Progressive Photon Mapping Extensions

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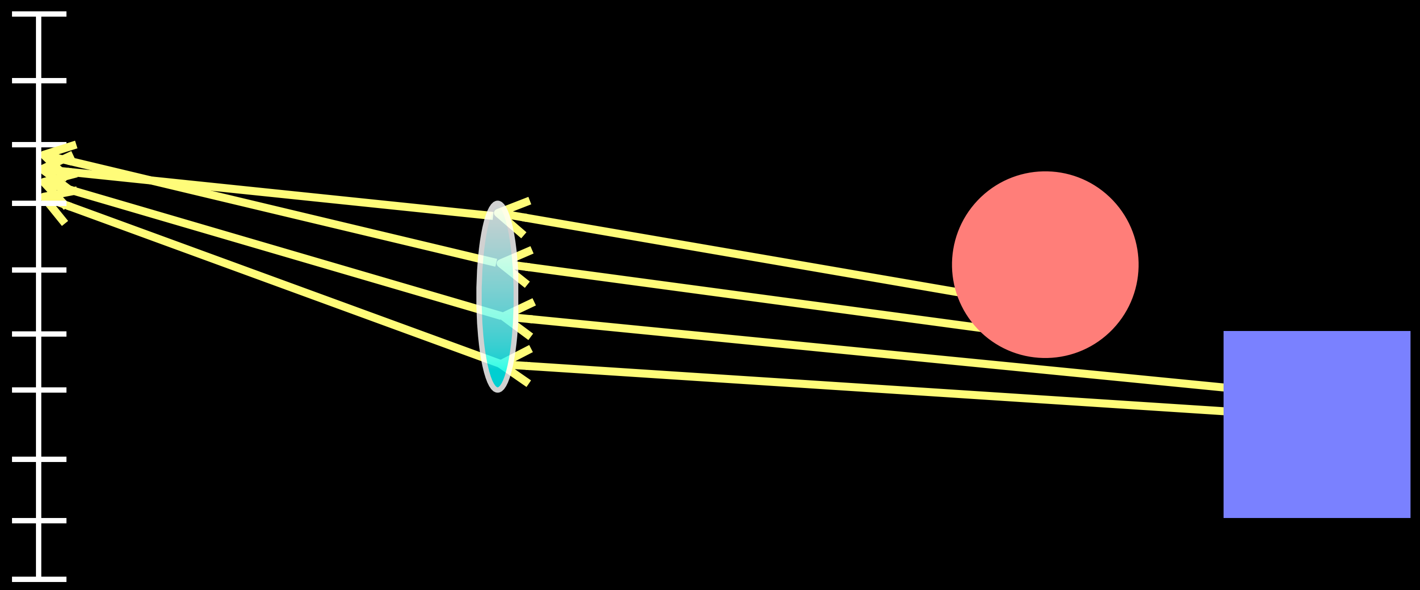
State of the Art in Photon Density Estimation
SIGGRAPH 2012 Course

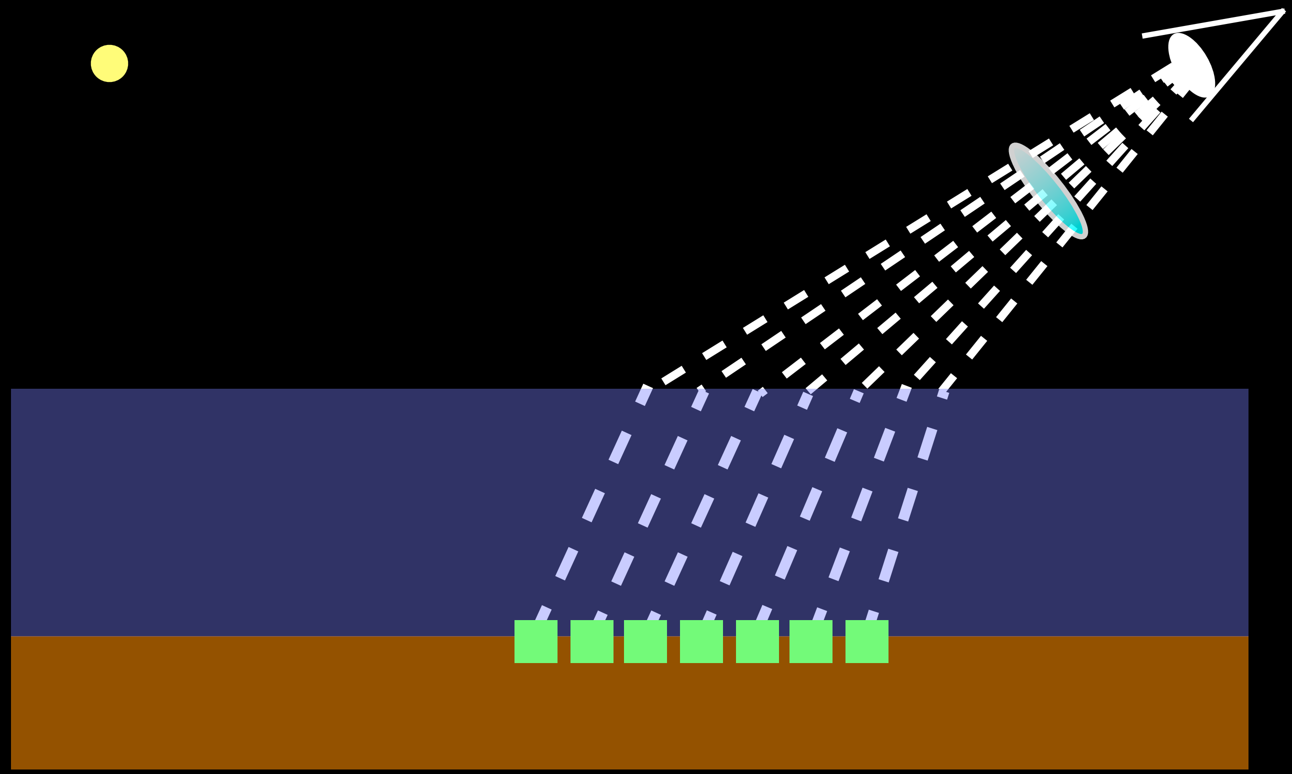

SANDY
contractors
594461

Distributed Ray Tracing

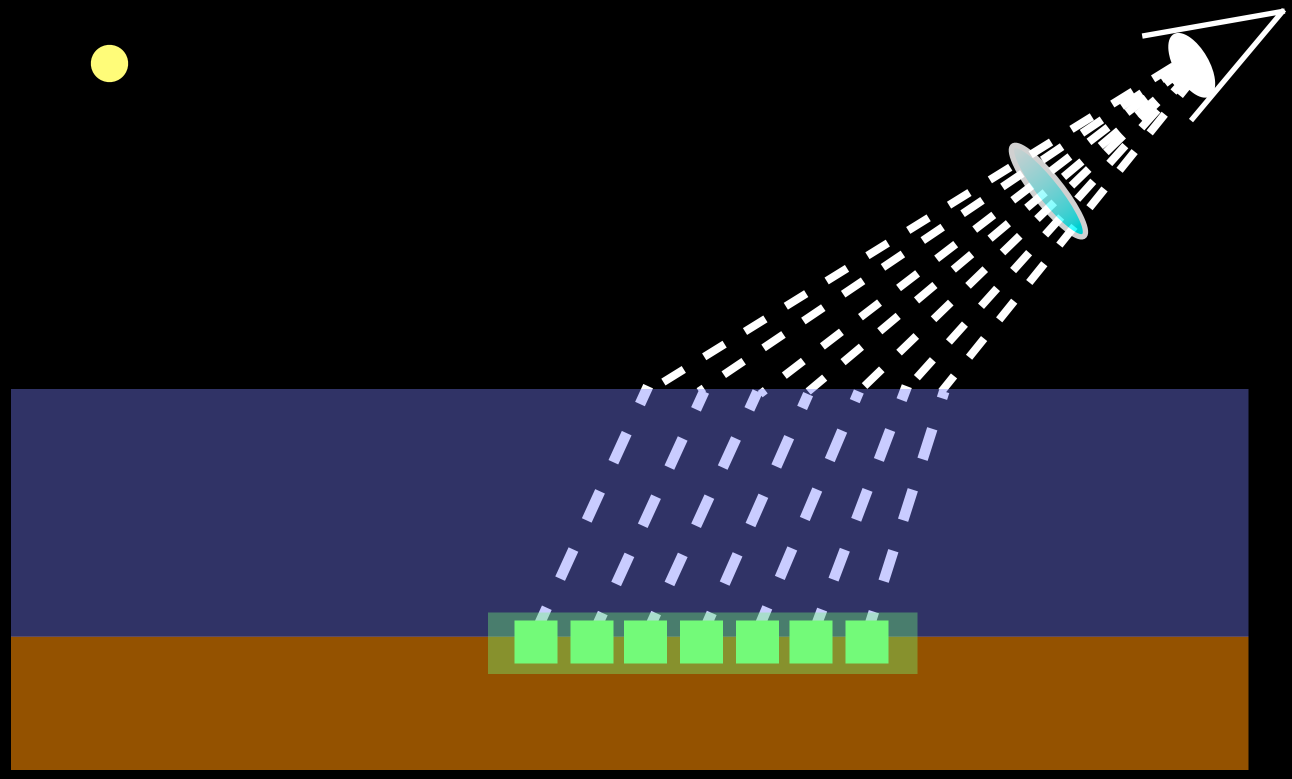
- Computes average illumination [Cook et al. 84]



Lens Simulation with PPM



Lens Simulation with PPM



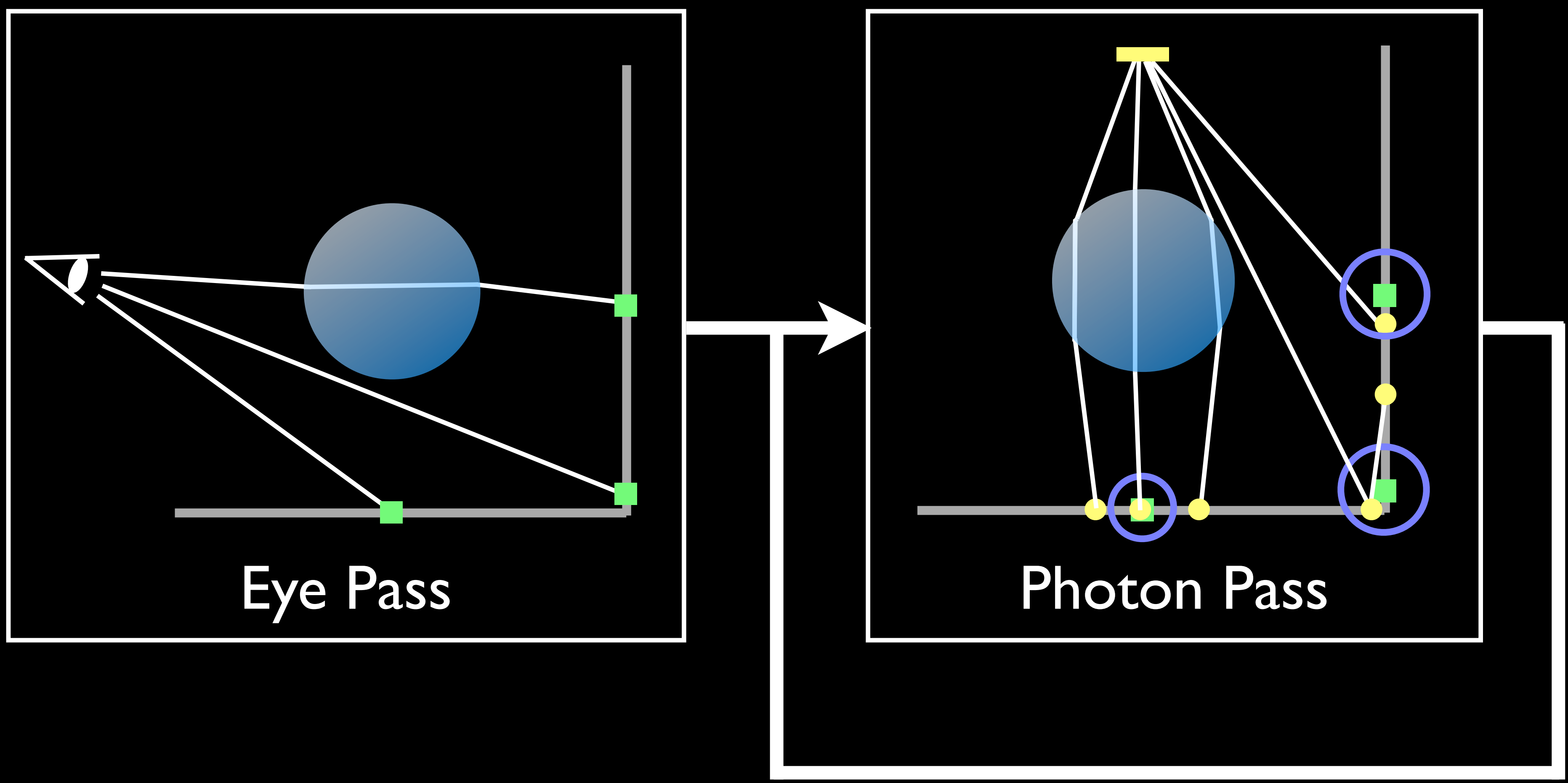
Infinite number of measurement points

Stochastic Progressive Photon Mapping

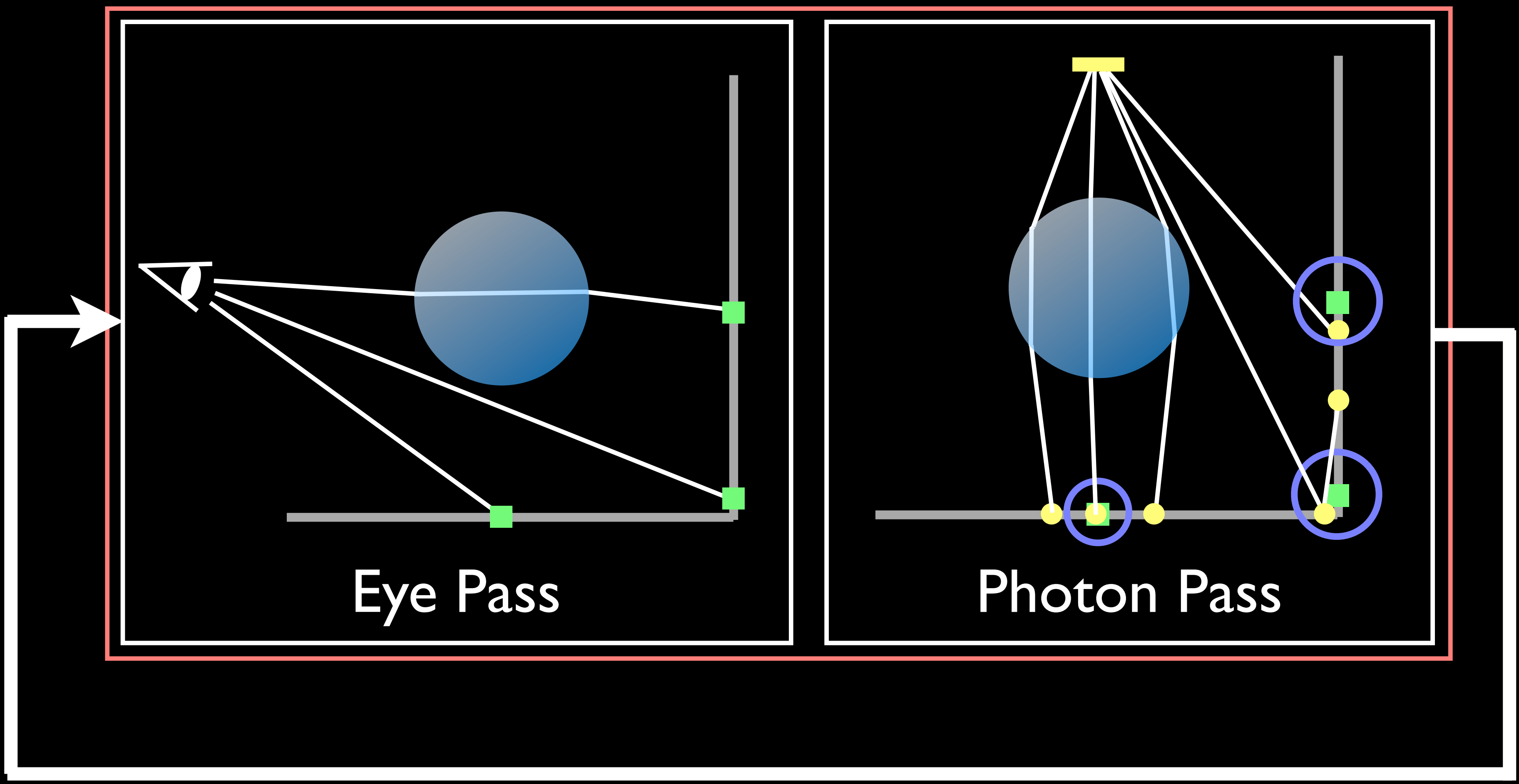
Toshiya Hachisuka   Henrik Wann Jensen

Published at SIGGRAPH Asia 2009

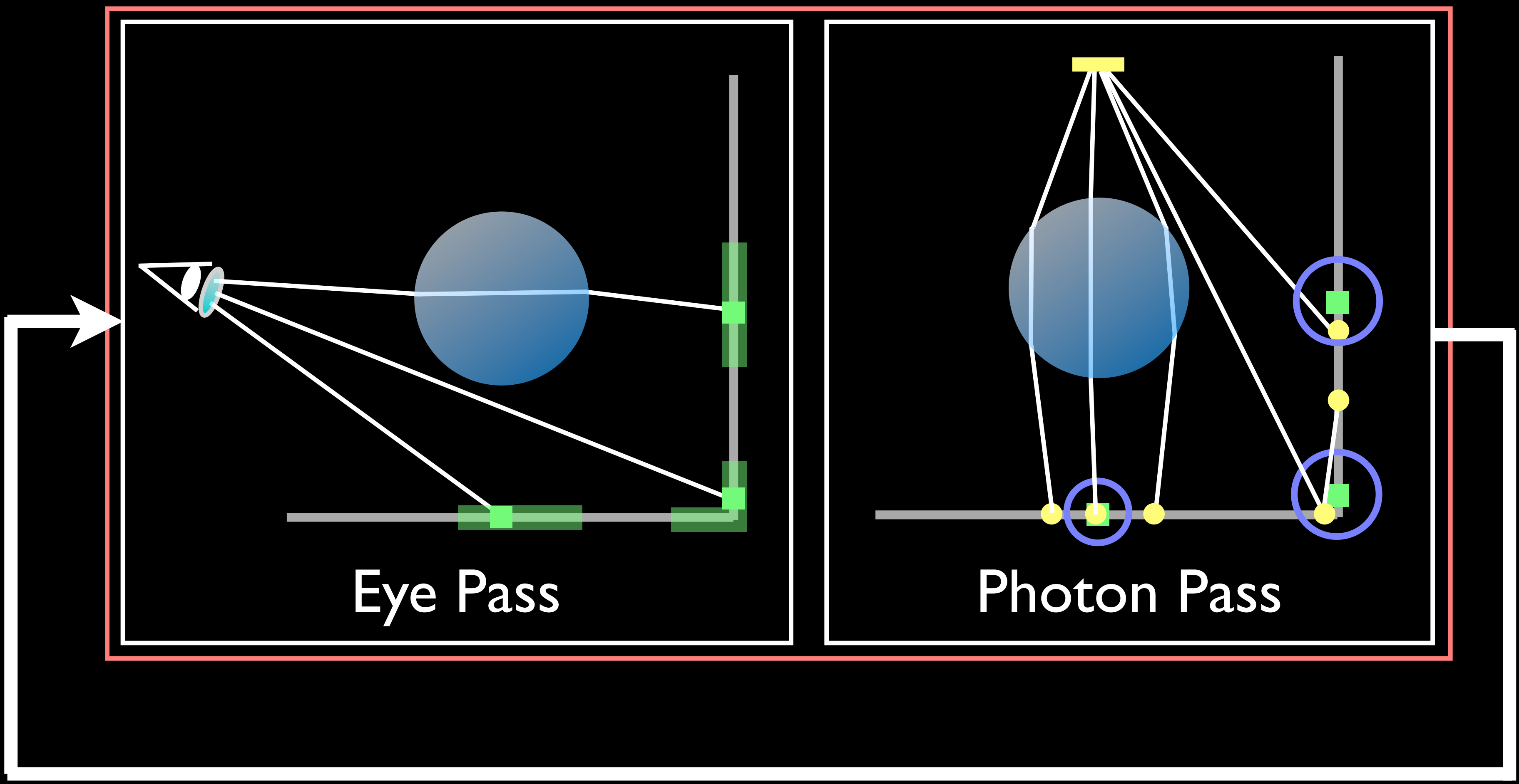
PPM



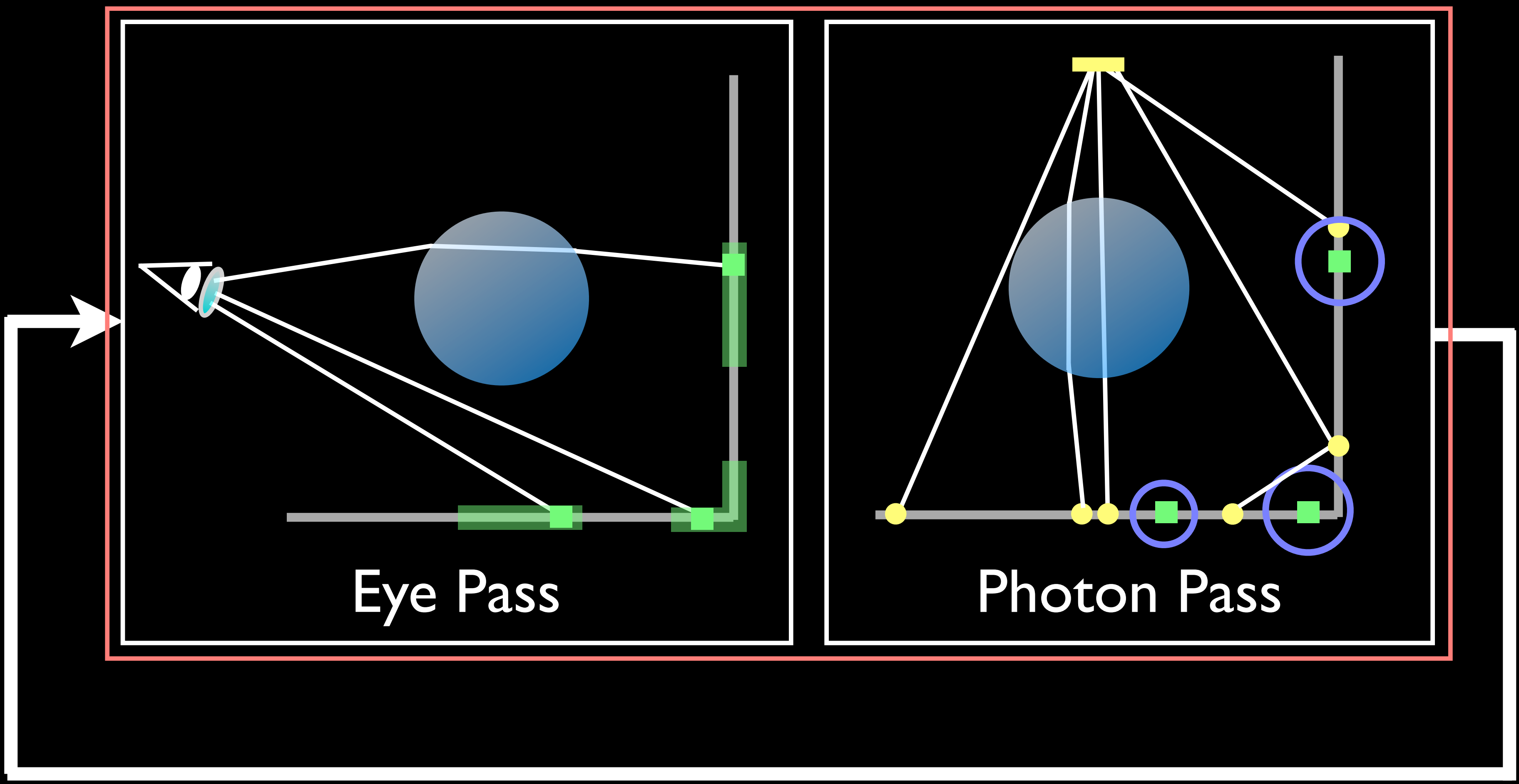
Stochastic PPM



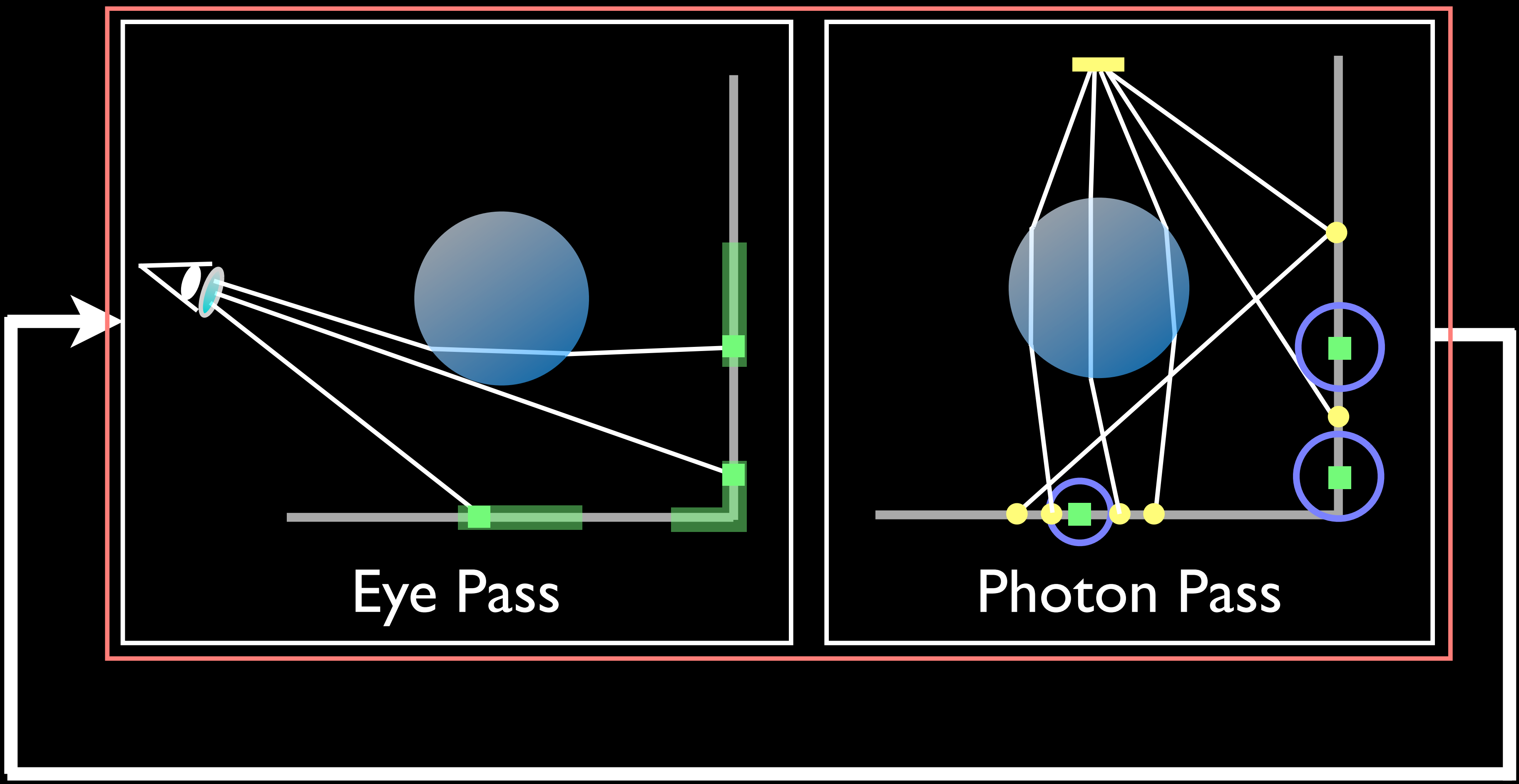
Stochastic PPM



Stochastic PPM



Stochastic PPM



Stochastic Progressive Density Estimation

$$L_i\left(S,\vec{\omega}\right) = \frac{\tau_i\left(S,\vec{\omega}\right)}{\pi R_i\left(S\right)^2 N_e(i)}$$

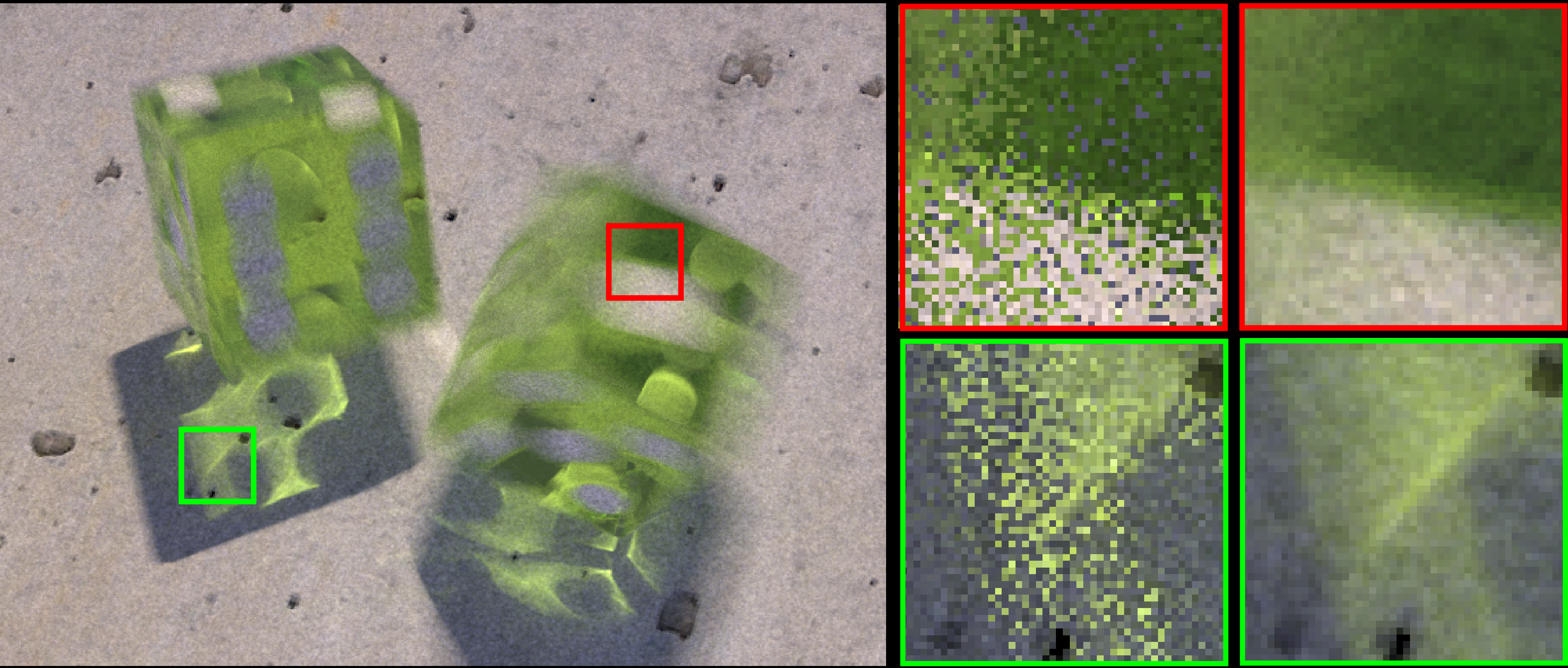
$$\boxed{\lim_{i\to\infty} L_i\left(S,\vec{\omega}\right) = L\left(S,\vec{\omega}\right)}$$

Provable convergence to
average photon density over a region S

Bidirectional Path Tracing

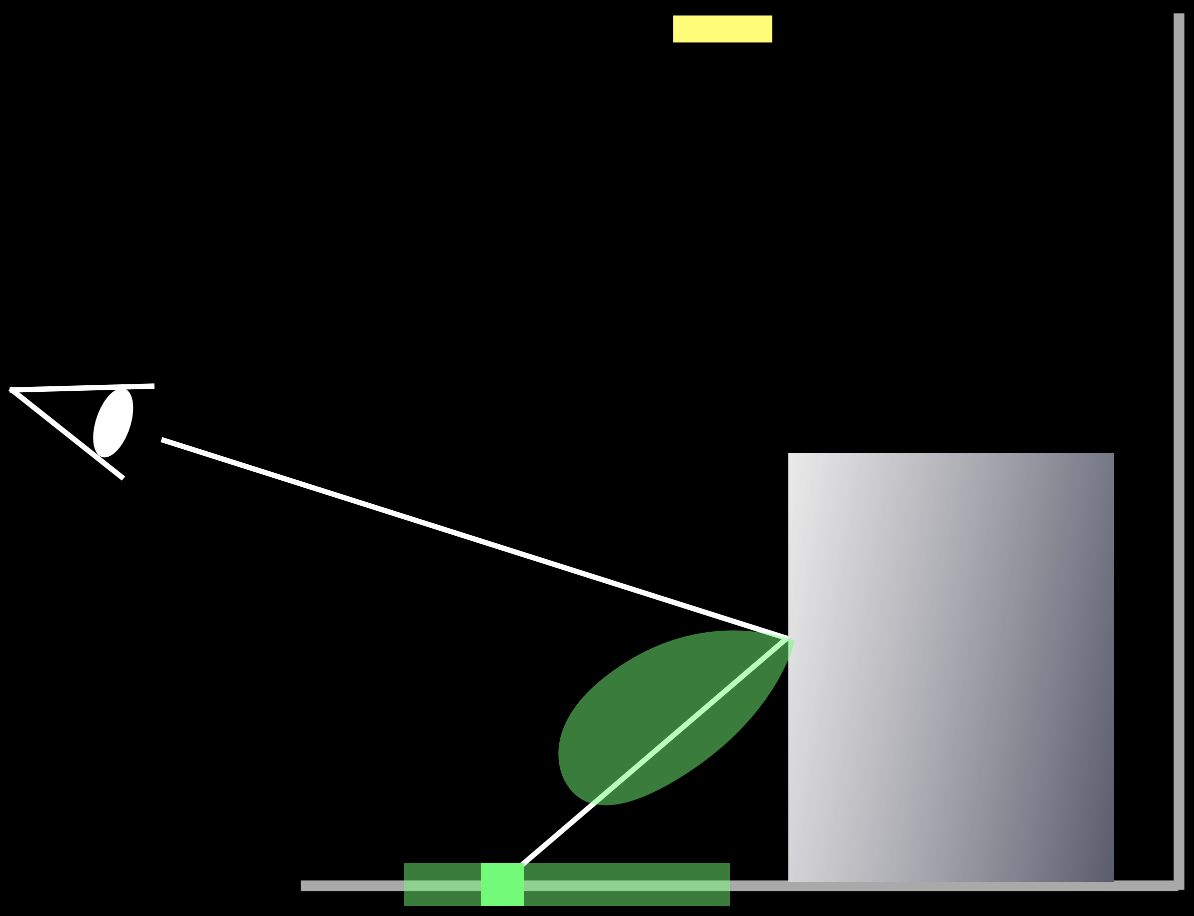
Stochastic PPM

Motion Blur



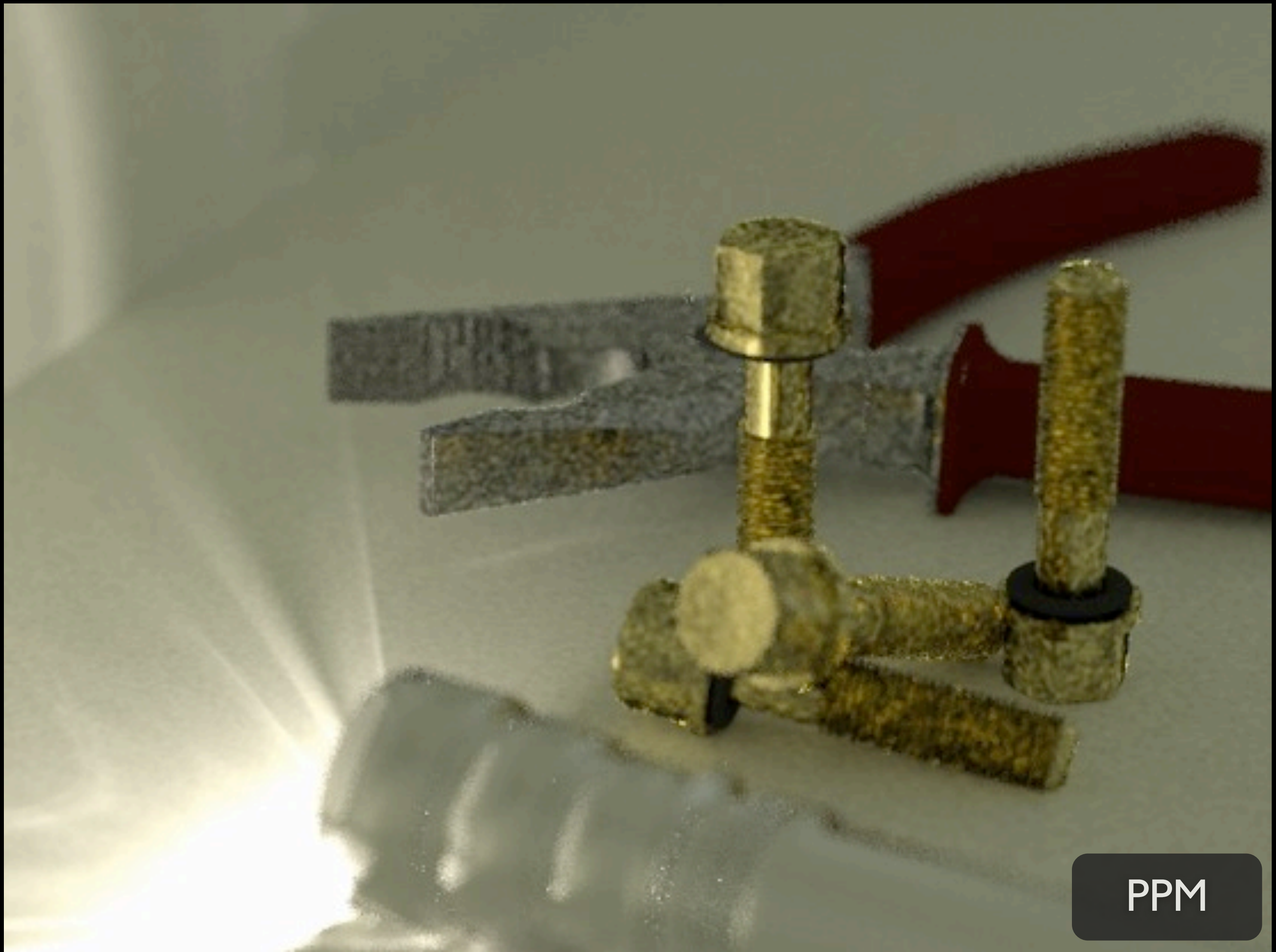
Equal time, Equal memory | PPM | SPPM

Glossy Materials with SPPM

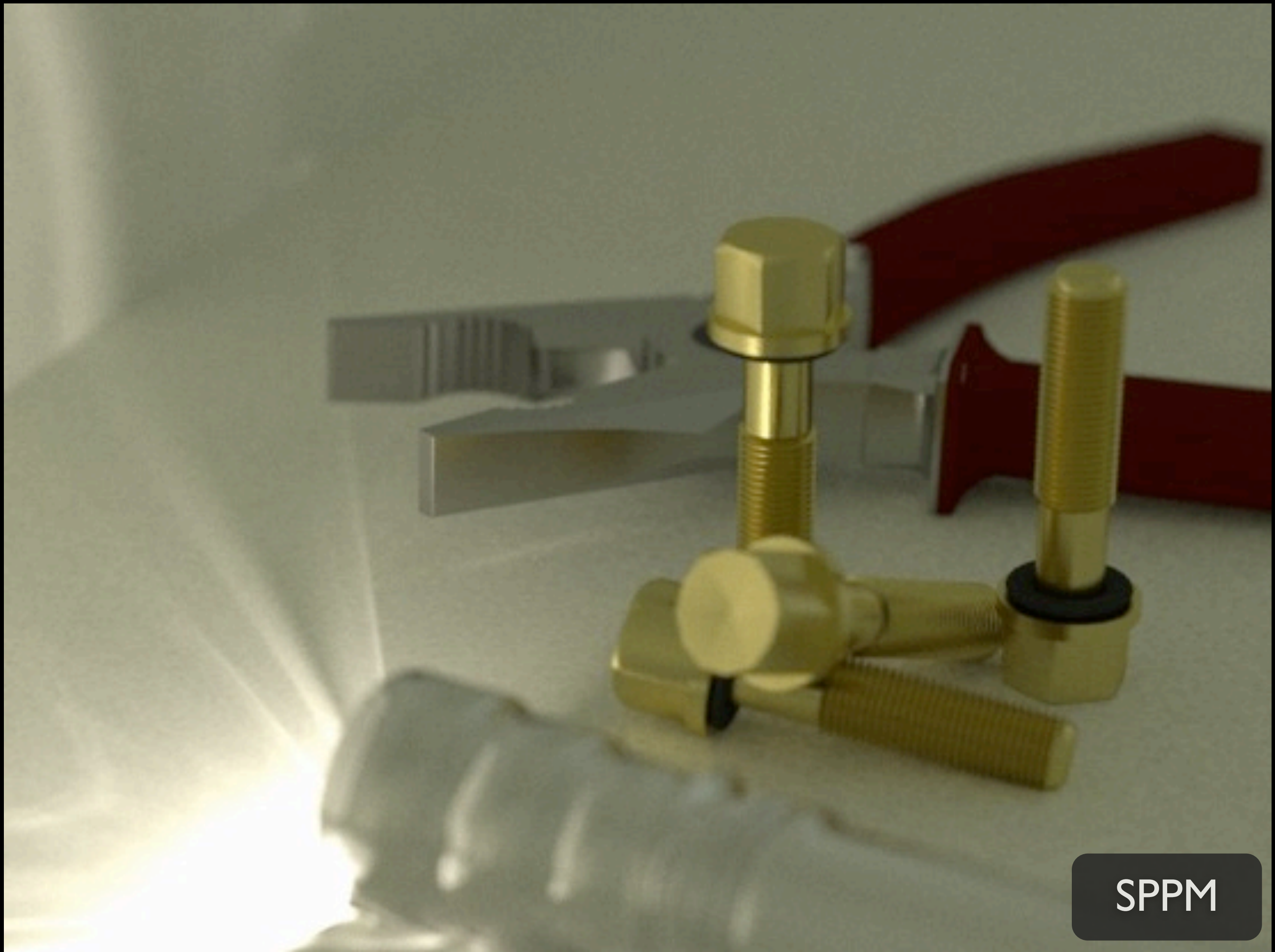


Trace one bounce rays

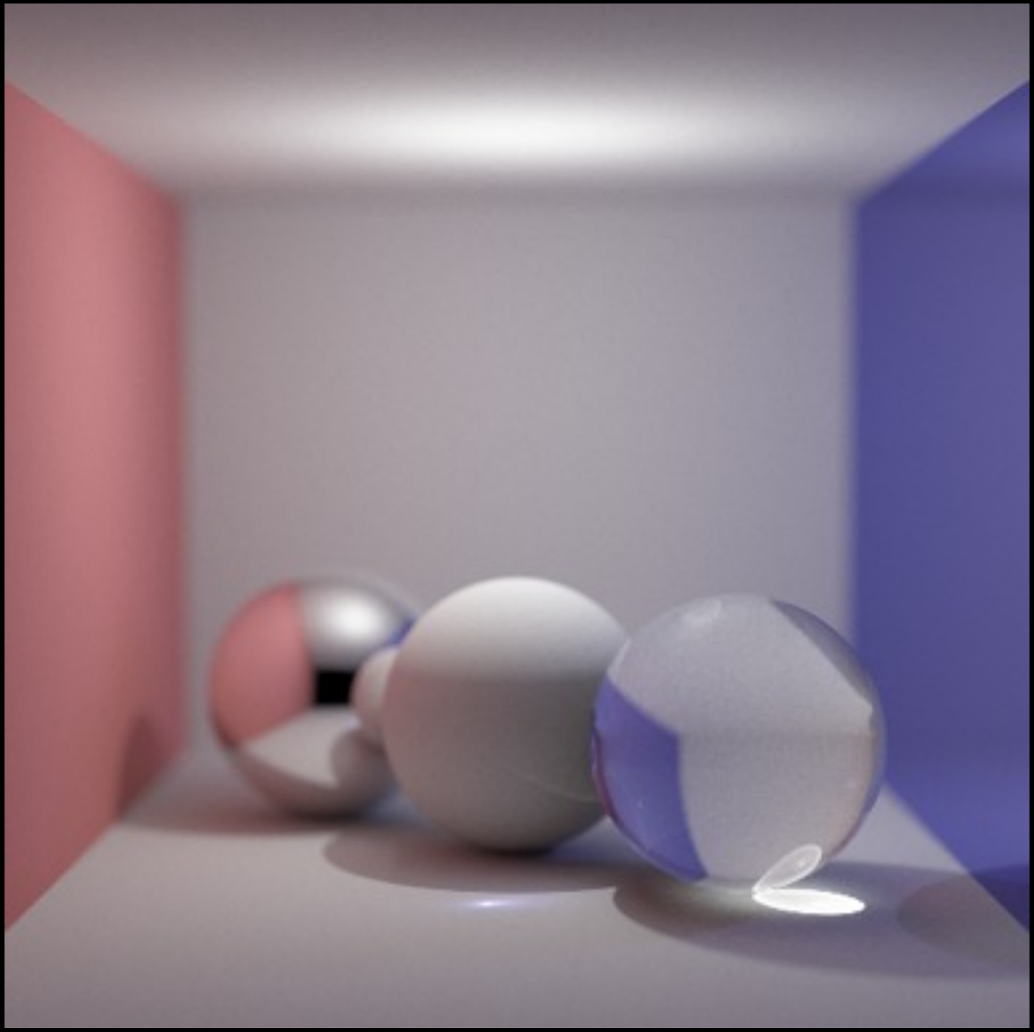
DOF + Glossy Reflection + Caustics



DOF + Glossy Reflection + Caustics



GPUSPPM



cs.au.dk/~toshiya/gpusppm.zip

How much computation is enough?

A Progressive Error Estimation Framework for Photon Density Estimation

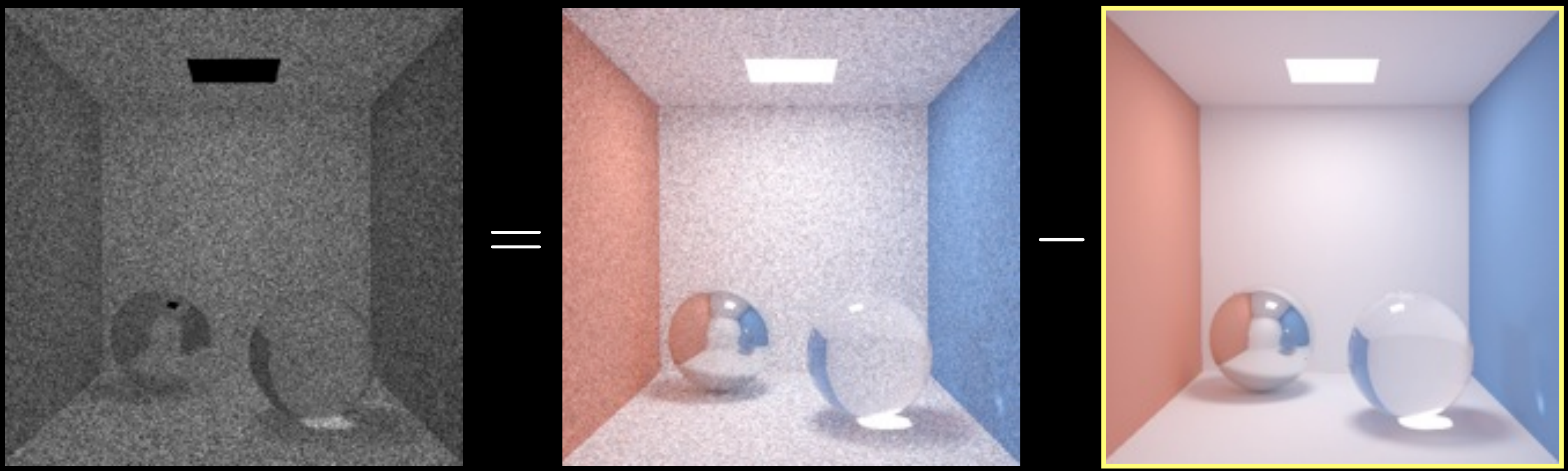
Toshiya Hachisuka   Wojciech Jarosz   Henrik Wann Jensen

Presented & Published at SIGGRAPH/SIGGRAPH Asia 2010

Definition of Error

- Difference between computed and exact

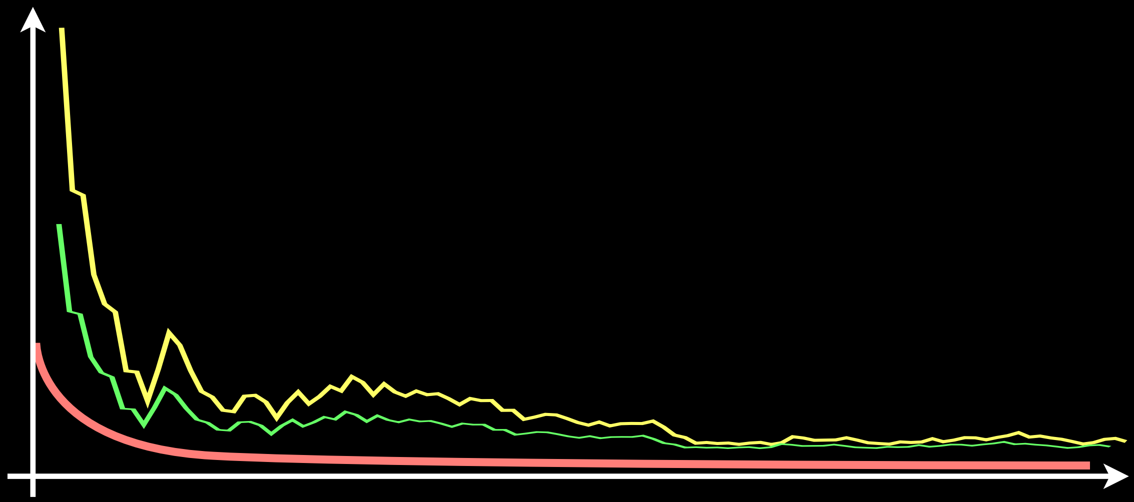
$$E_i = L_i - \boxed{L}$$ Unknown



Decomposition of Error

- Bias-Noise decomposition

$$E_i = L_i - L = B_i + N_i$$



Stochastic Error Bound Derivation

$$E_i = L_i - L = B_i + N_i$$

Stochastic error bound

User-defined Probability

$$P(|E_i| \leq E_{b,i}) \leq 1 - \beta$$

$$E_{b,i} = C_{i,1-\frac{\beta}{2}} \sqrt{\frac{\text{Variance}}{i}} + |B_i|$$

Stochastic Error Bound Derivation

$$E_i = L_i - L = B_i + N_i$$

$$P(|E_i| \leq E_{b,i}) \leq 1 - \beta$$

$$E_{b,i} = \boxed{C_{i,1-\frac{\beta}{2}} \sqrt{\frac{\text{Variance}}{i}}} + |B_i|$$

Error due to Noise

Stochastic Error Bound Derivation

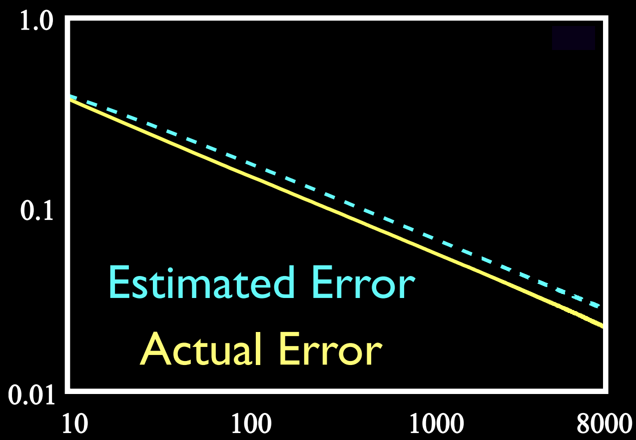
$$E_i = L_i - L = B_i + N_i$$

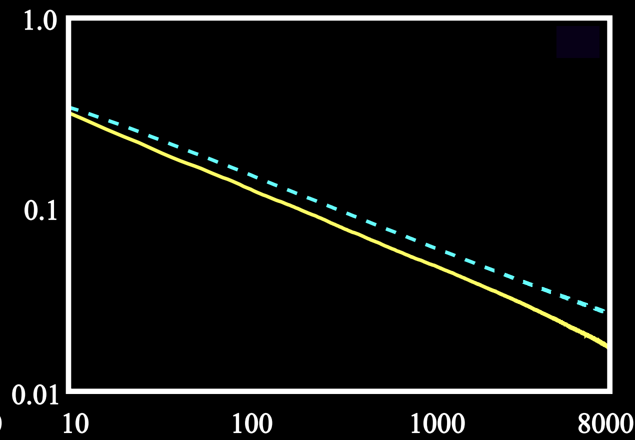
$$P(|E_i| \leq E_{b,i}) \leq 1 - \beta$$

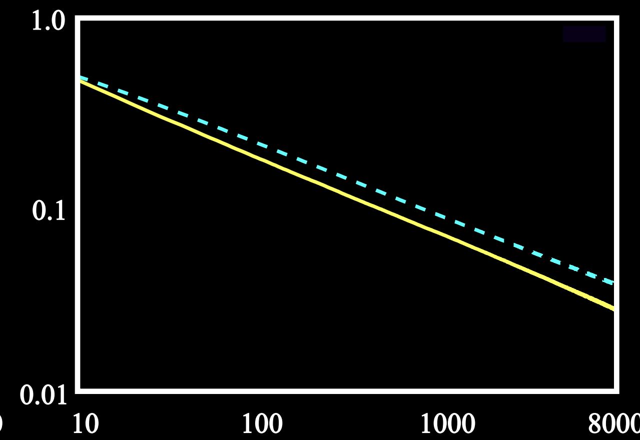
$$E_{b,i} = C_{i,1-\frac{\beta}{2}} \sqrt{\frac{\text{Variance}}{i}} + \boxed{|B_i|}$$

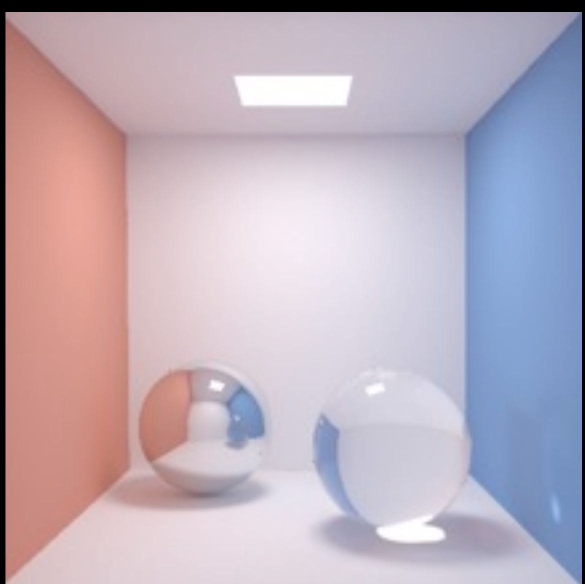
Error due to Bias

Error Estimation

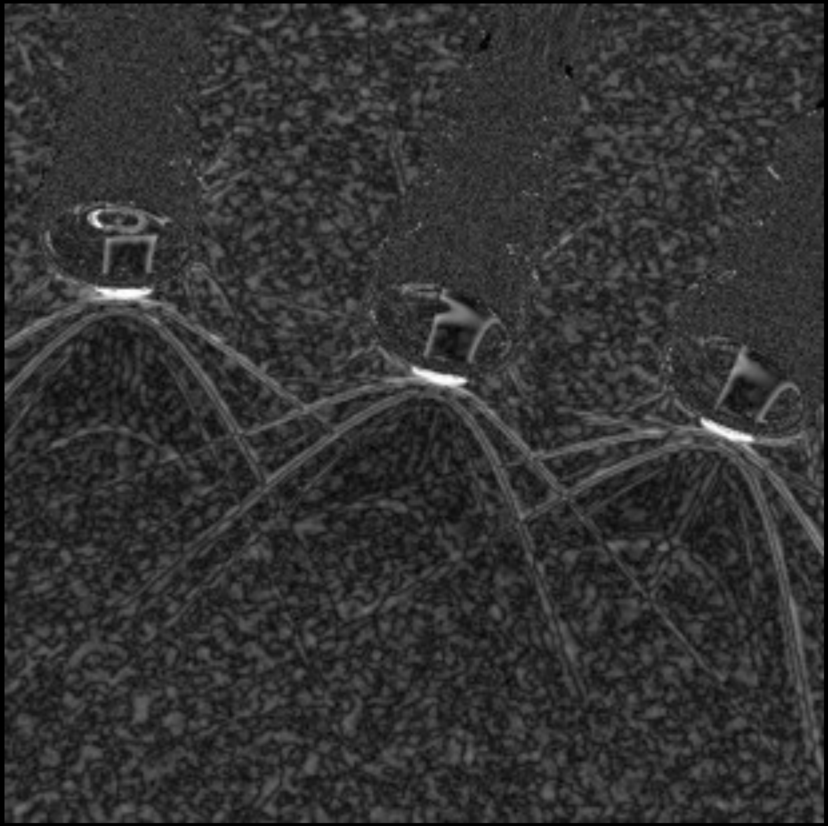




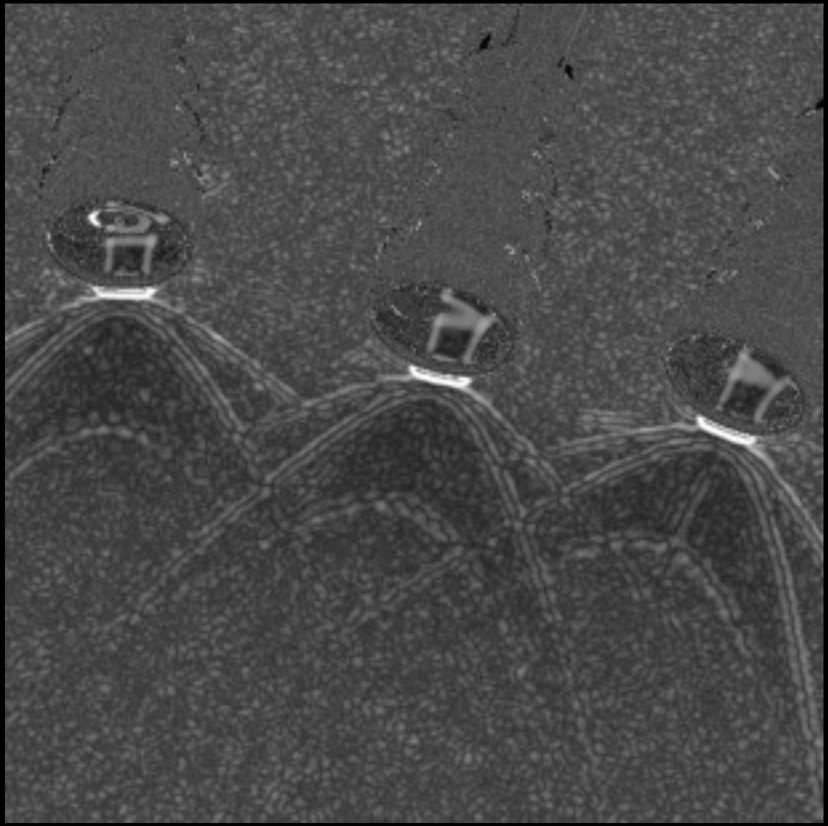




Error Estimation

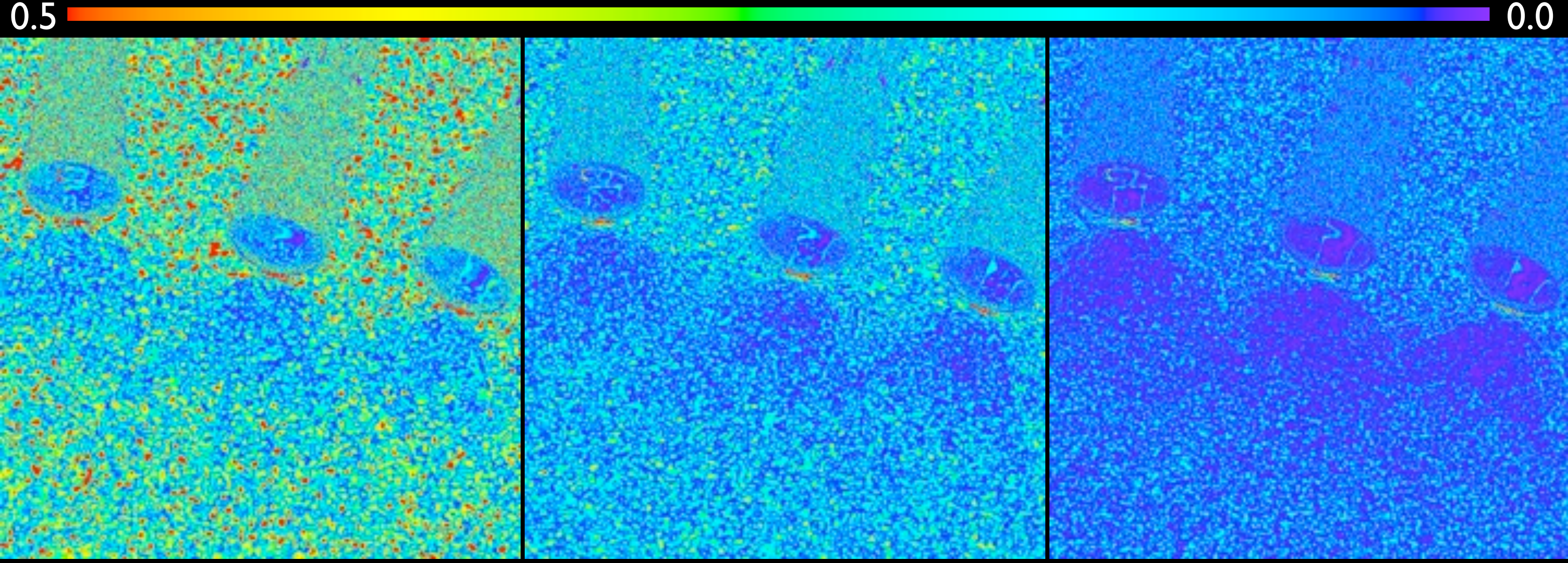


Actual Error



Estimated Error Bound

Automatic Rendering Termination



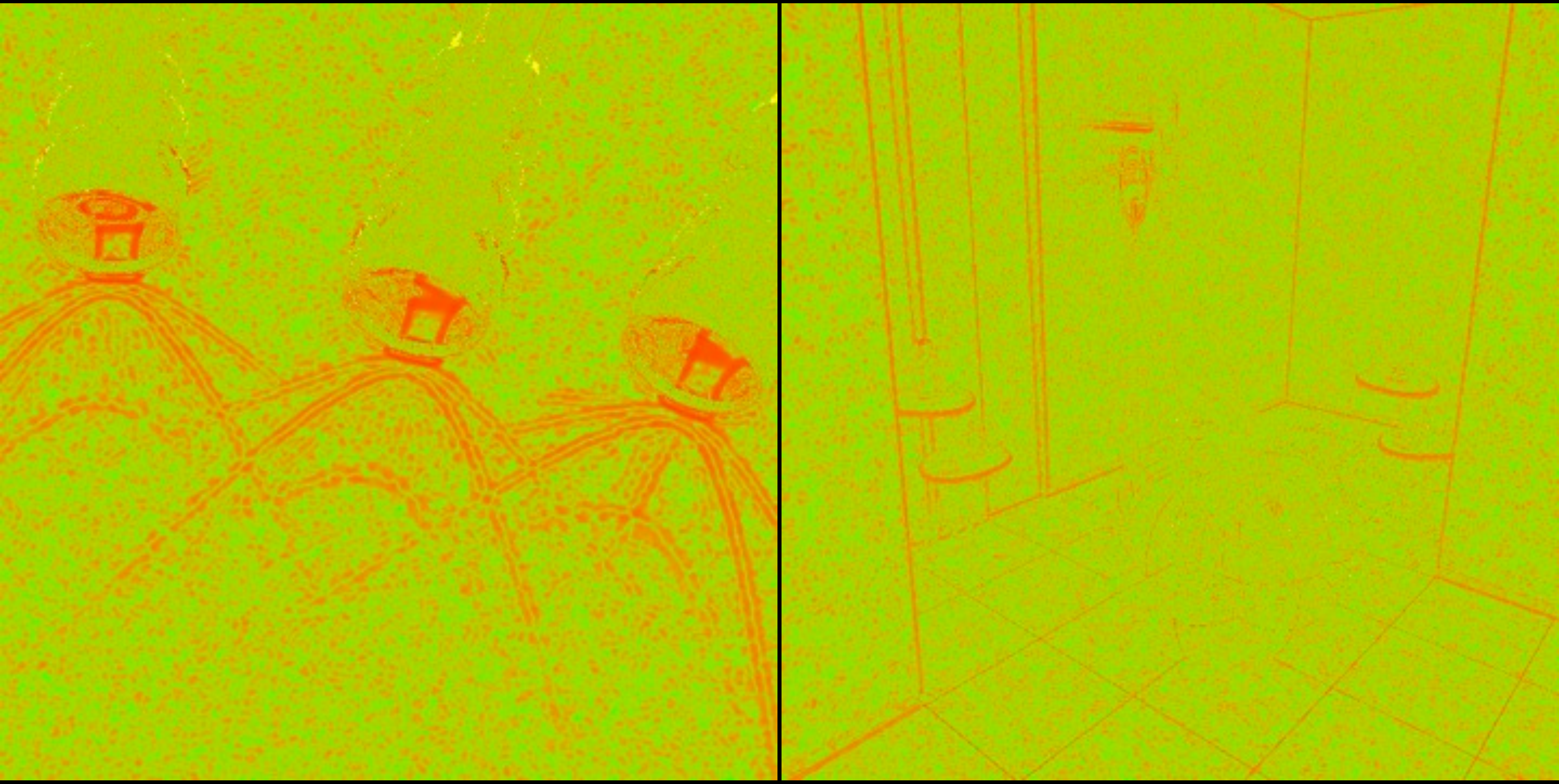
specified: 0.25 | actual: 0.1916

specified: 0.125 | actual: 0.09294

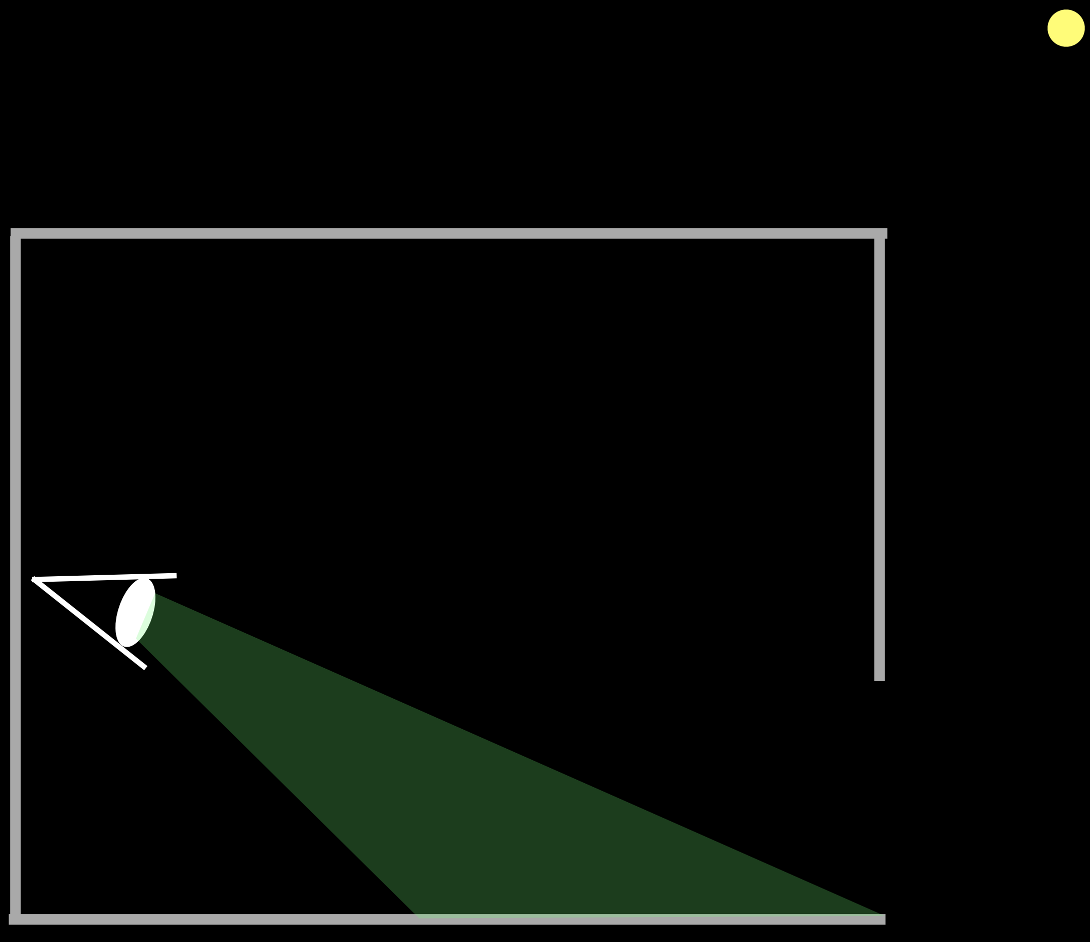
specified: 0.0625 | actual: 0.04482

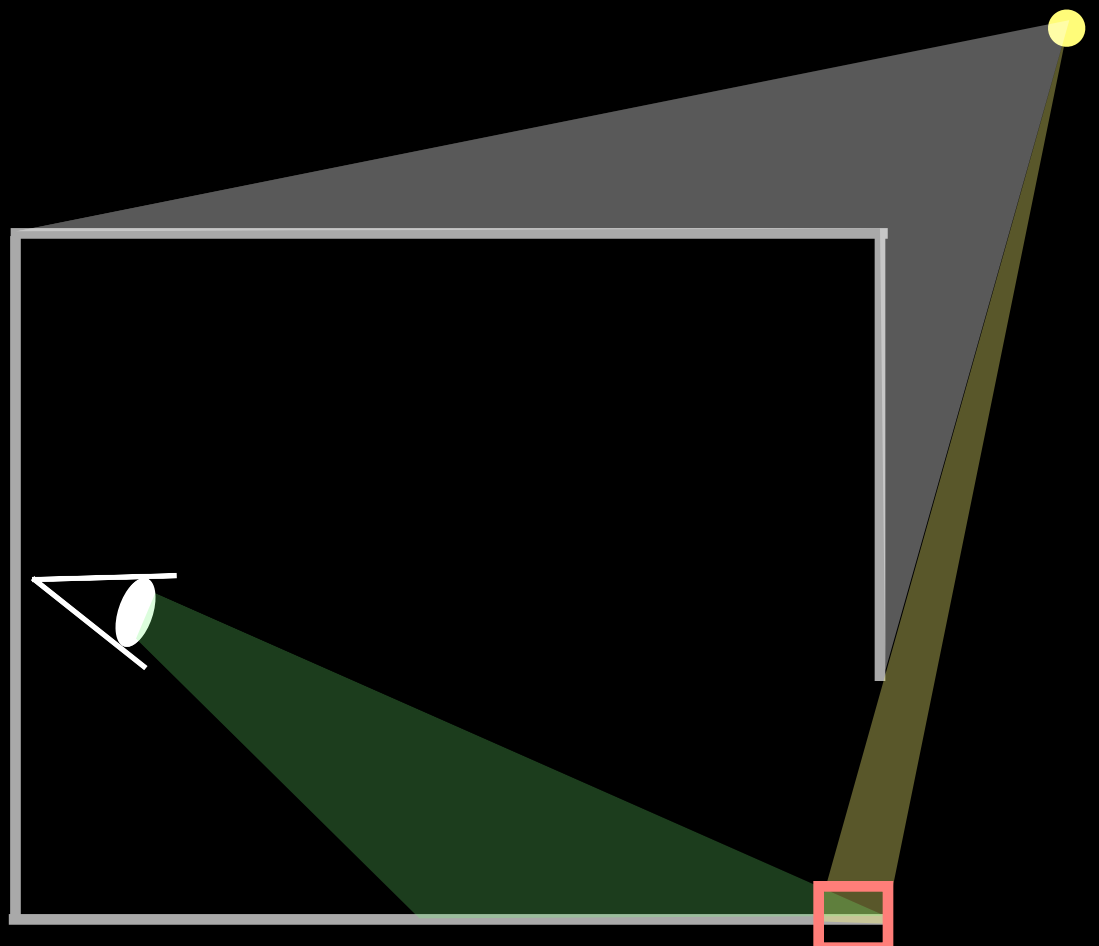
1.3 times overestimation on average

Noise-Bias Ratio



Inefficient Case



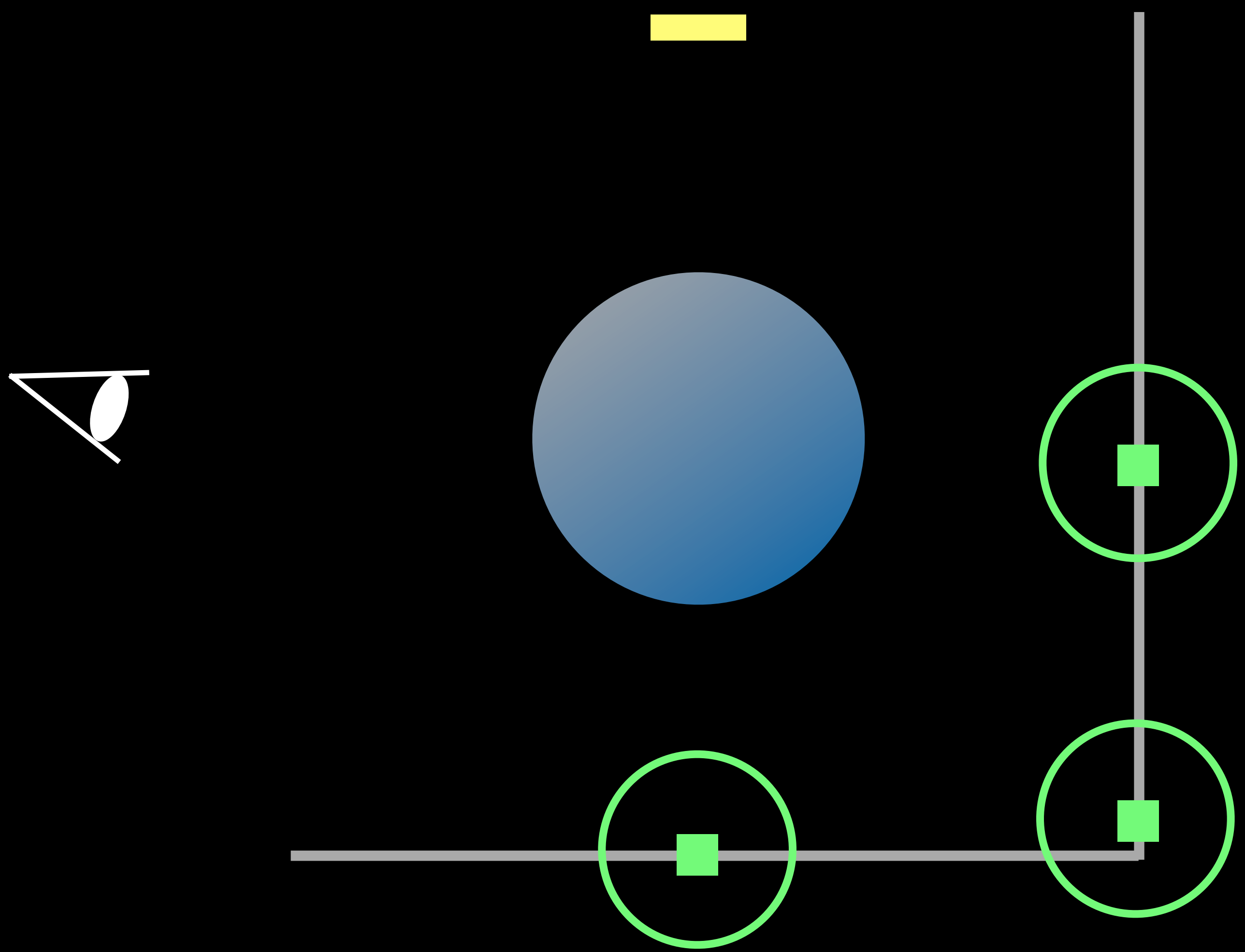


Robust Adaptive Photon Tracing using Photon Path Visibility

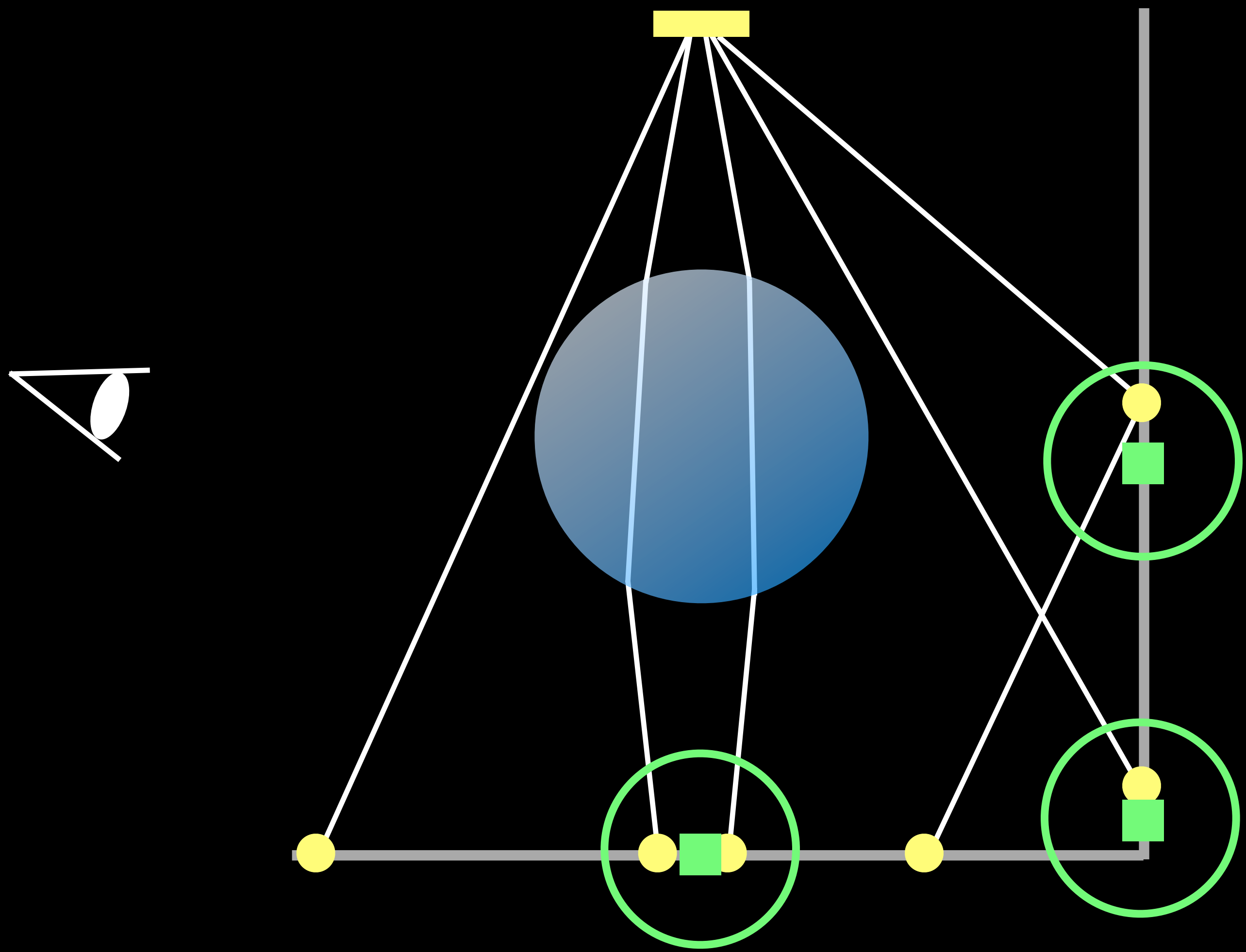
Toshiya Hachisuka   Henrik Wann Jensen

Published in ACM Transaction of Graphics
(to be presented at SIGGRAPH 2013)

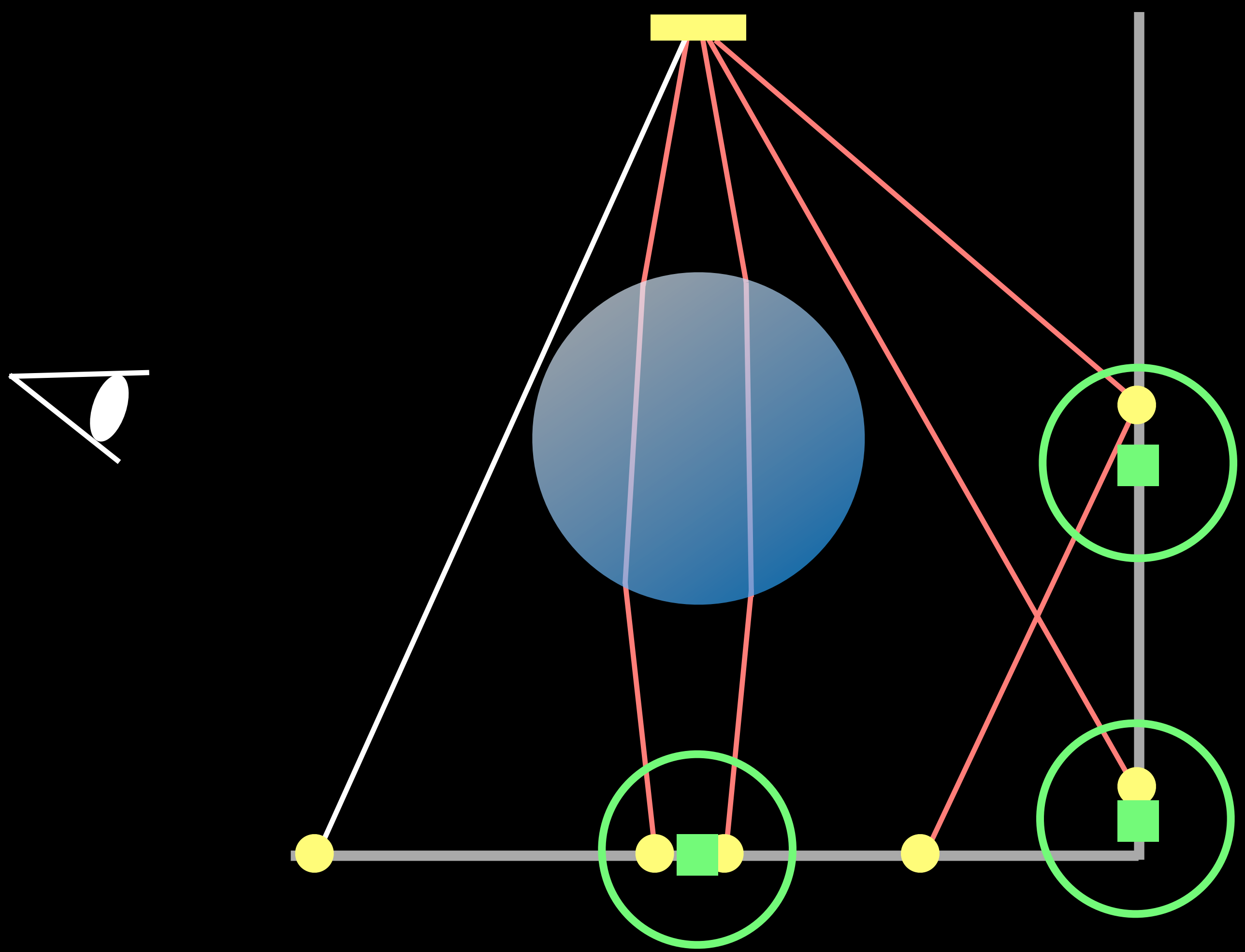
Photon Tracing using Visibility



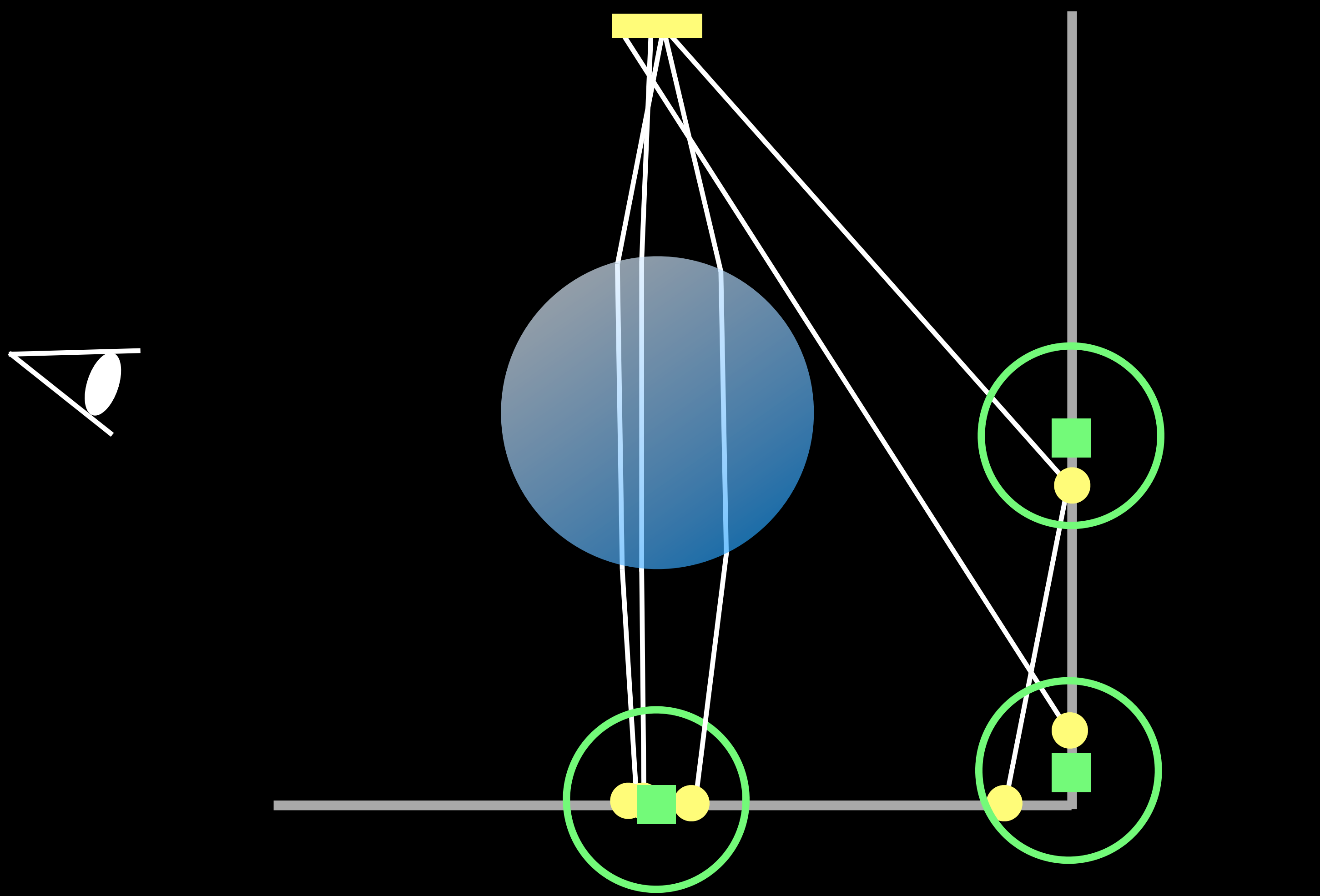
Photon Tracing using Visibility



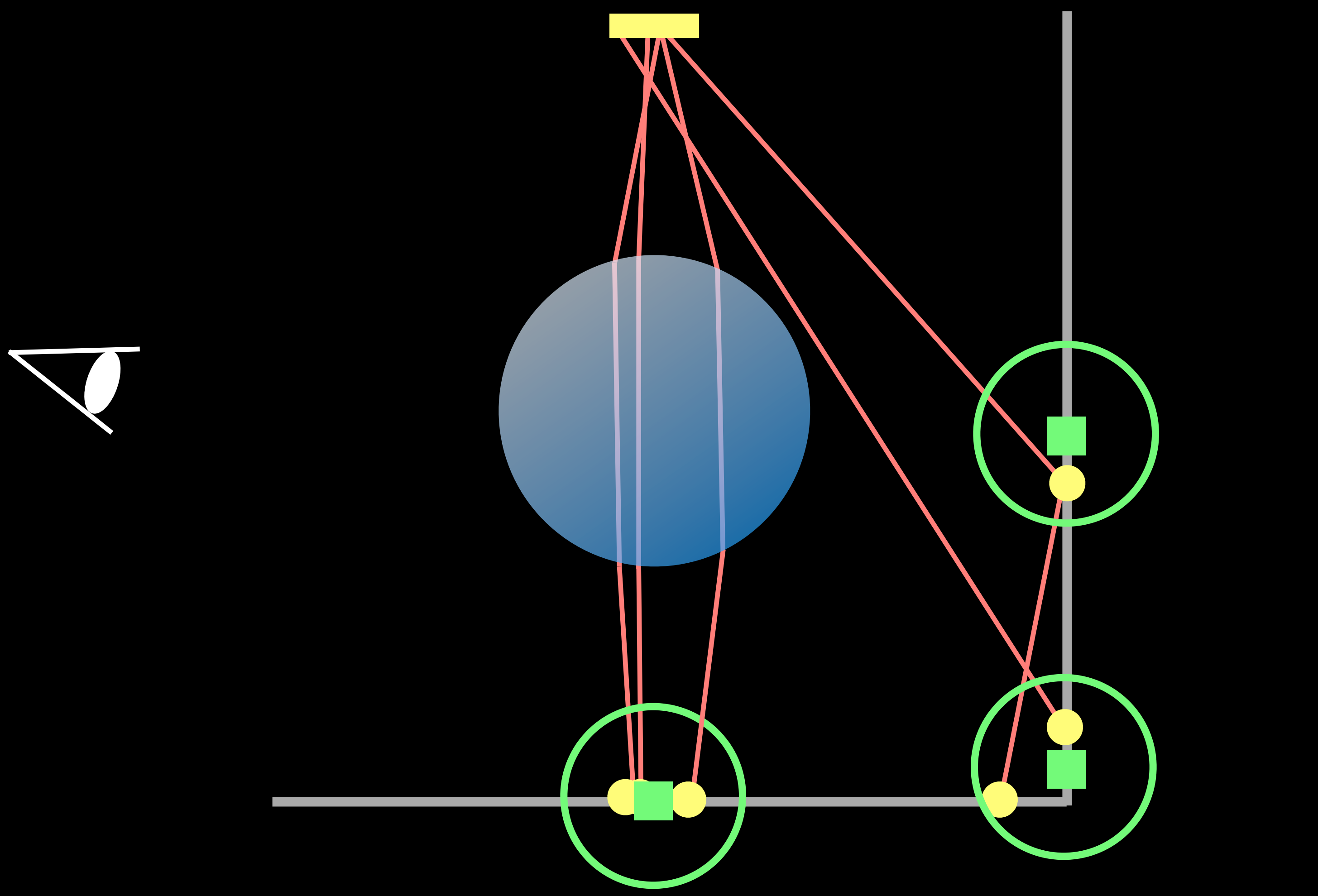
Photon Tracing using Visibility



Photon Tracing using Visibility



Photon Tracing using Visibility



Approach

- Consider space of random numbers $\vec{u} \in (0,1)^N$
- Photon path visibility function

If the photon is not visible:

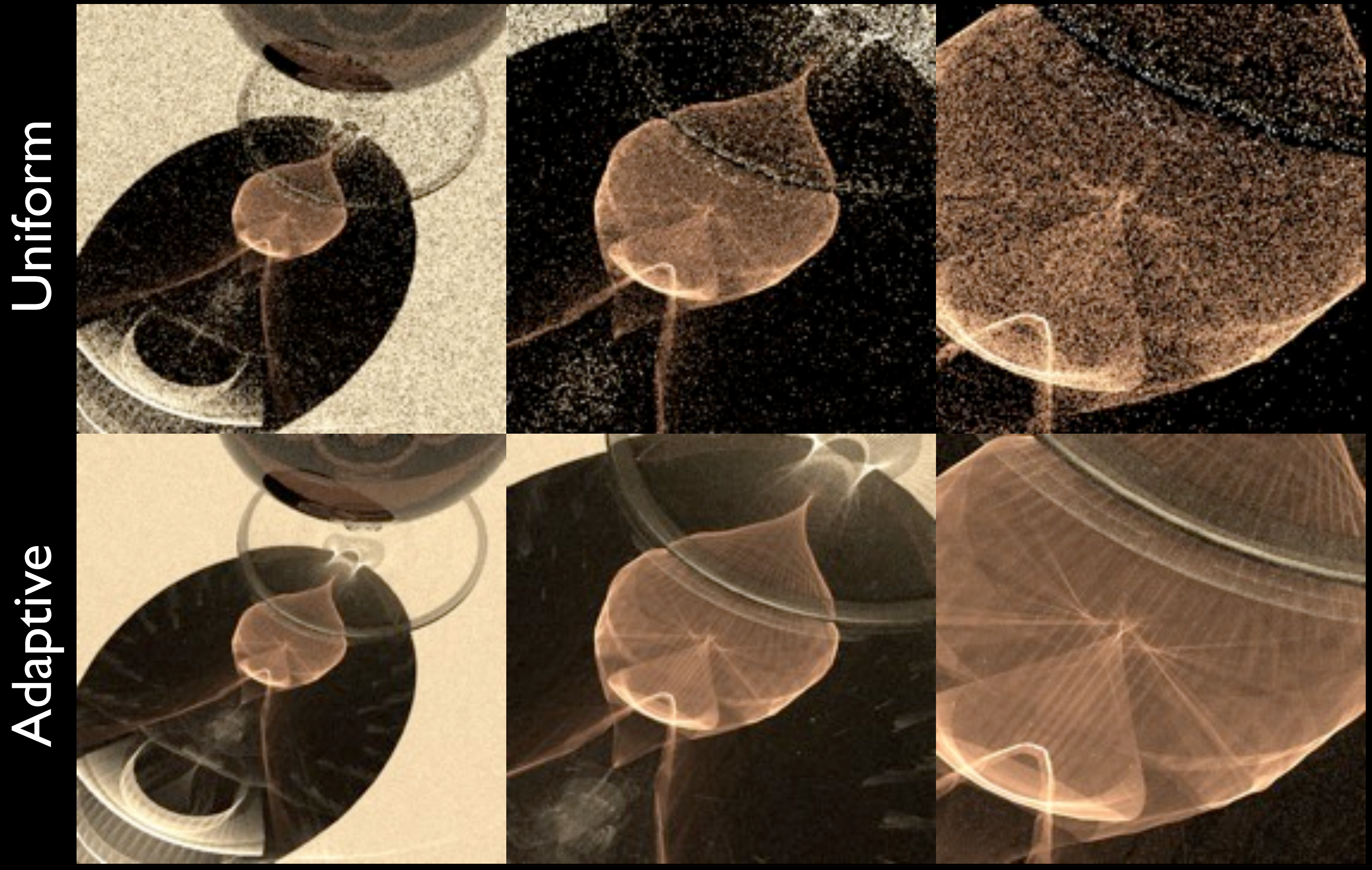
$$V\left(\vec{u}\right) = 0$$

If the photon is visible:

$$V\left(\vec{u}\right) = 1$$

Sample $V\left(\vec{u}\right)$ using Markov chain Monte Carlo Methods

Small-scale Lighting Details



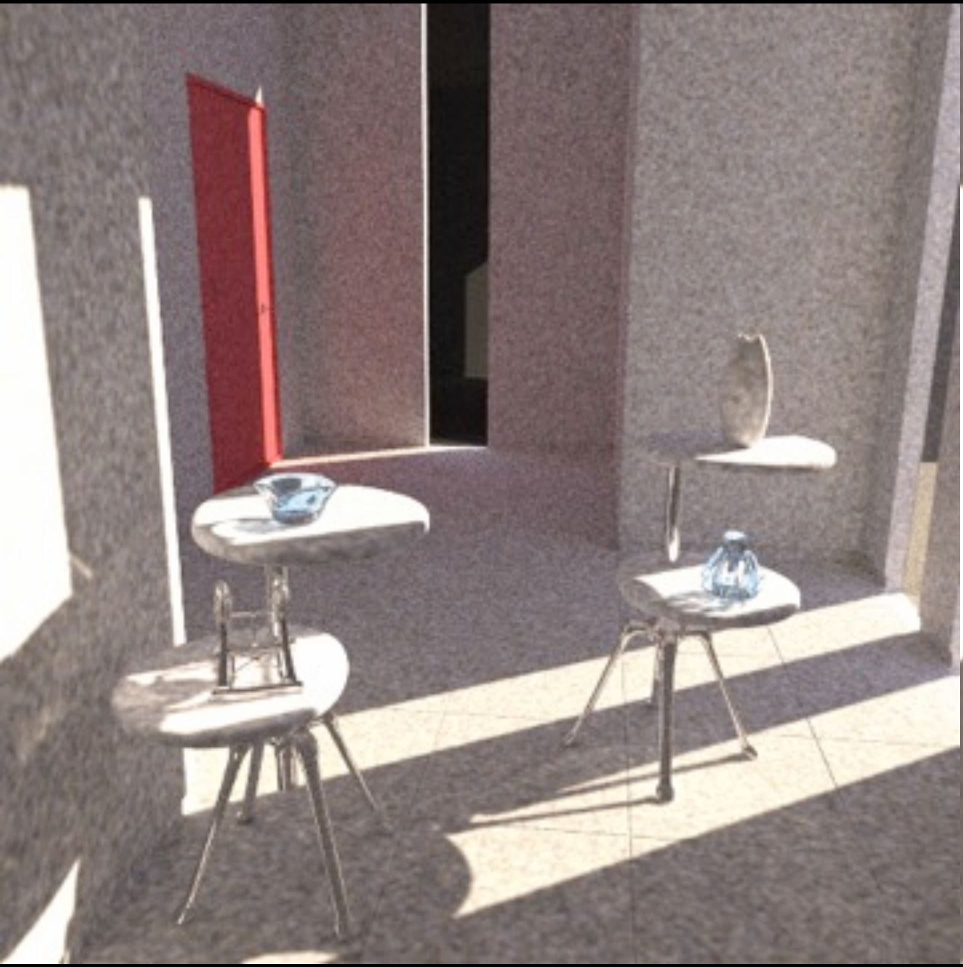
Automatic Parameter Tuning

Value is too small

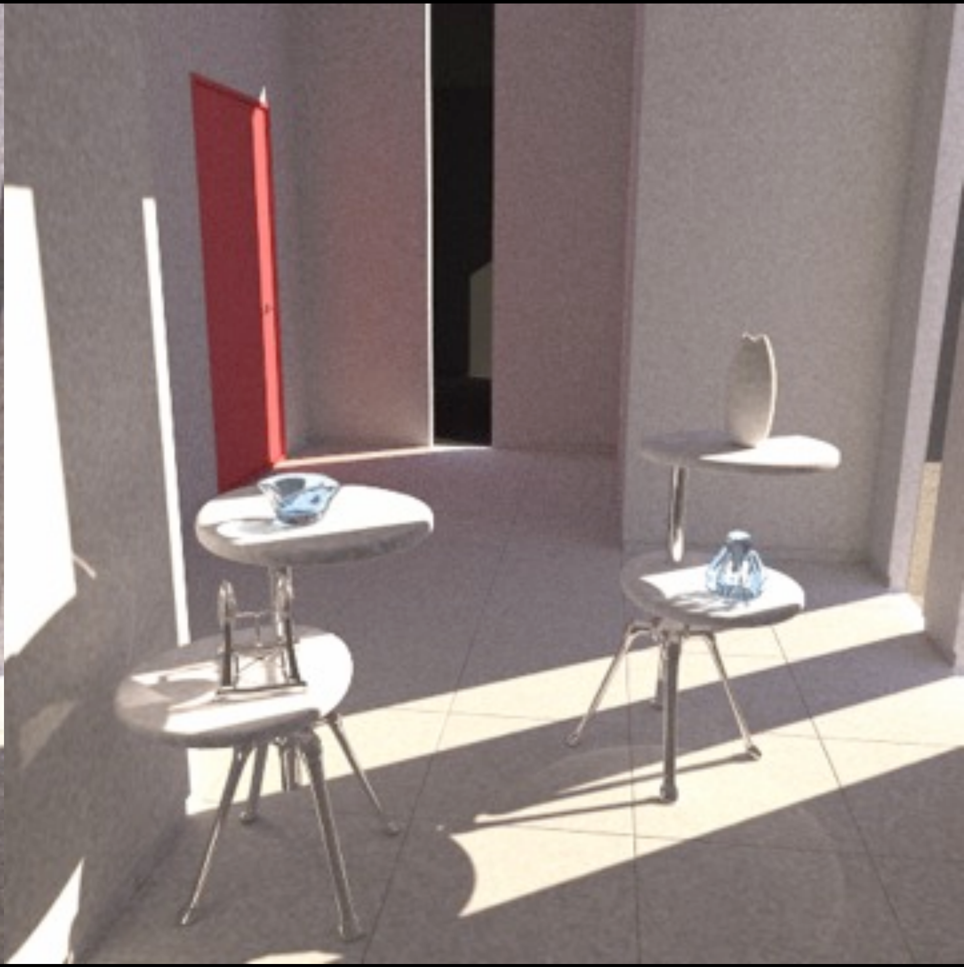
Automatic

Value is too large

Sunlit Room



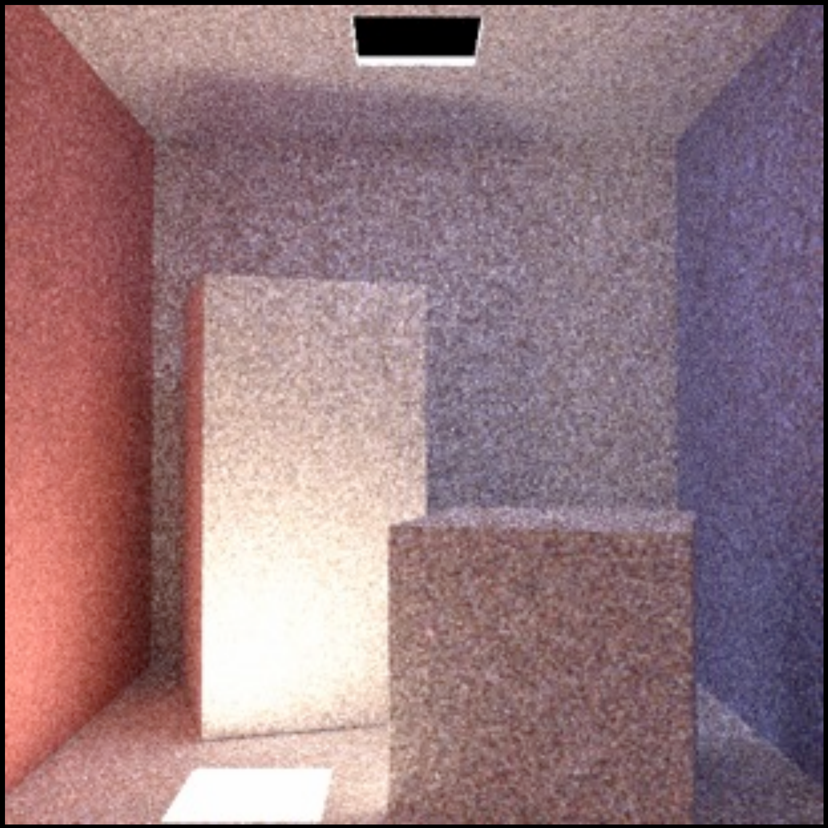
Uniform



Adaptive

Another Example

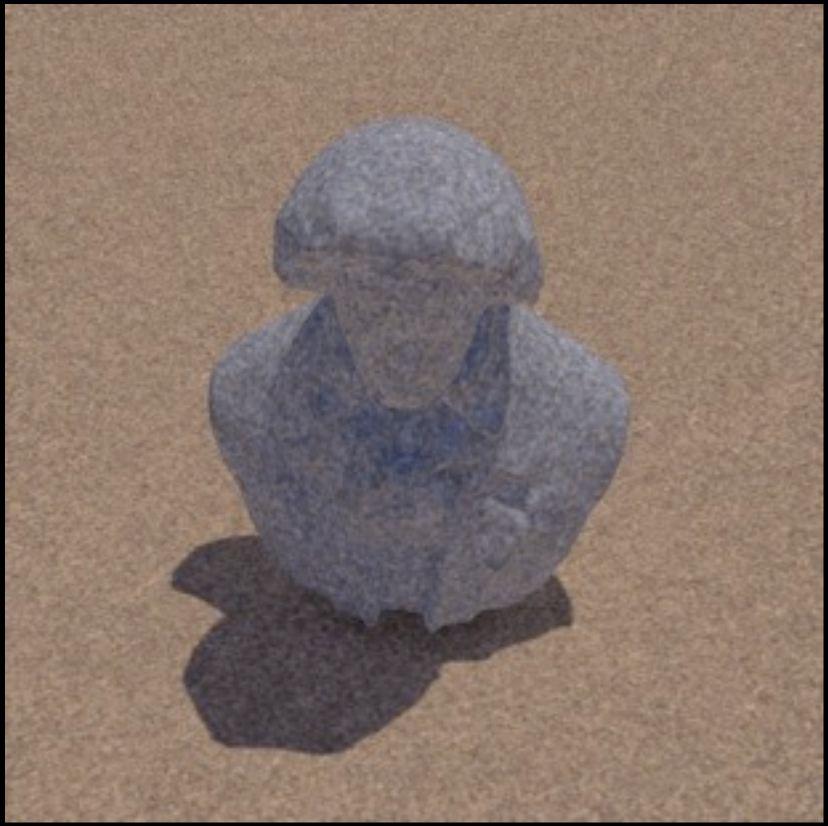
Uniform



Adaptive

Another Example

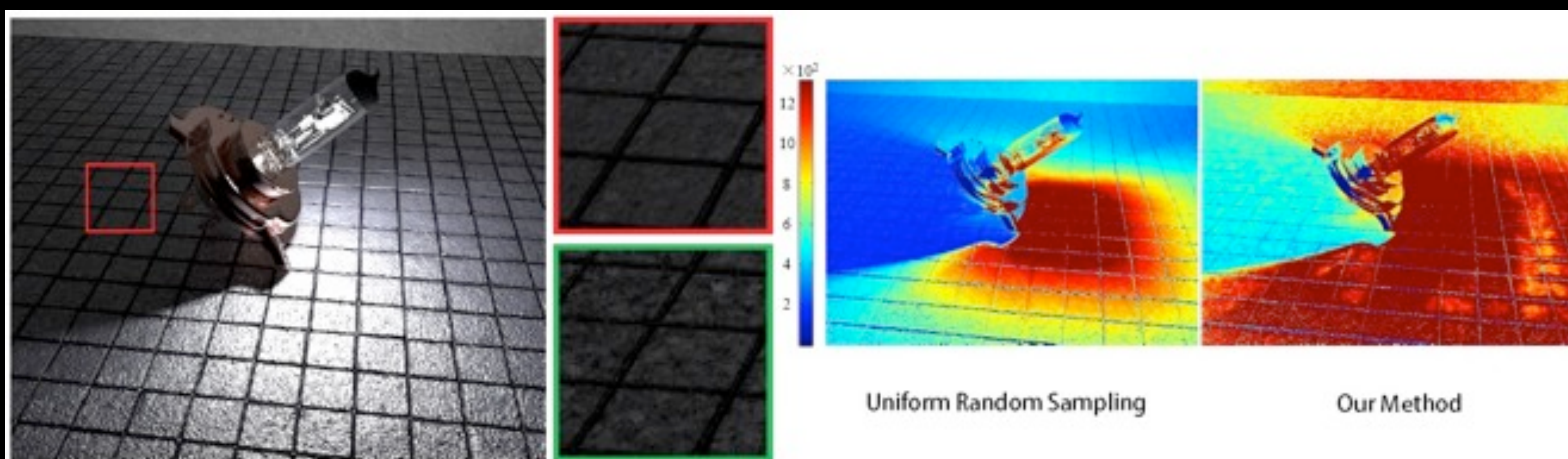
Uniform



Adaptive

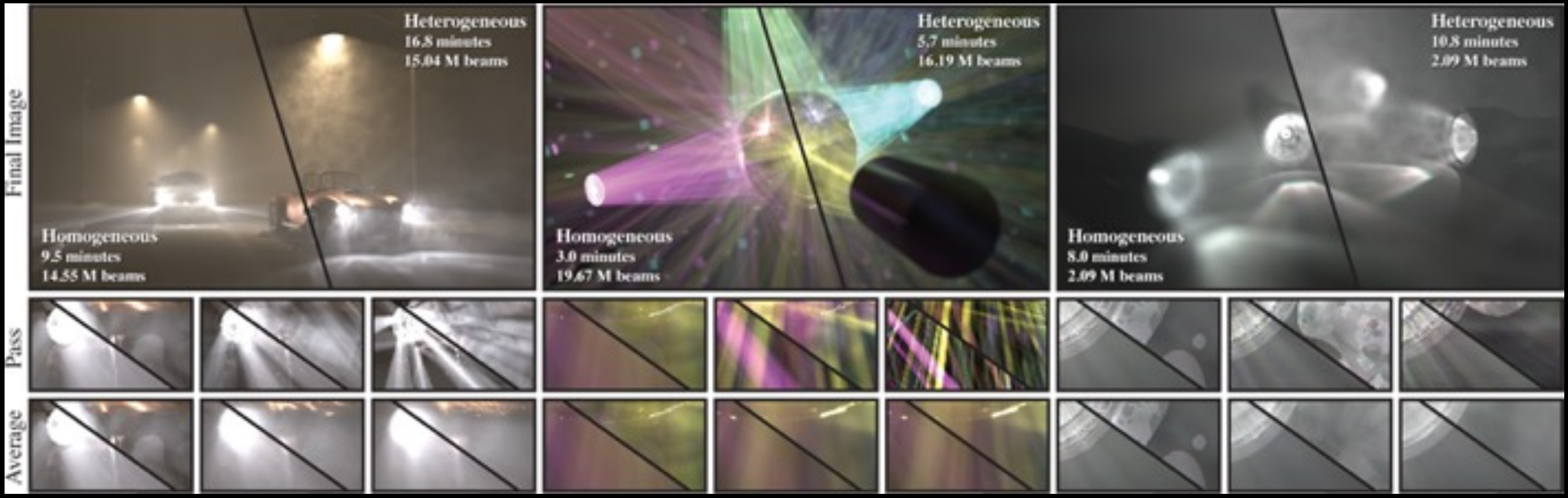
Some Related Work

- Adaptive photon tracing based on photon density on the image [Chen et al. 2011]



Some Related Work

- Progressive photon beams [Jarosz et al. 2011]



Some Related Work

- Efficient rendering of dynamic scenes [Weiss and Grosch 2012]

Some Related Work

- Combine density estimation and MC integration [Hachisuka et al. 2012]

FAQs

- Q: Is PPM unbiased?

FAQs

- Q: Is PPM unbiased?
- A: It is biased and consistent, but does not matter in practice.

$$\mathrm{E}[X] = \lim_{N \to \infty} \sum_{i=1}^{N} x_i$$

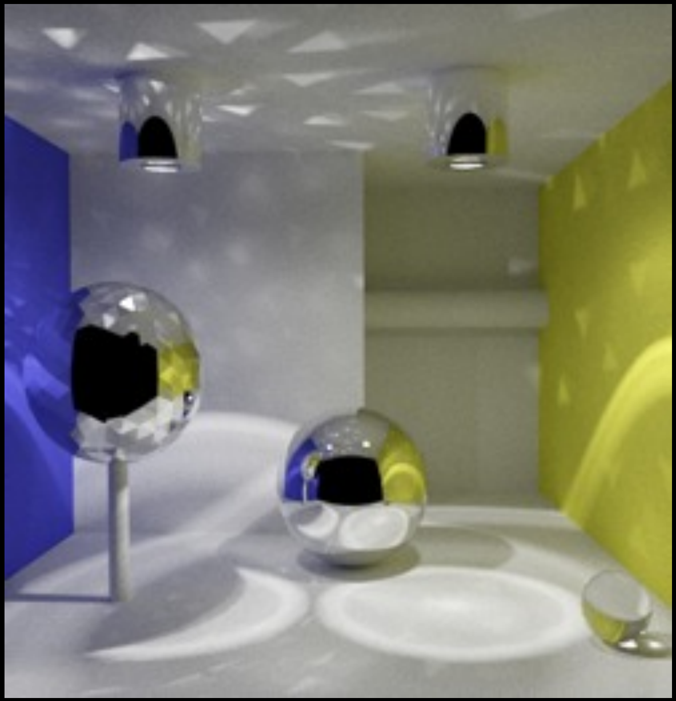
BOTH unbiased and consistent methods need inf. samples!

FAQs

- Q: Do we still use global + caustics separation?

FAQs

- Q: Do we still use global + caustics separation?
- A: Just render everything as one.



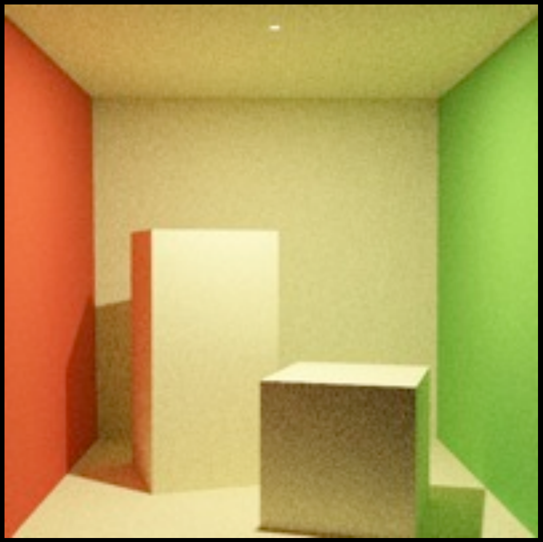
FAQs

- Q: Is PPM slower for diffuse scenes than other methods?

FAQs

- Q: Is PPM slower for diffuse scenes than other methods?
- A: True, but not much, and you can do more.

PT



PPM

Summary

- SPPM = PPM + Distributed Ray Tracing
- Error estimation is available
- Adaptive photon tracing based on visibility
- Lots of interesting extensions

- My opinion: PPM + Extensions is the hardest rendering algorithm to “break” at the moment

cs.au.dk/~toshiya

Next Talk

- Probabilistic formulation of PPM
- "How to turn your PM into PPM in a minute!"