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Bidirectional Light Transport with Vertex Merging

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DFKI

Motivation



Path tracing



Bidirectional path tracing



Progressive photon mapping

1 minute

Motivation



Path tracing



Bidirectional path tracing



Progressive photon mapping

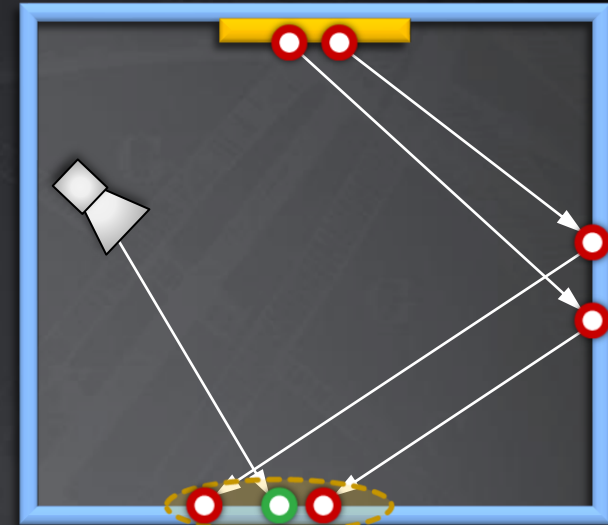
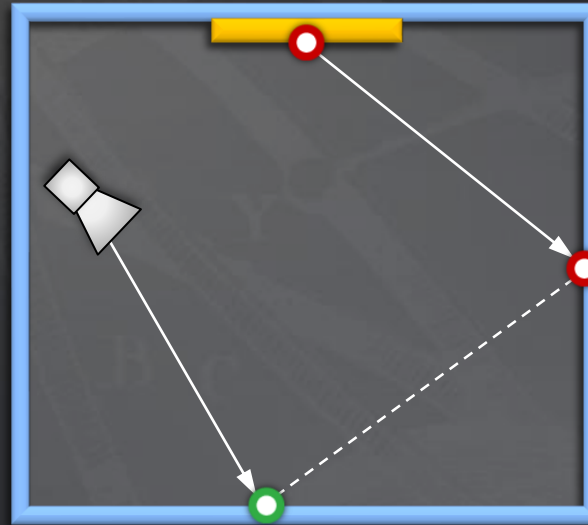
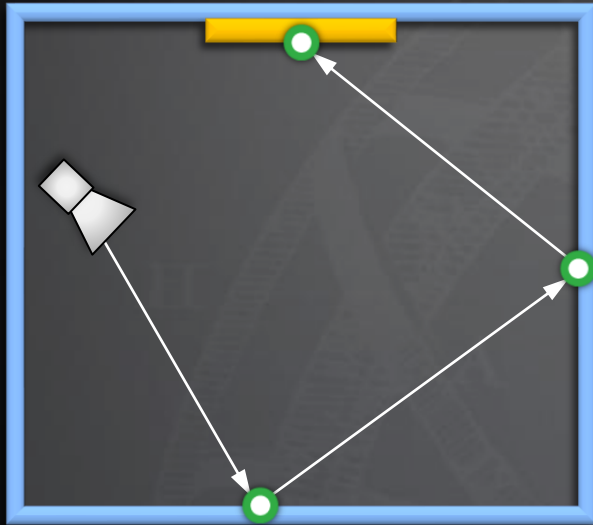
1 minute

Motivation



Bidirectional path tracing Result of Progressive photon mapping

BDPT vs PM



Unidirectional sampling

Vertex connection

Density estimation

Bidirectional path tracing

Photon mapping

✗ Problem: different math frameworks

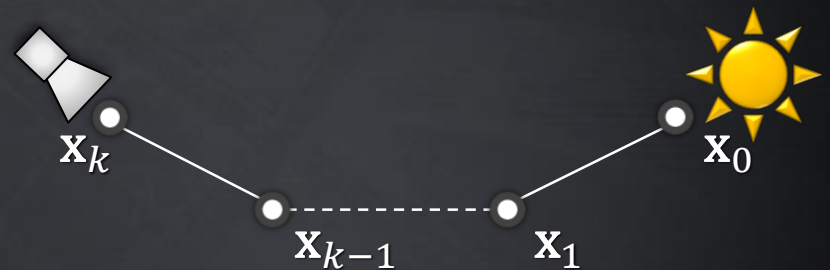
- BDPT: Monte Carlo integration
- PM: Density estimation

👉 Key idea: *Reformulate PM as a bidirectional path sampling technique*

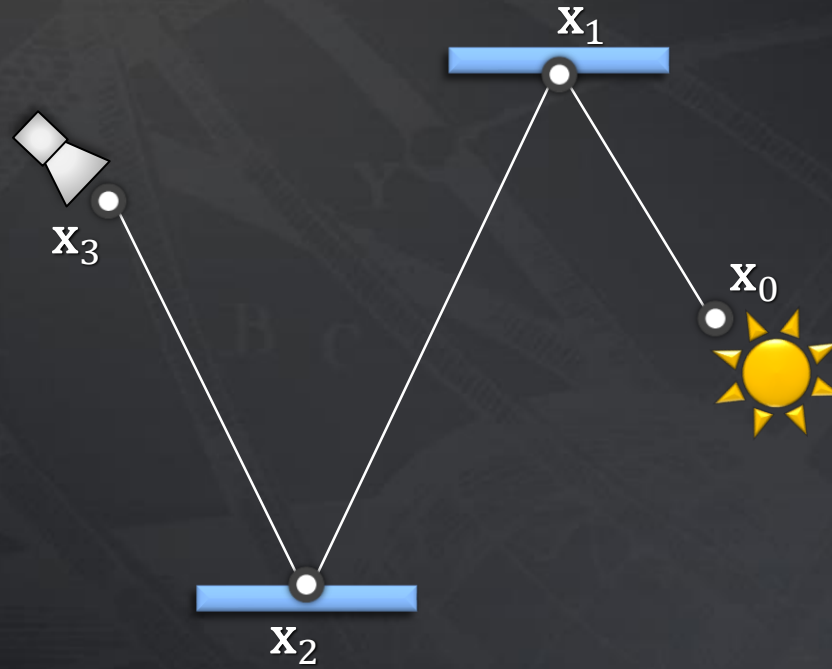
* Path integral framework

- $$I_j = \int_{\Omega} f_j(\bar{\mathbf{x}}) d\mu(\bar{\mathbf{x}})$$

- $$\langle I_j \rangle = \frac{f_j(\bar{\mathbf{x}})}{p(\bar{\mathbf{x}})} \quad \blacksquare p(\bar{\mathbf{x}}) = p(\mathbf{x}_0)p(\mathbf{x}_1)\dots p(\mathbf{x}_k)$$

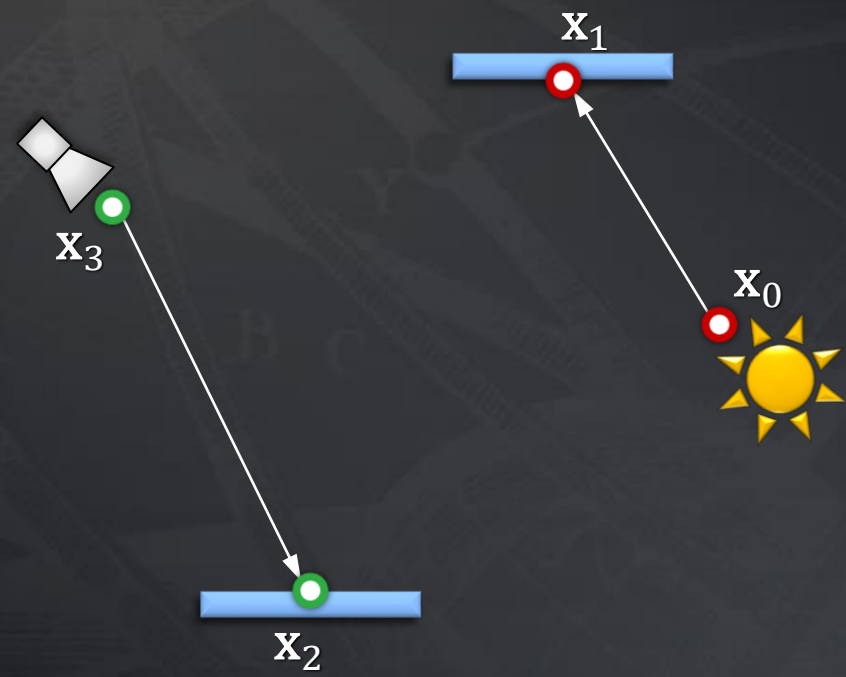


Bidirectional MC path sampling



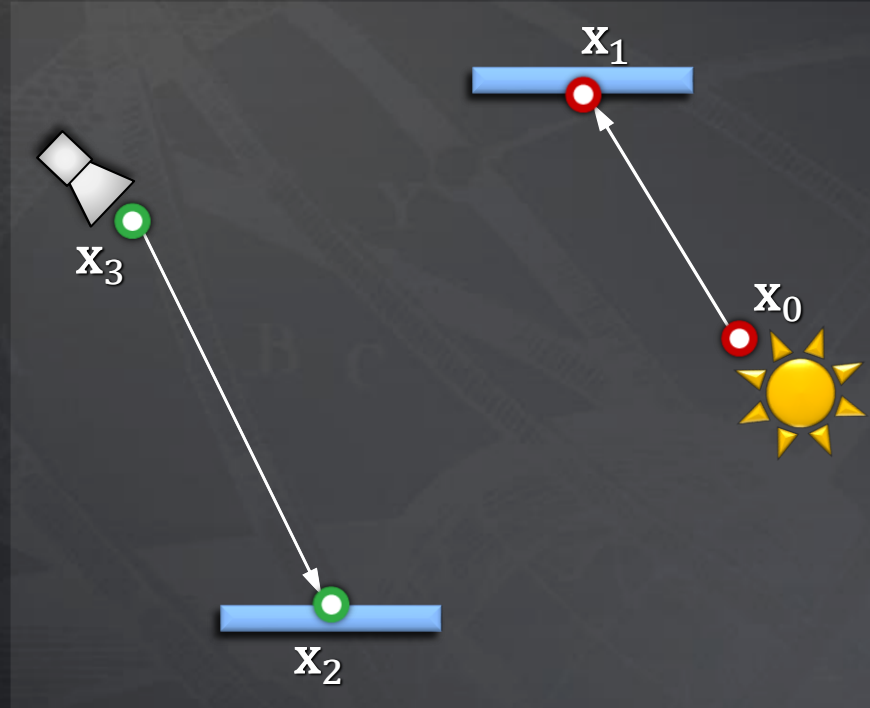
Bidirectional MC path sampling

- Light vertex
- Camera vertex



Bidirectional MC path sampling

- Light vertex
- Camera vertex

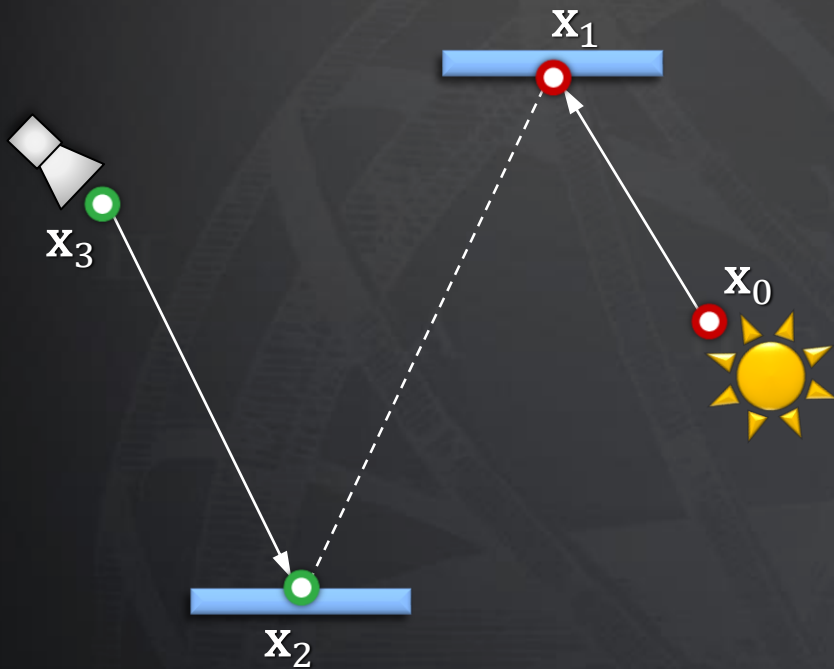


Bidirectional path tracing

Photon mapping

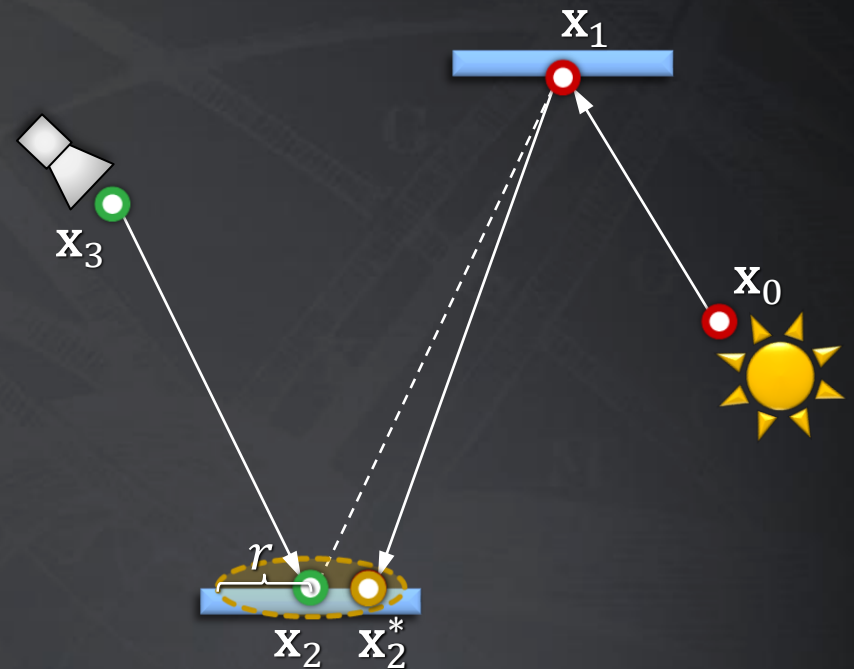
Bidirectional MC path sampling

- Light vertex
- Camera vertex



Bidirectional vertex preforming

$$p_{VC}(\bar{x}) = p(x_0)p(x_0 \rightarrow x_1) p(x_3)p(x_3 \rightarrow x_2)$$



Vertex merging

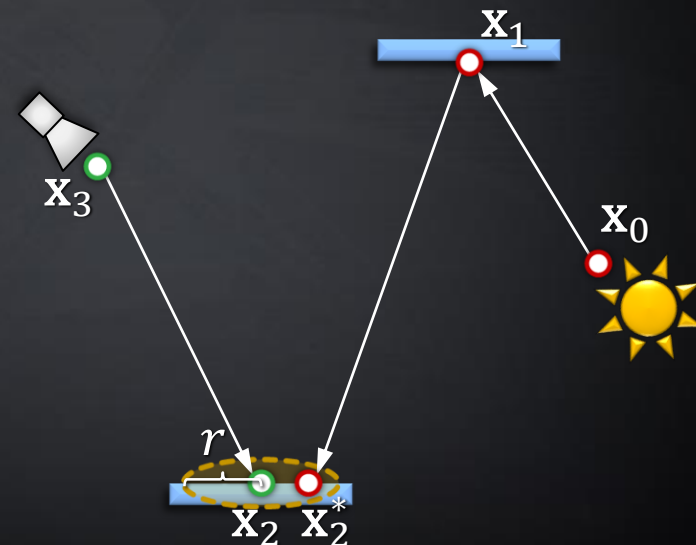
$$p_{VM}(\bar{x}) \approx p(x_0)p(x_0 \rightarrow x_1) p(x_3)p(x_3 \rightarrow x_2) p(x_2 \rightarrow x_1) p(x_2^* \rightarrow x_1) \mathbb{1}_{\|x_2 - x_2^*\| \leq r}$$

Vertex merging estimator

- Light vertex
- Camera vertex

$$\langle I \rangle = \frac{f_j(\bar{\mathbf{x}})}{p_{VM}(\bar{\mathbf{x}})} = \dots = \overbrace{\Delta W(\mathbf{x}_2)}^{\text{cumulative importance}} \underbrace{\frac{f_r(\mathbf{x}_3 \leftarrow \mathbf{x}_2, \mathbf{x}_2^* \rightarrow \mathbf{x}_1)}{\pi r^2} \Delta \Phi(\mathbf{x}_2^*)}_{\text{photon flux}} \equiv \text{photon mapping estimator}$$

✓ No density estimation!



Sampling techniques

- Light vertex
- Camera vertex



Unidirectional 2 ways

Vertex connection 4 ways

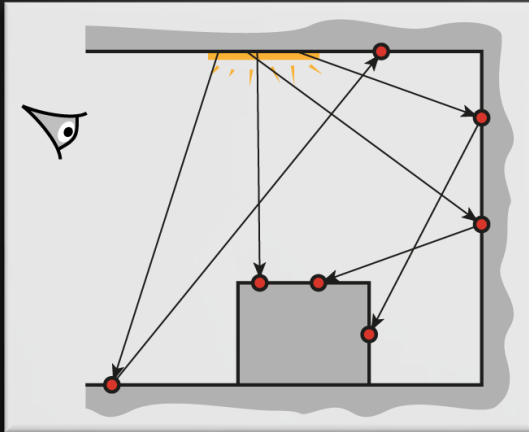
Vertex merging 5 ways

Total 11 ways

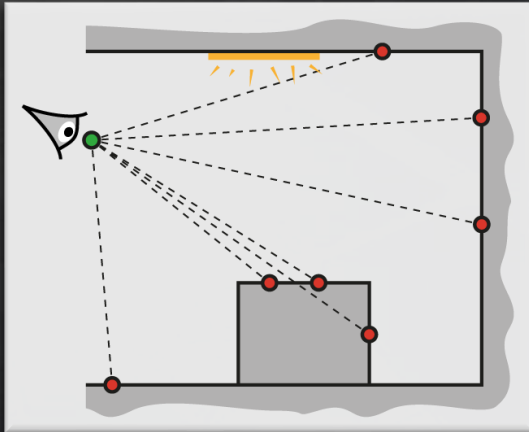
Vertex connection and merging



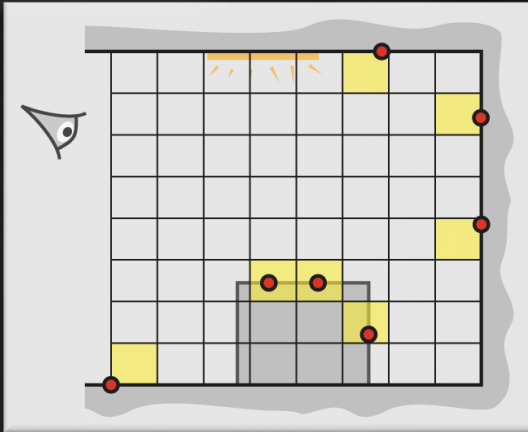
Stage 1: Light sub-path sampling



a) Trace sub-paths

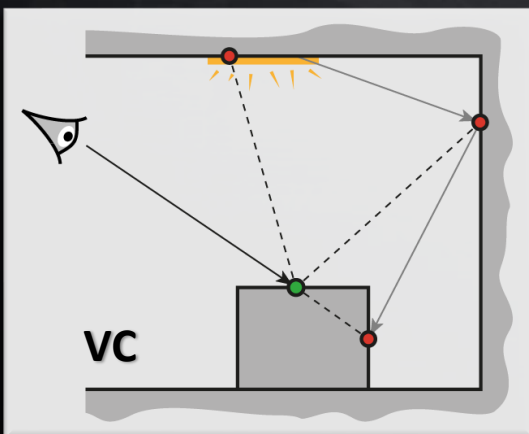


b) Connect to eye

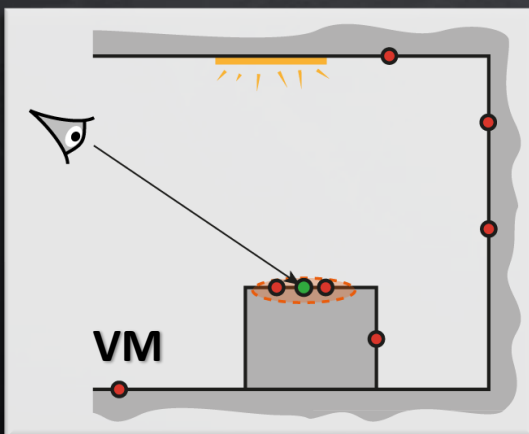


c) Build search structure

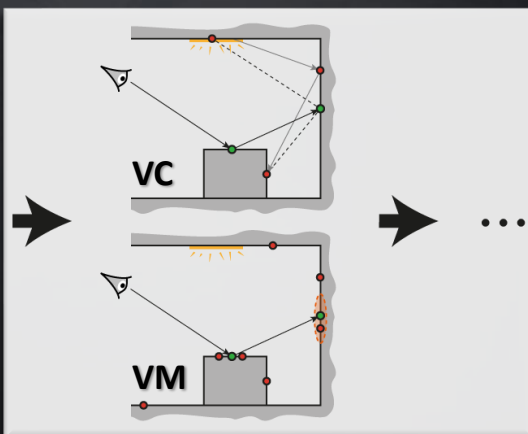
Stage 2: Eye sub-path sampling (reduced radius at each iteration)



a) Vertex connection

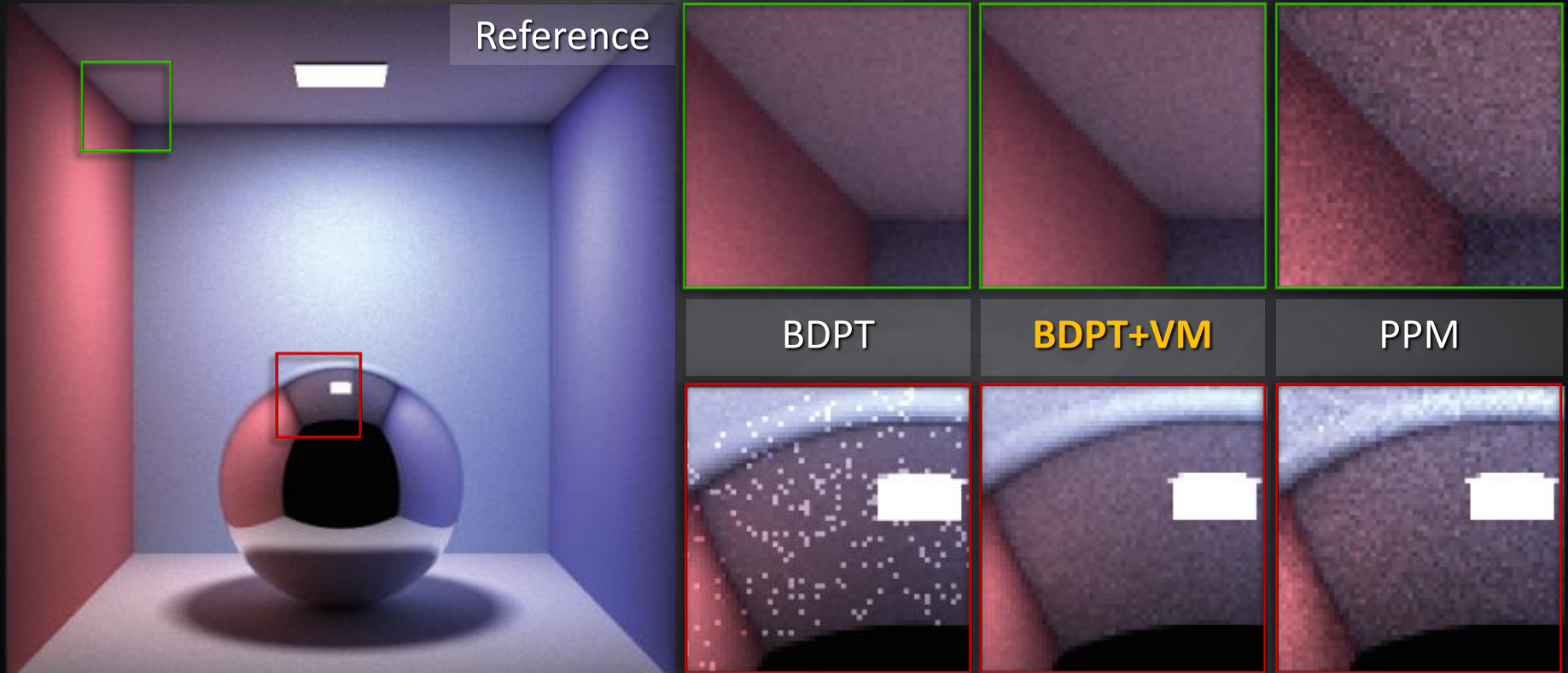


b) Vertex merging



c) Continue sub-path

Results



Same time (1 minute)

PT

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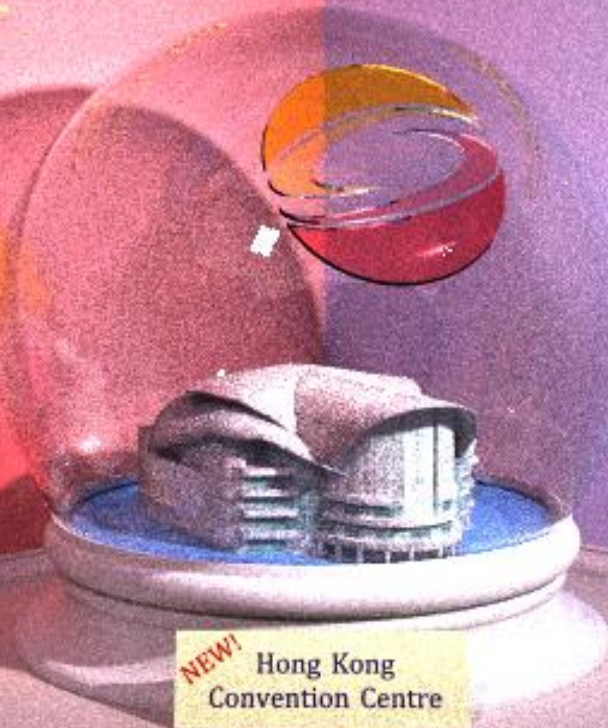
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Results

Path tracing



Results

Bidirectional path tracing



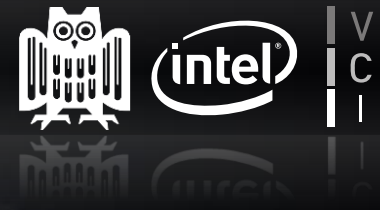
Results

Progressive photon mapping



Results

Our combination



Results

Relative contributions

PPM

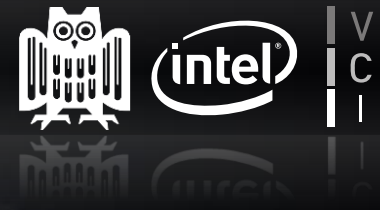


BPT



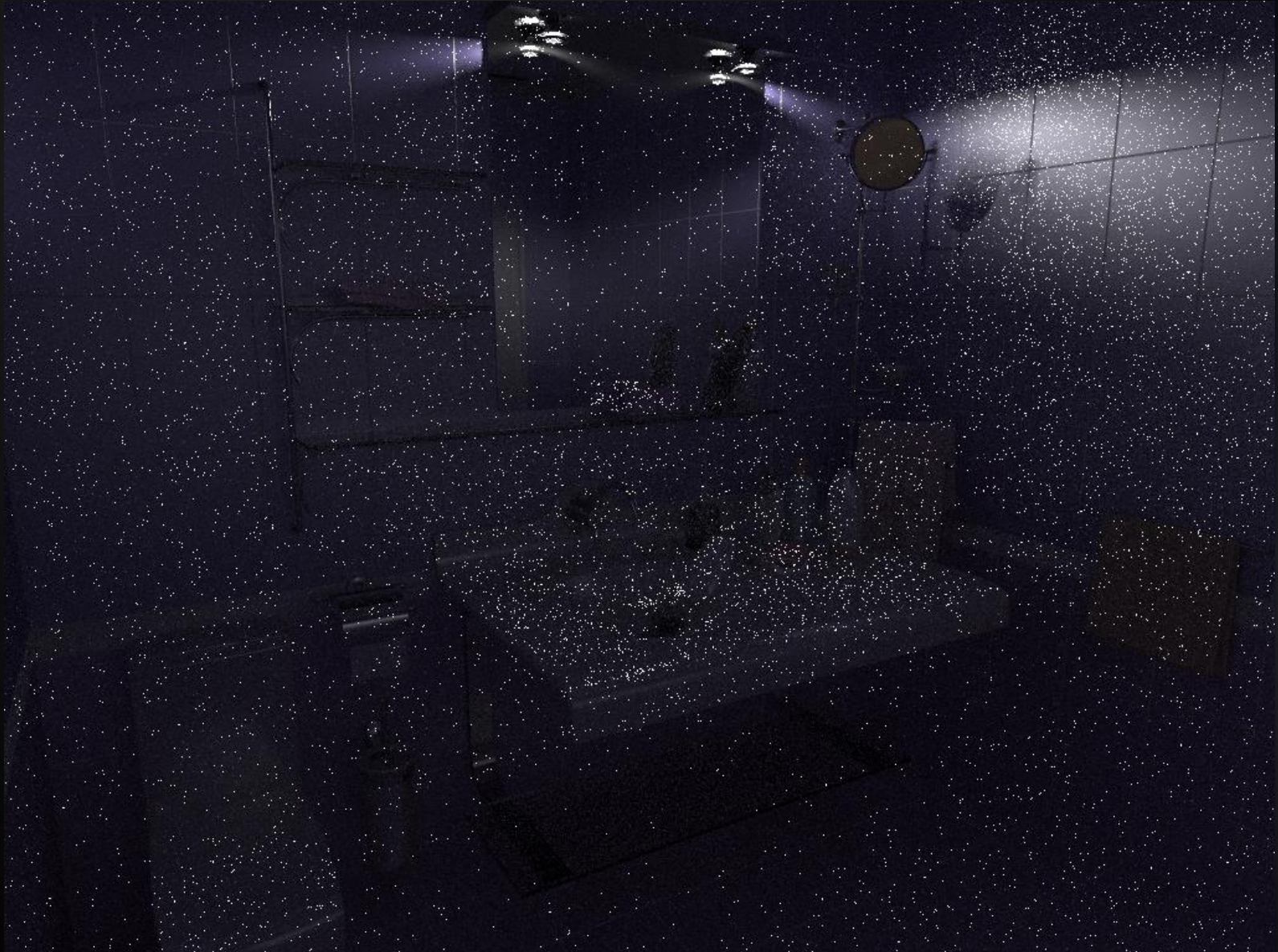
Results

Our combination



Results

Path tracing



Results

Bidirectional path tracing



Results



V
C
I

Progressive photon mapping



Results

Our combination



Results

Relative contributions

PPM



BPT



Results

Our combination



V
C
I



Results

Path tracing



Results

Bidirectional path tracing



Results



V
C
I

Progressive photon mapping



Results

Our combination



V
C
I



Results

Relative contributions

PPM



BPT



Results

Our combination

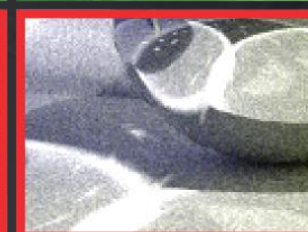
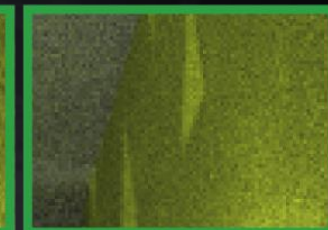
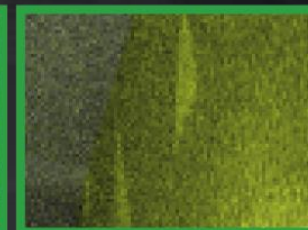
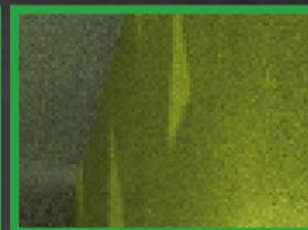


V
C
I



Results

Order of convergence



PT

BDPT

PPM

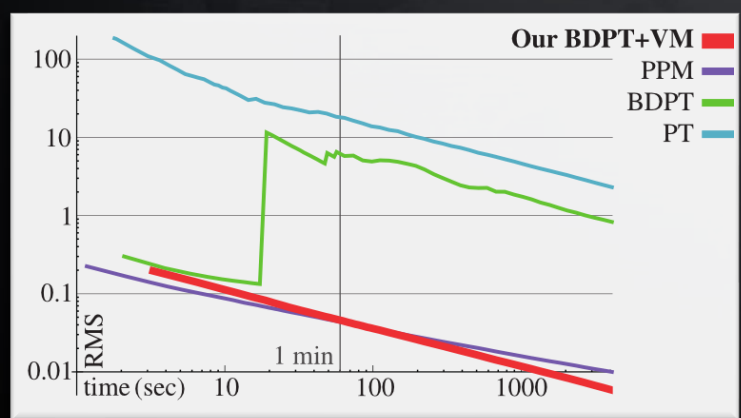
BDPT+VM

✓ $O(N^{-0.5})$

✓ $O(N^{-0.5})$

✗ $O(N^{-0.33})$

✓ $O(N^{-0.5})$



- * Photon mapping as a path sampling technique
- * Elegant implementation
- * Good order of convergence
 - VM efficiency diminishes over time
- * Challenges
 - Glossy paths

Challenges



BDPT+VM

Challenges



BDPT+VM

Challenges



V
C
I



BDPT+VM

Challenges



V
C
I



BDPT