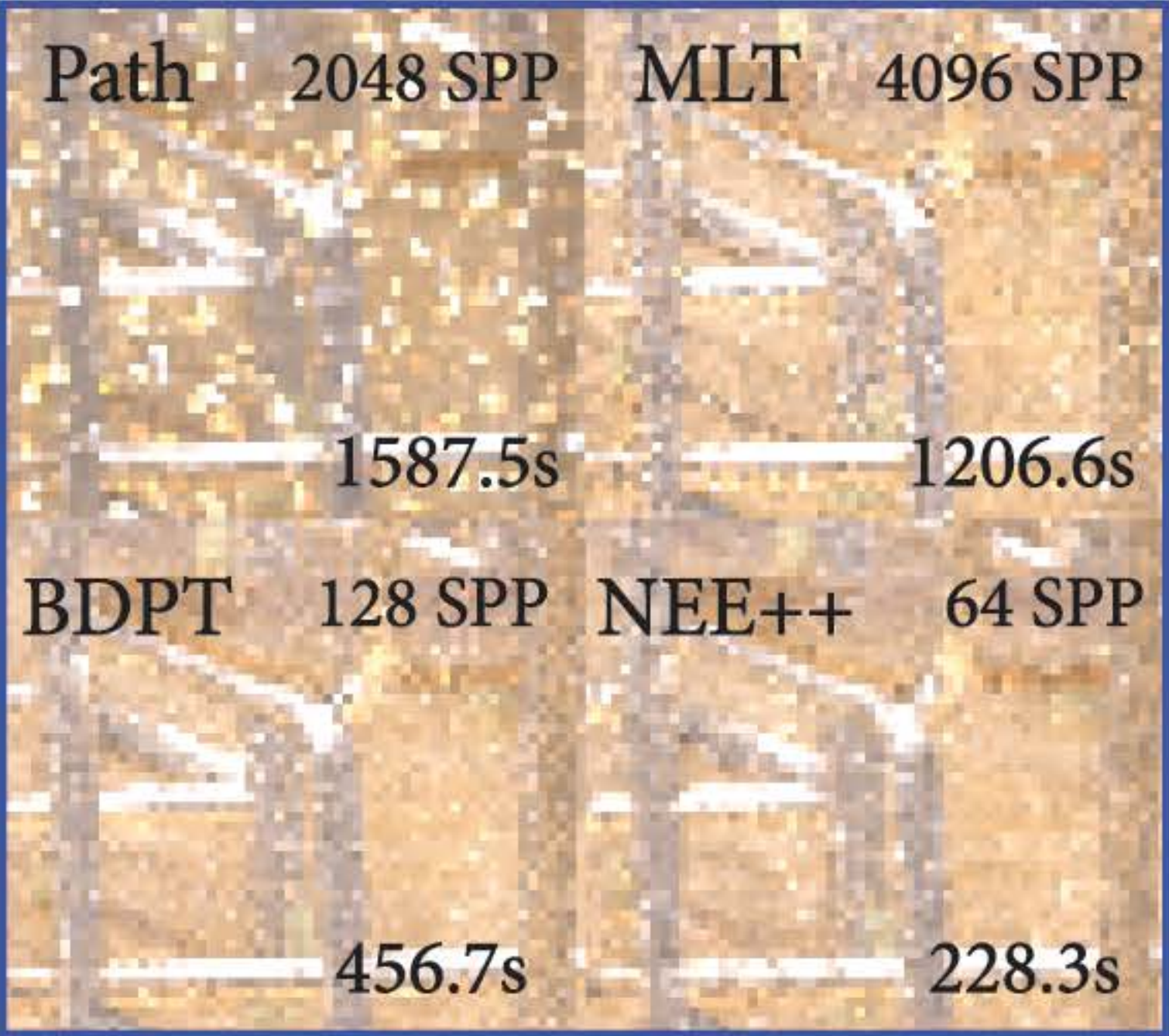# Light Subpath Sampling for BDPT

Light Subpath Sampling for BDPT

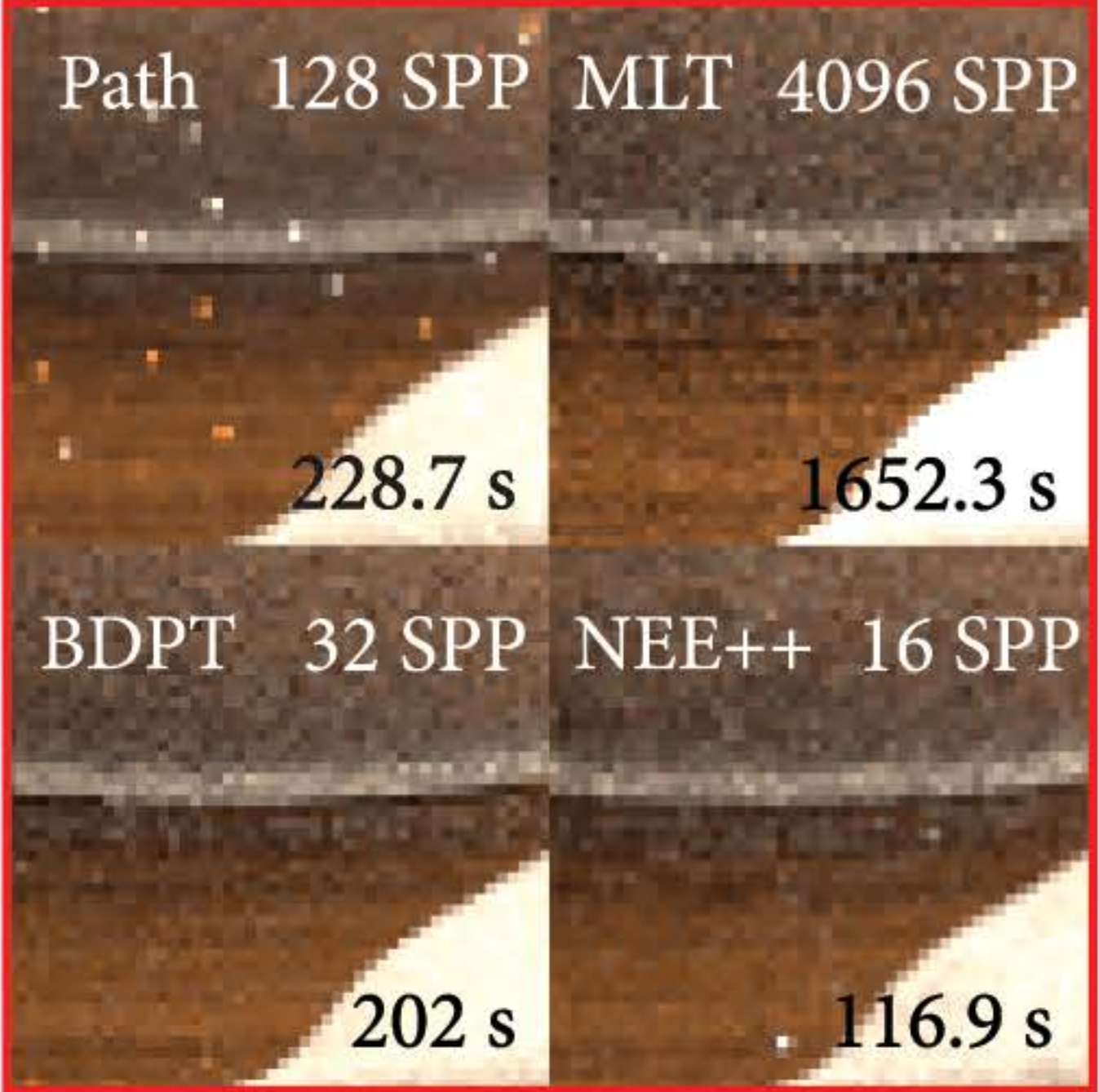# Light Subpath Sampling for BDPT

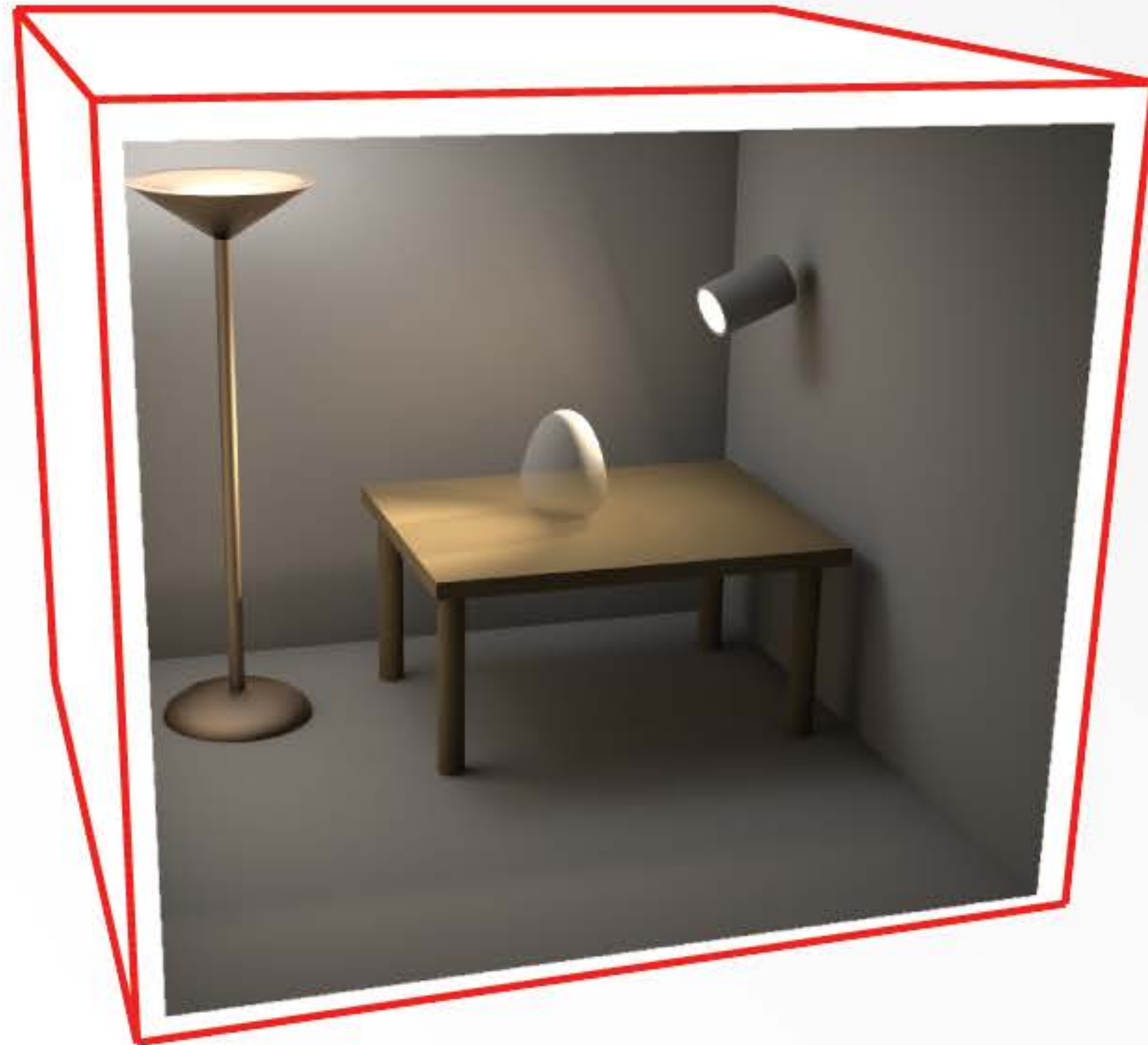# Light Subpath Sampling for BDPT
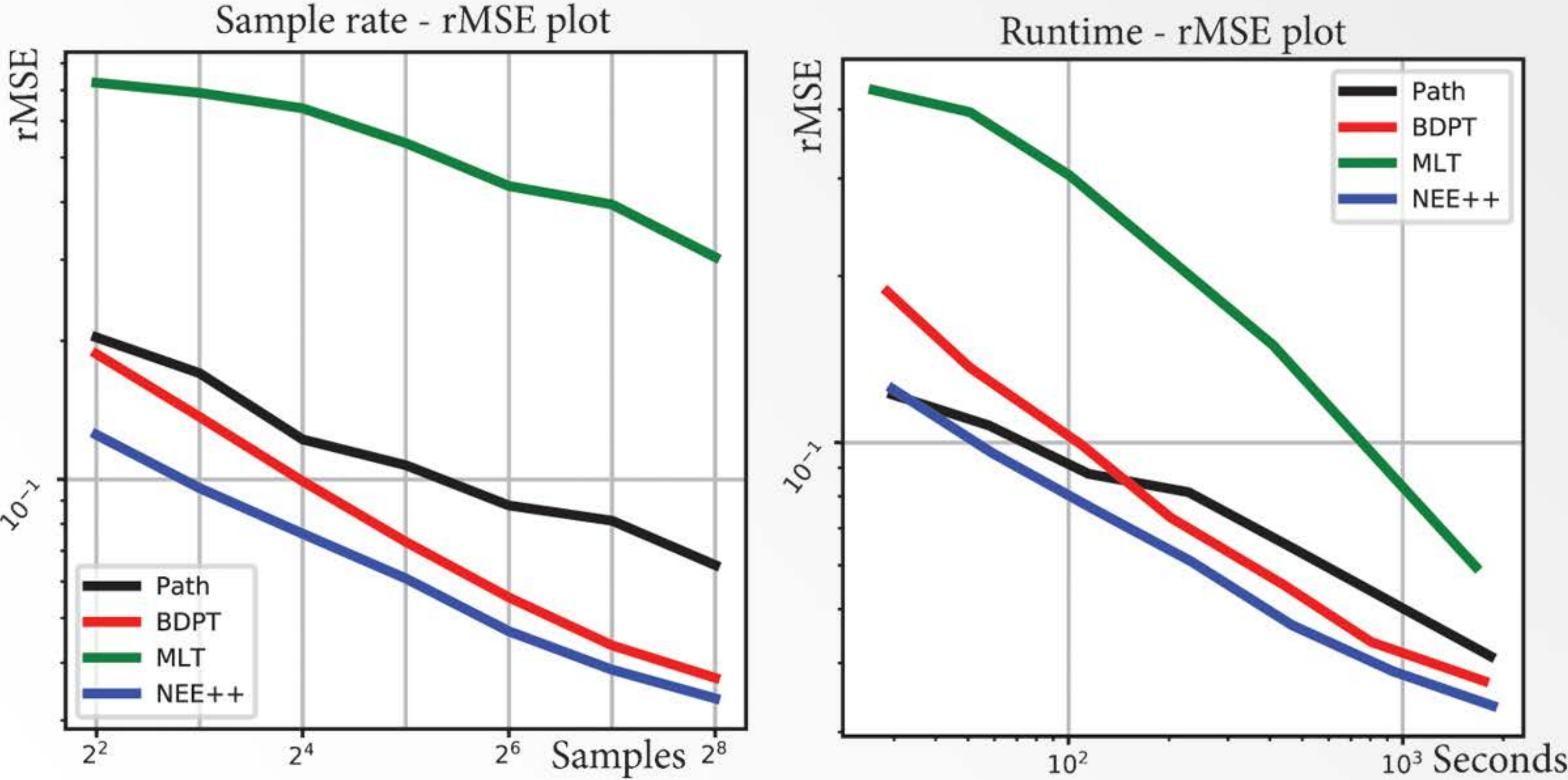
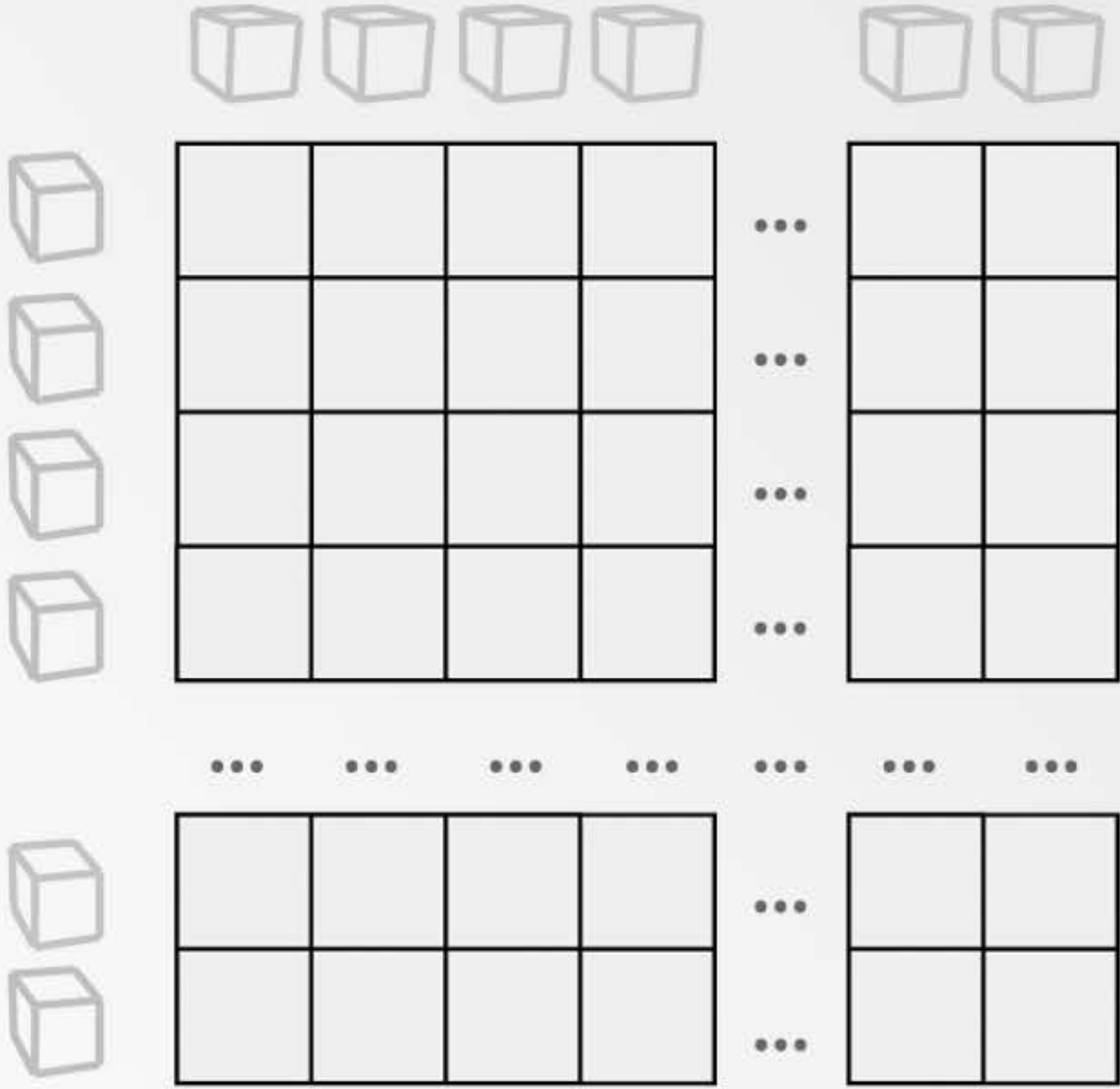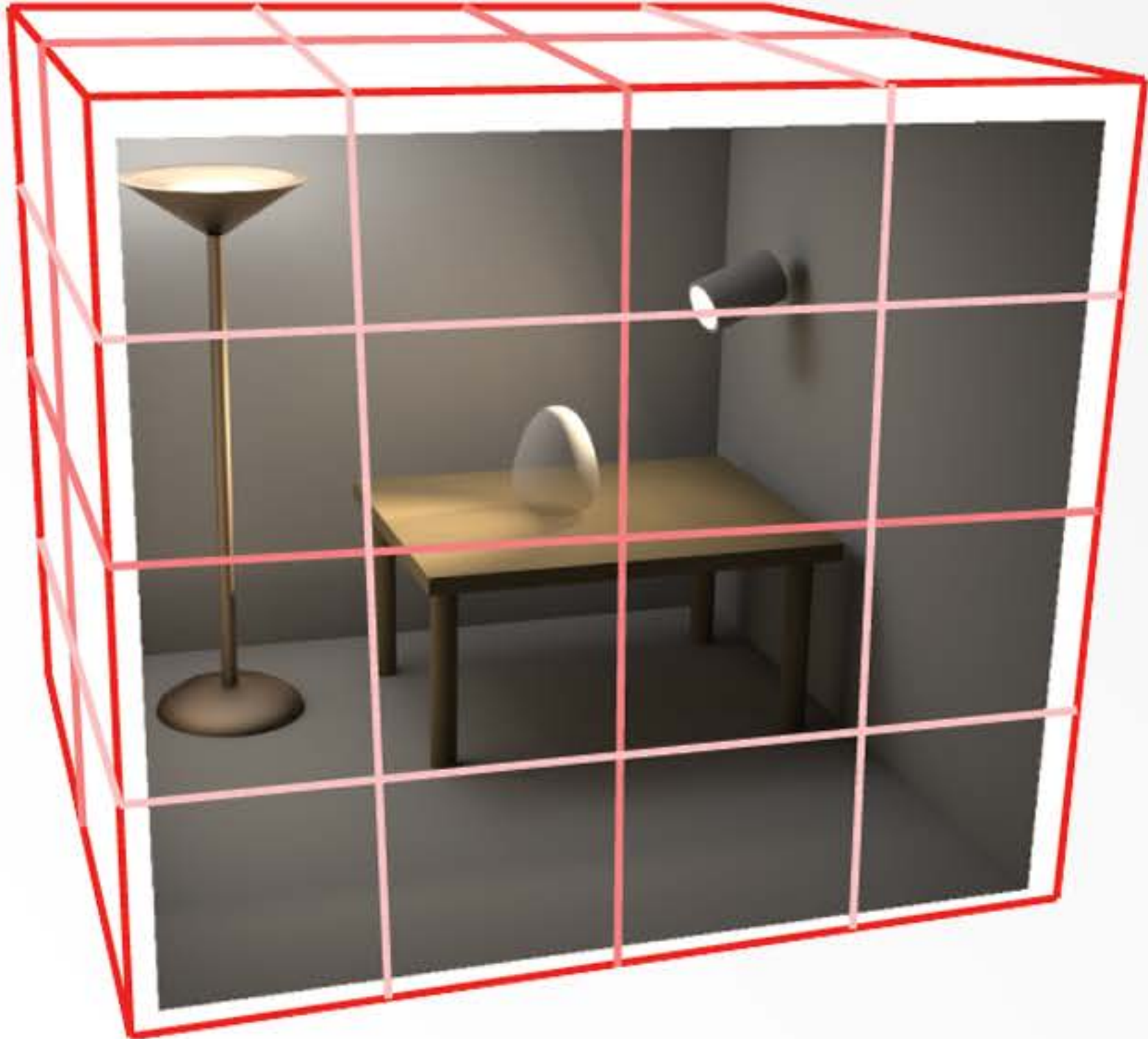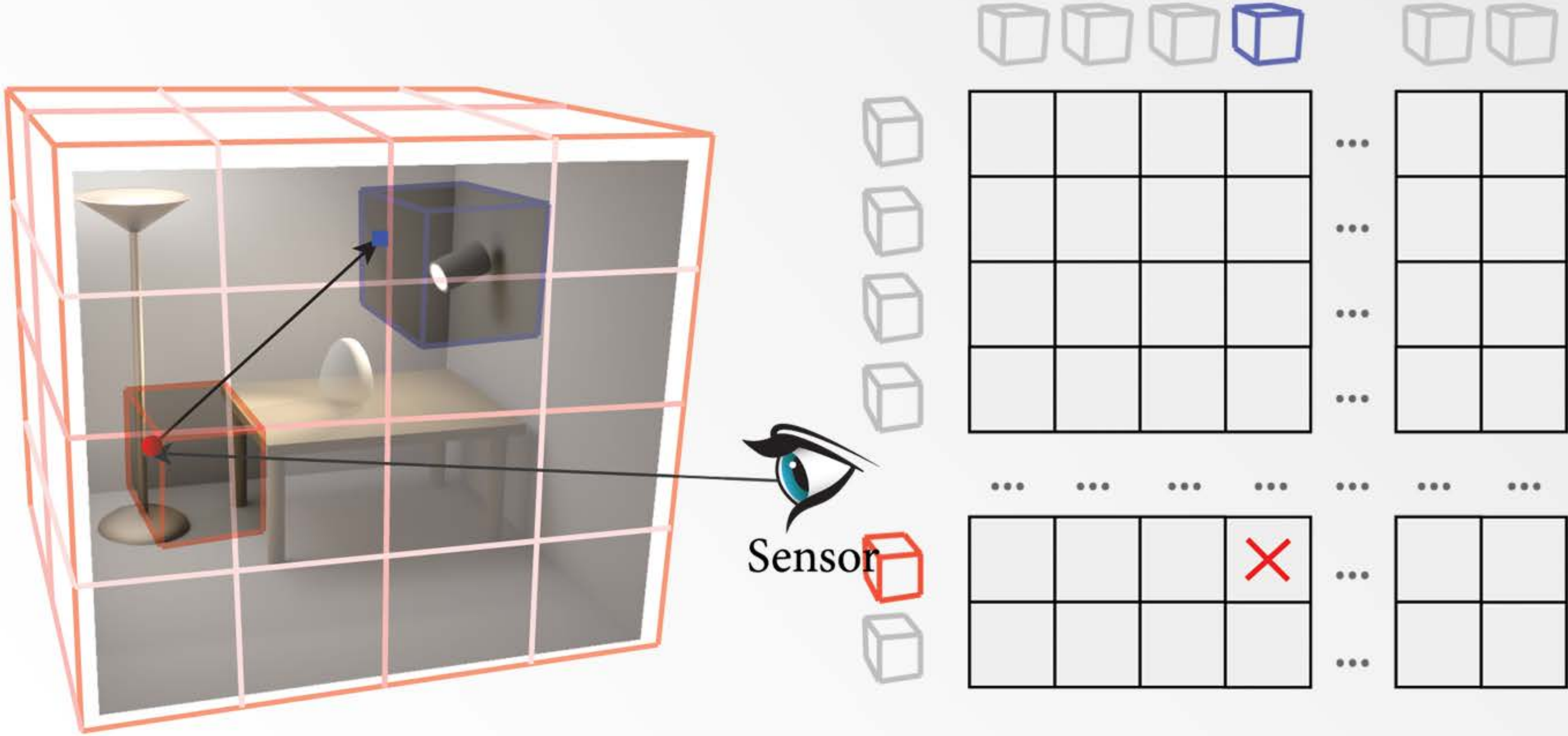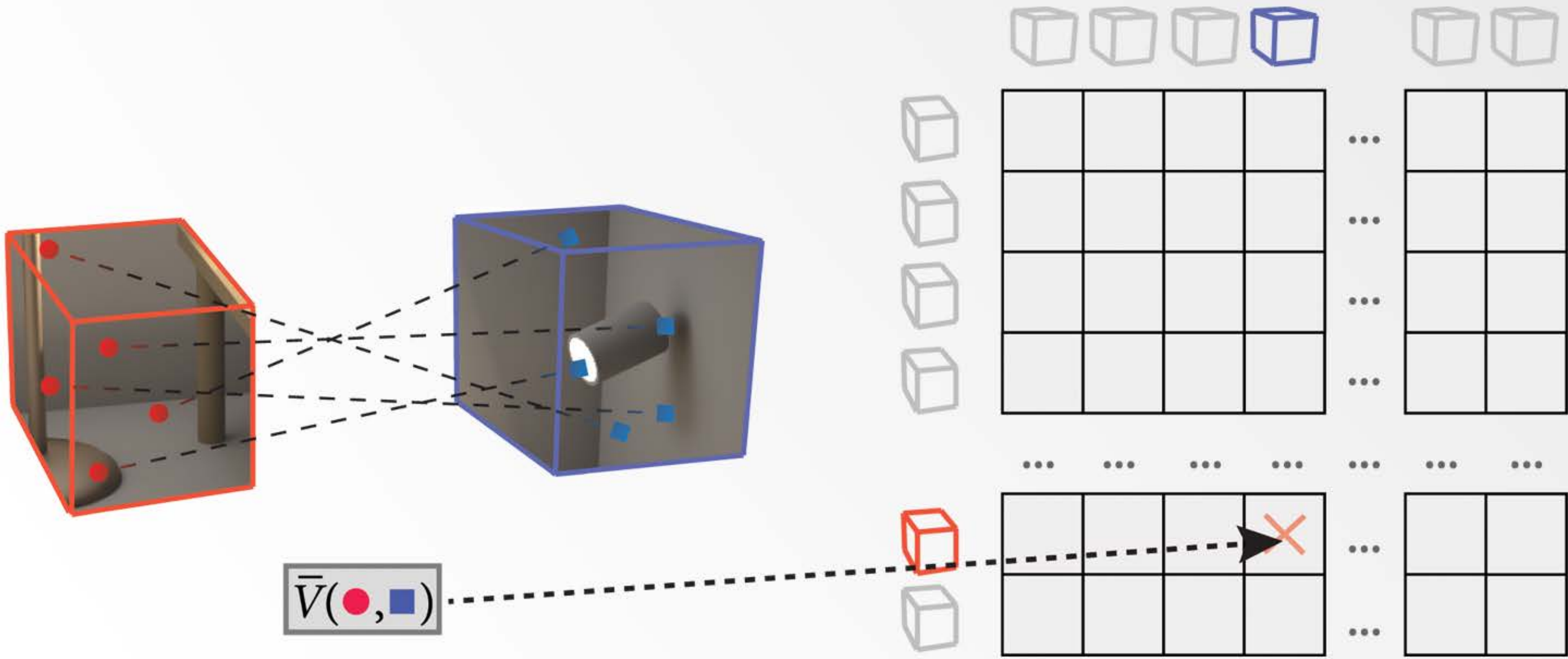# Light Subpath Sampling for BDPT

Classroom   Bathroom
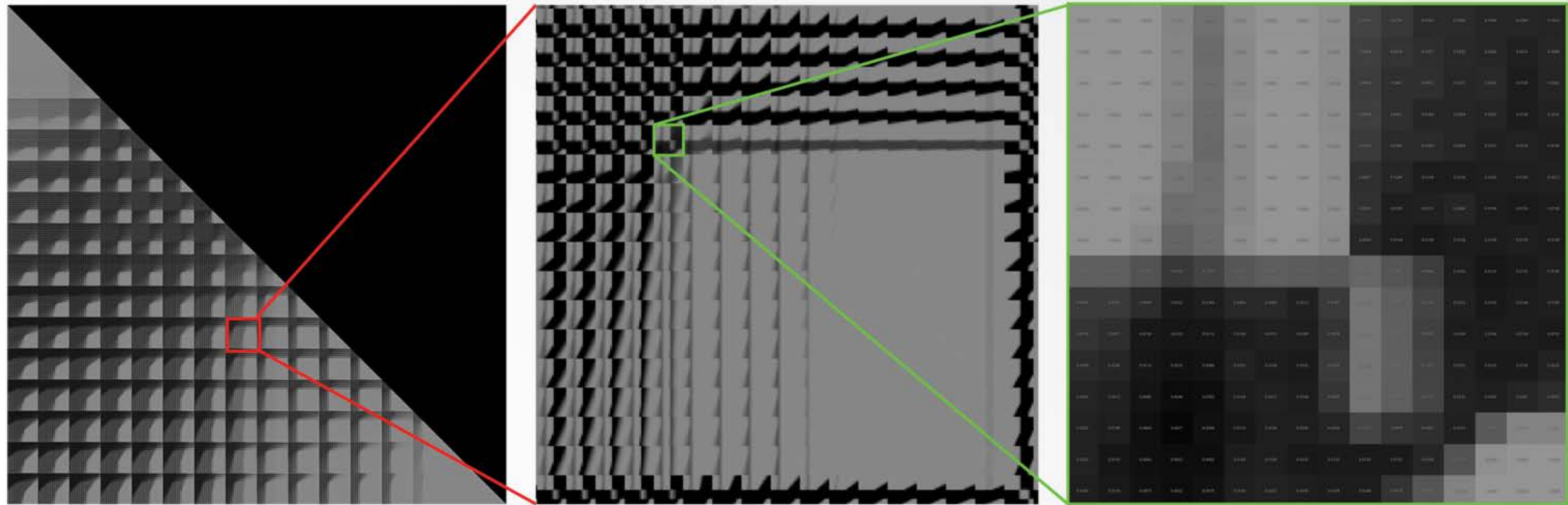
Visibility Map Generation
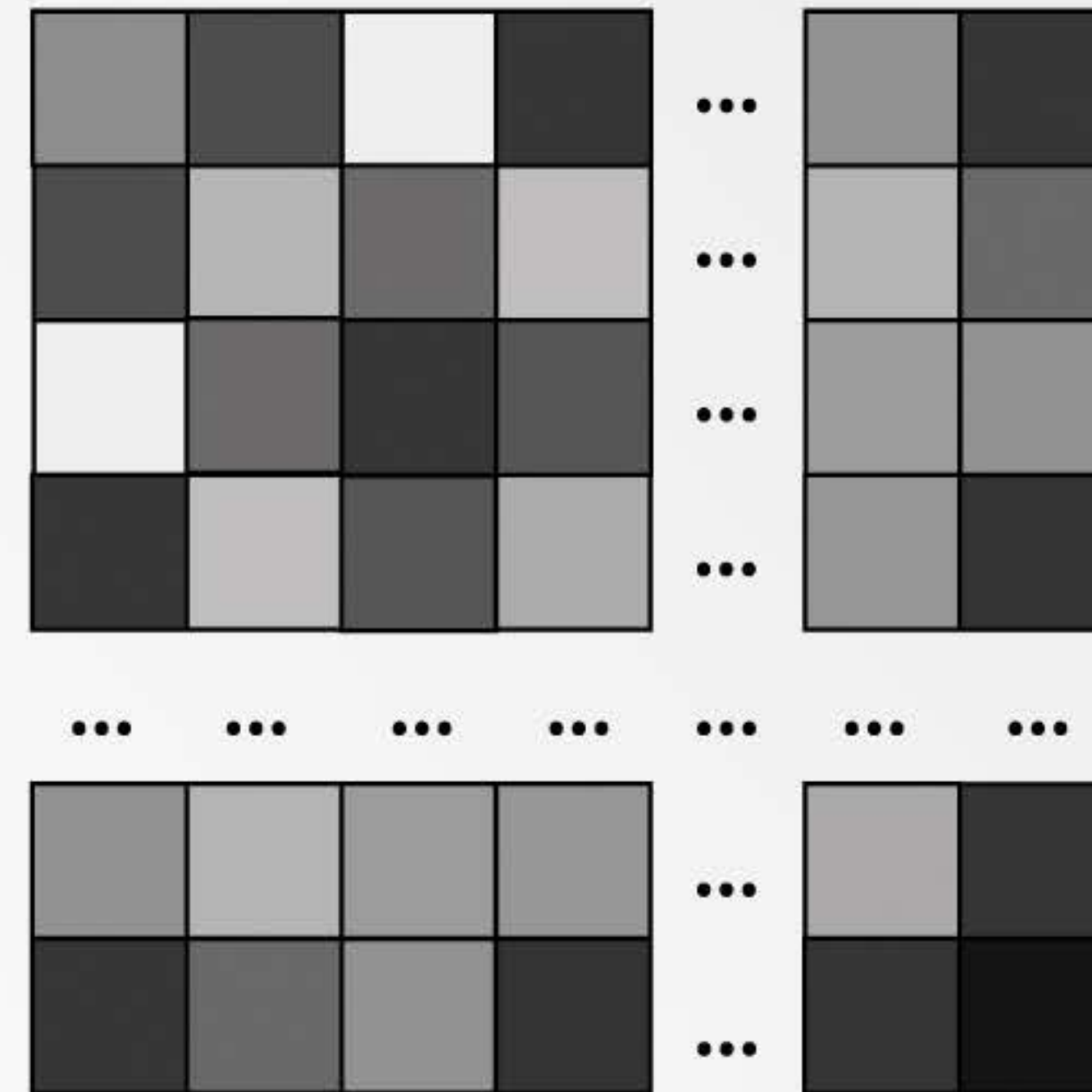
Visibility Map Generation

Visibility Map Generation

Sensor

Visibility Map Generation

$\overline{V}(\bullet, \blacksquare)$

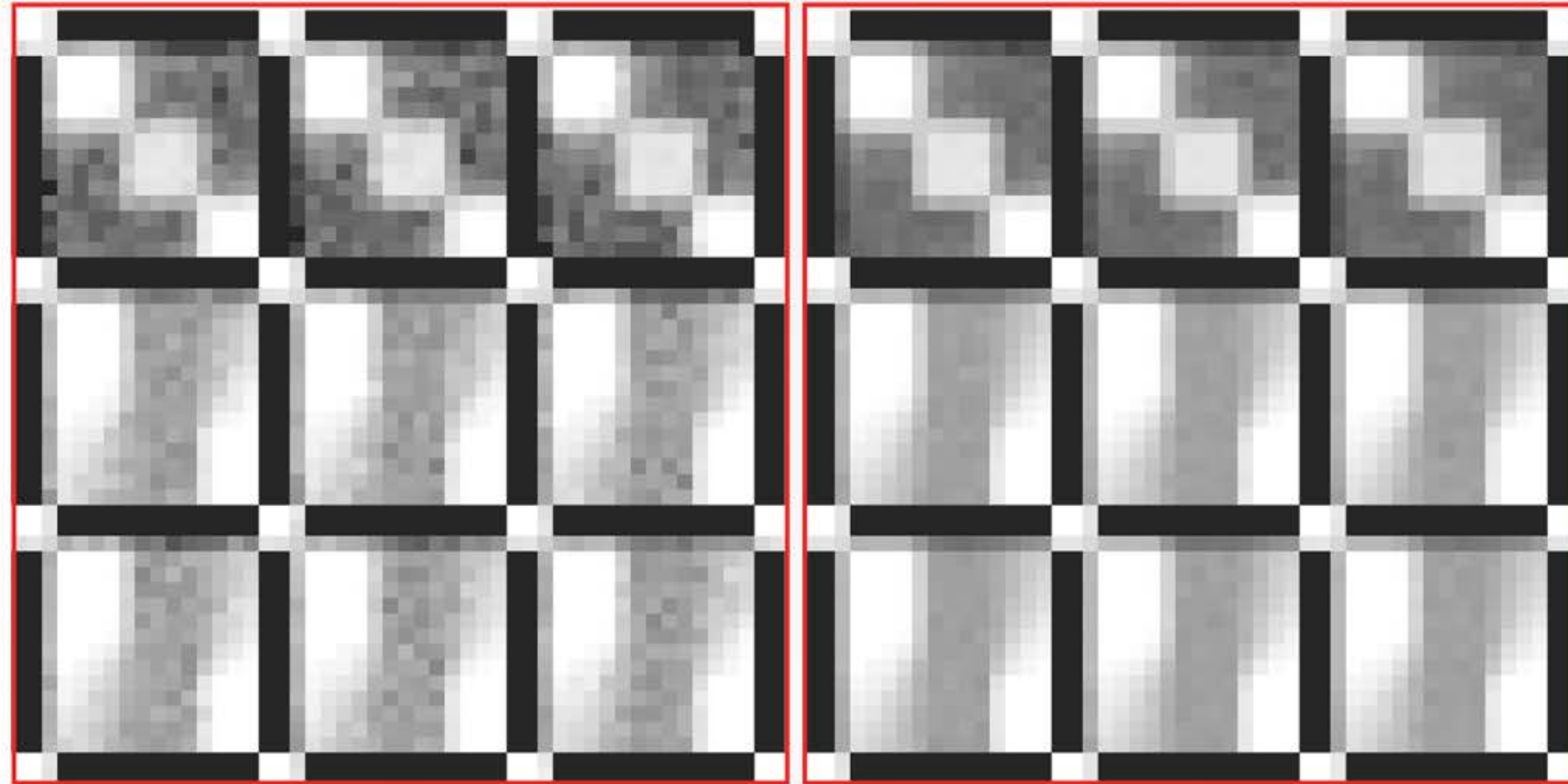# Visibility Map Generation

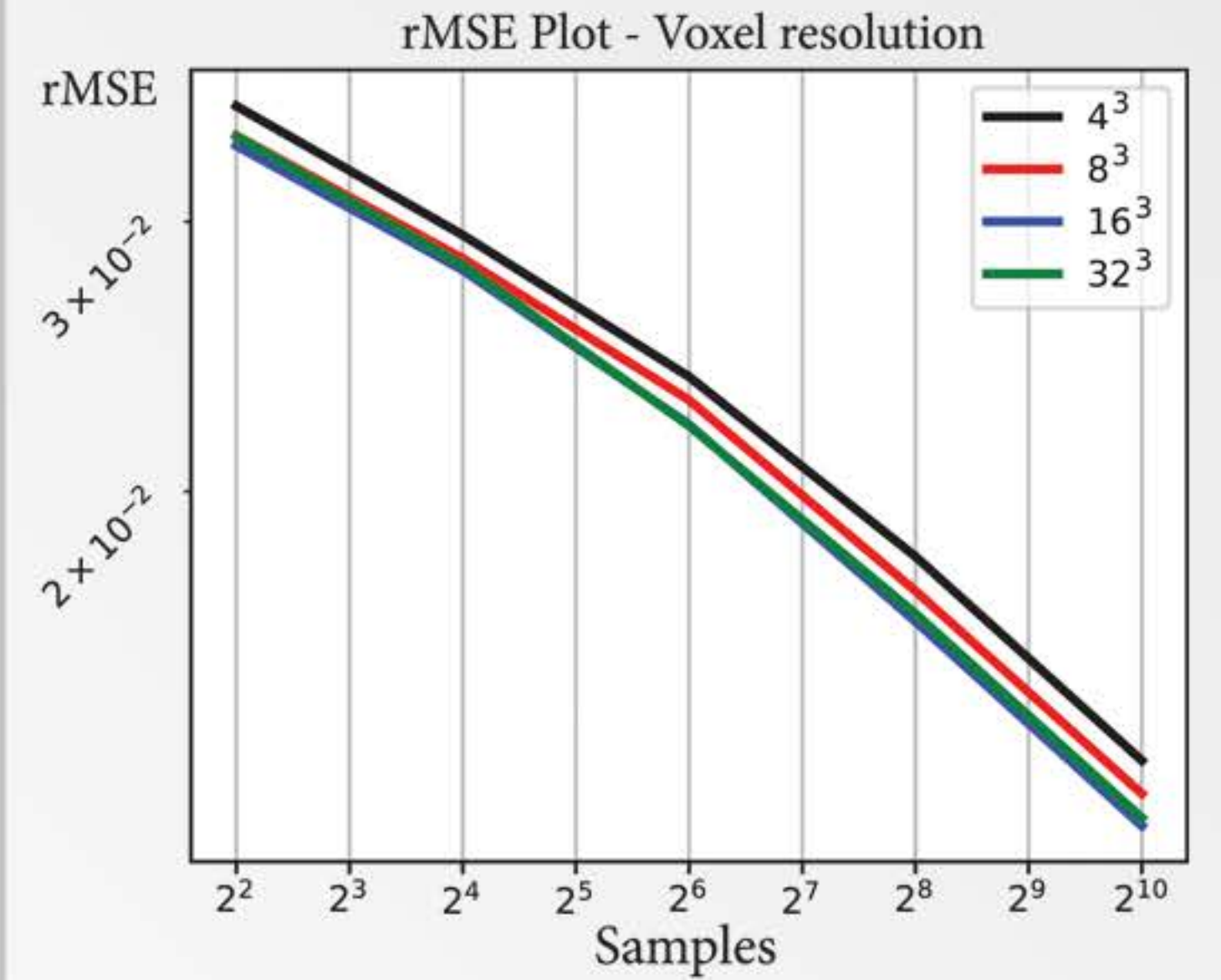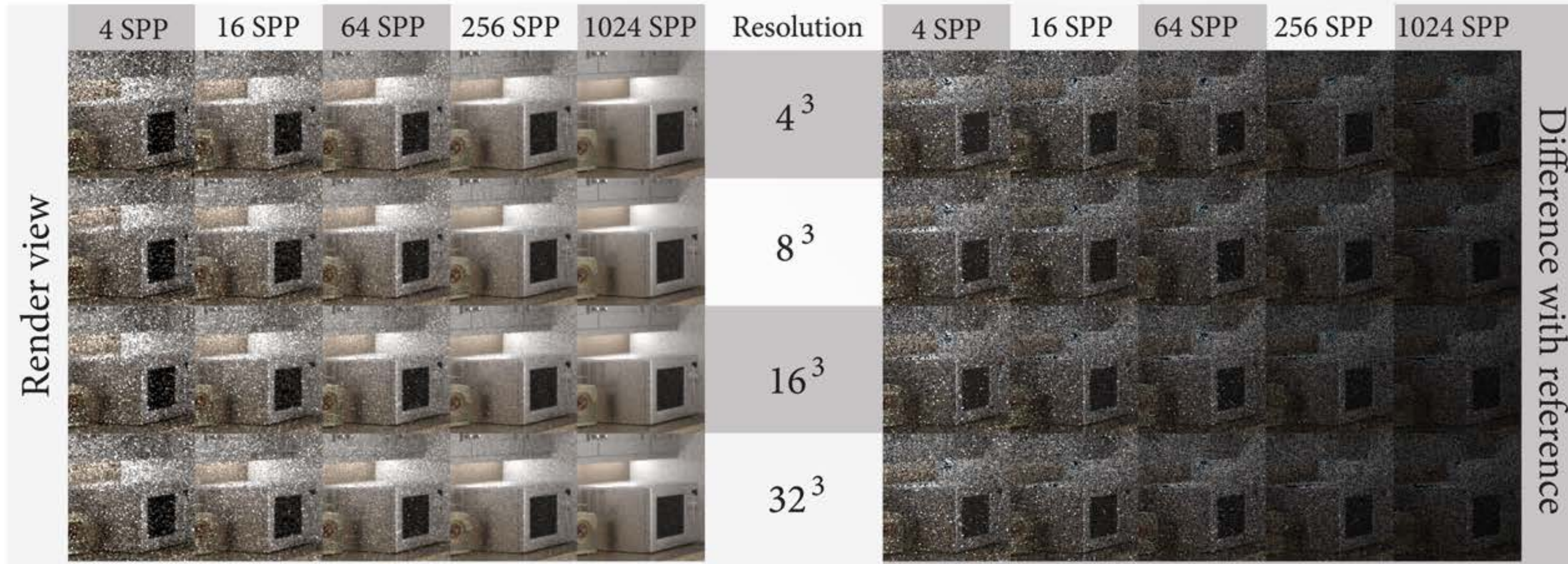# Visibility Map Generation

16 vis-sample   64 vis-sample

Implementation Details

Grid resolution 16x16x16
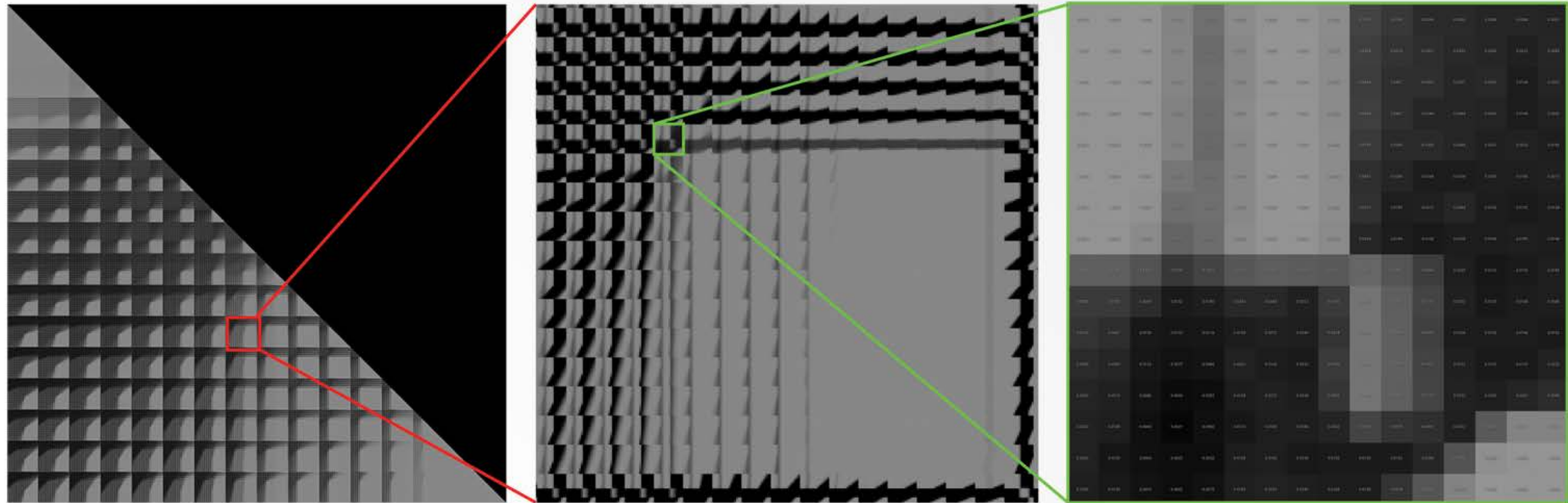
Higher resolution does not result in better result
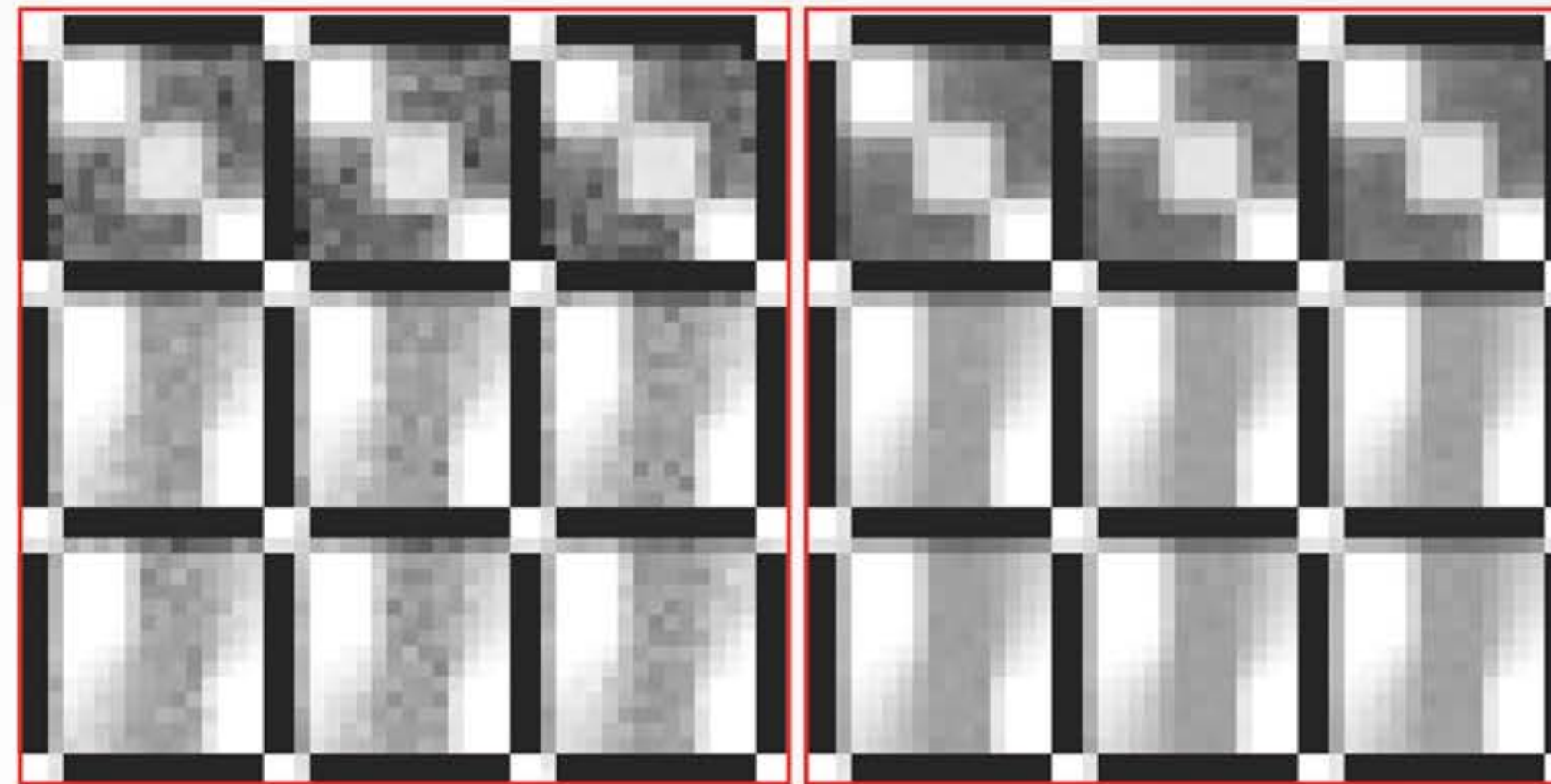
Implementation Details

Map 4096x4096

Implementation Details

Map 4096x4096

Explicit visibility samples: 16 is good enough

16 vis-sample   64 vis-sample

Conclusion

Visibility mapping for light transport simulation

   Simple to implement and plug into existing solutions

   Effective, robust and efficient

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Limitations

    Scenes with simple visibility

    Scenes with non-physical light source

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Visibility mapping for light transport simulation

Simple to implement and plug into existing solutions

Effective, robust and efficient

Limitations

Scenes with simple visibility

Scenes with non-physical light source

Future work

Interactive light transport

Thank you!

Next Event Estimation++
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