UNIVERSITÄT DES SAARLANDES

VISUAL COMPUTING INSTITUTE

Bidirectional Light Transport with Vertex Merging

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Saarland University

DFKI

Motivation

Path tracing

Bidirectional path tracing

Progressive photon mapping

1 minute

Motivation

Path tracing

Bidirectional path tracing

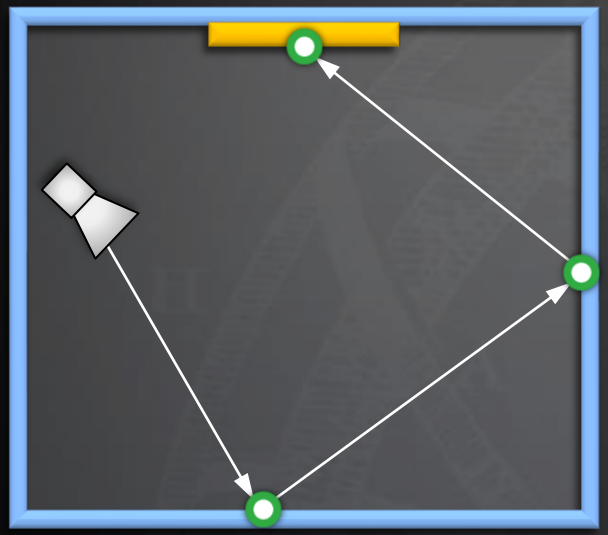
Progressive photon mapping

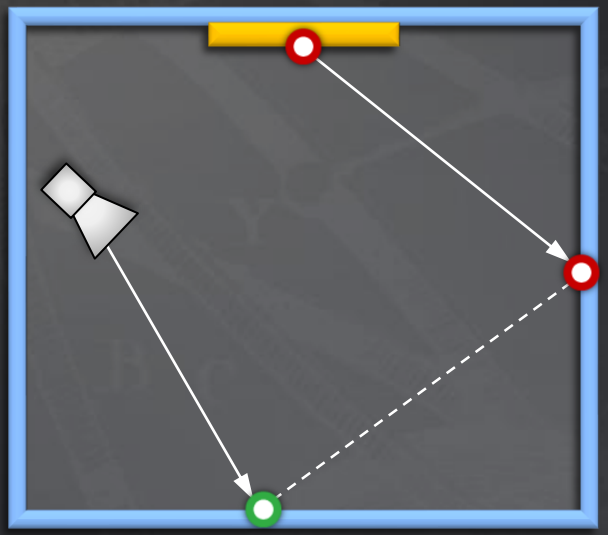
1 minute

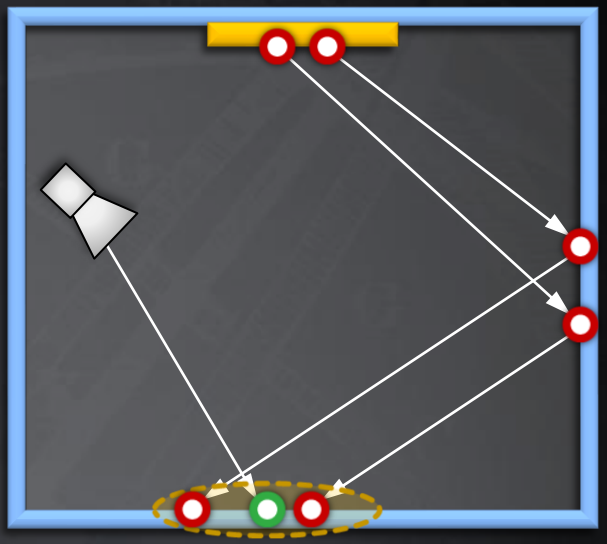
Motivation


Bidirectional path tracing
Result
Progressive photon mapping

BDPT vs PM







Unidirectional sampling

Vertex connection

Density estimation

Bidirectional path tracing

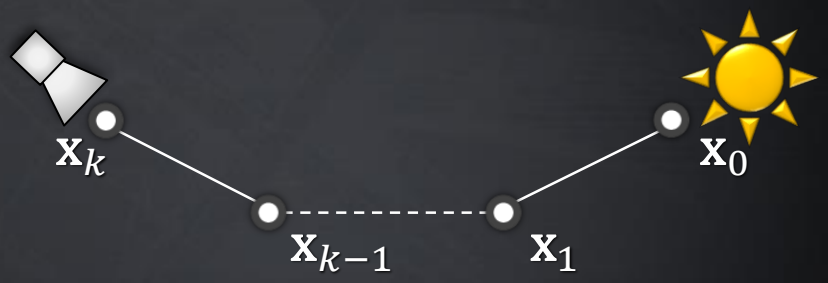
Photon mapping

Overview

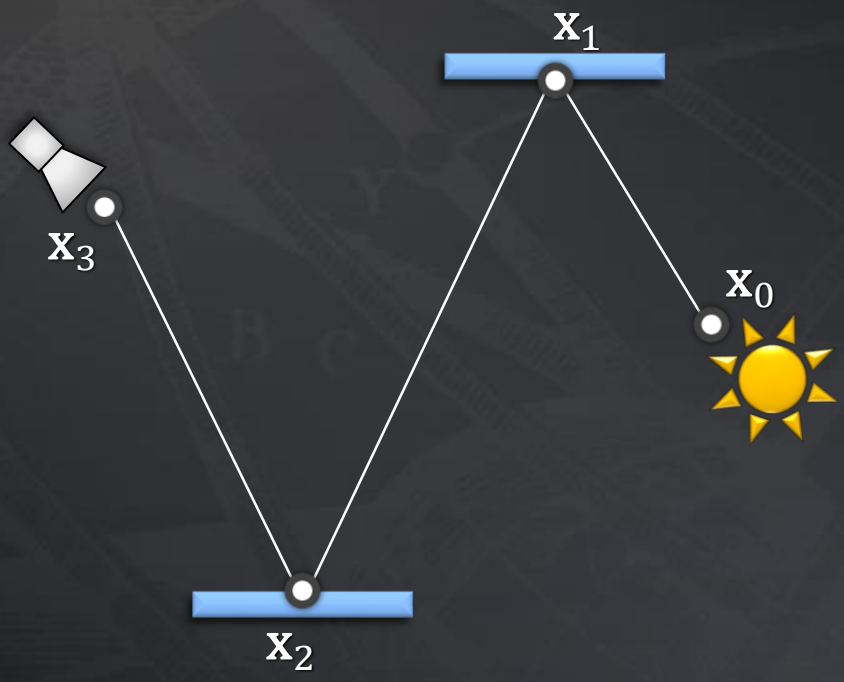
- Problem: different math frameworks
  - **BDPT**: Monte Carlo integration
  - **PM**: Density estimation

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

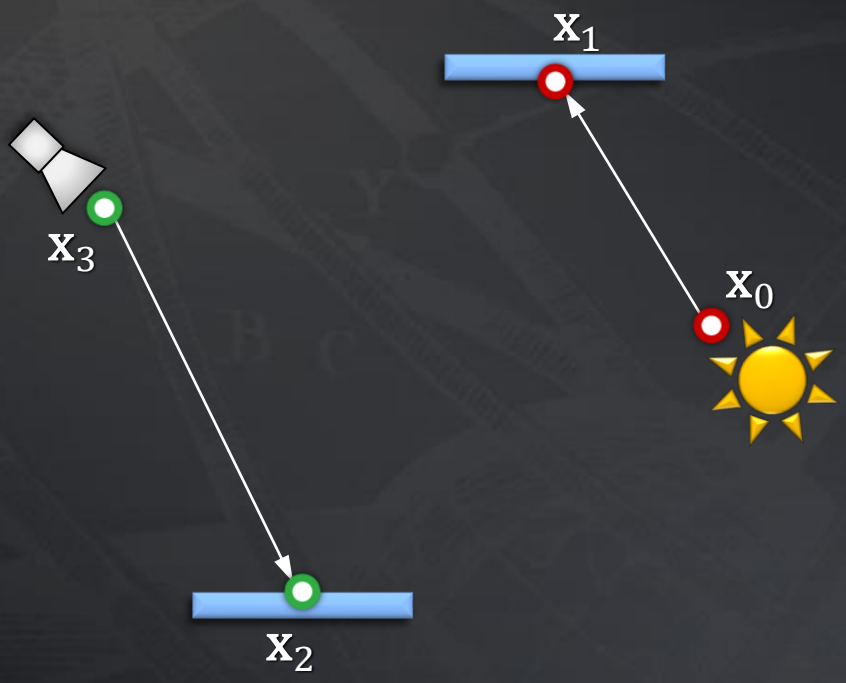
- Path integral framework
  - $I_j = \int_\Omega f_j(\bar{\mathbf{x}})\, d\mu(\bar{\mathbf{x}})$
  - $\langle I_j \rangle = \frac{f_j(\bar{\mathbf{x}})}{p(\bar{\mathbf{x}})}$
  - $p(\bar{\mathbf{x}}) = p(\mathbf{x}_0)p(\mathbf{x}_1)\dots p(\mathbf{x}_k)$



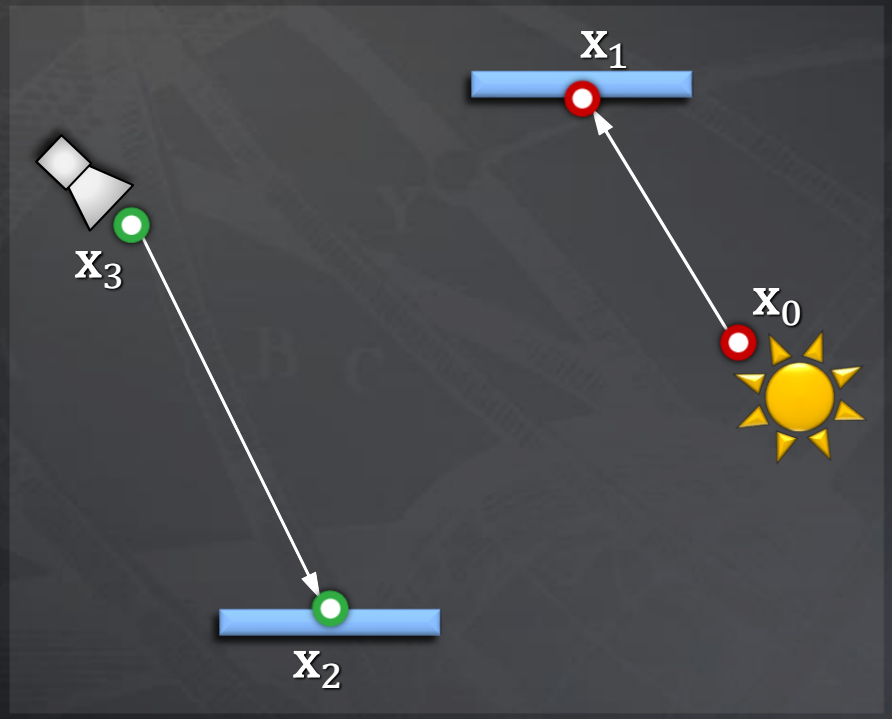
Bidirectional MC path sampling



Bidirectional MC path sampling



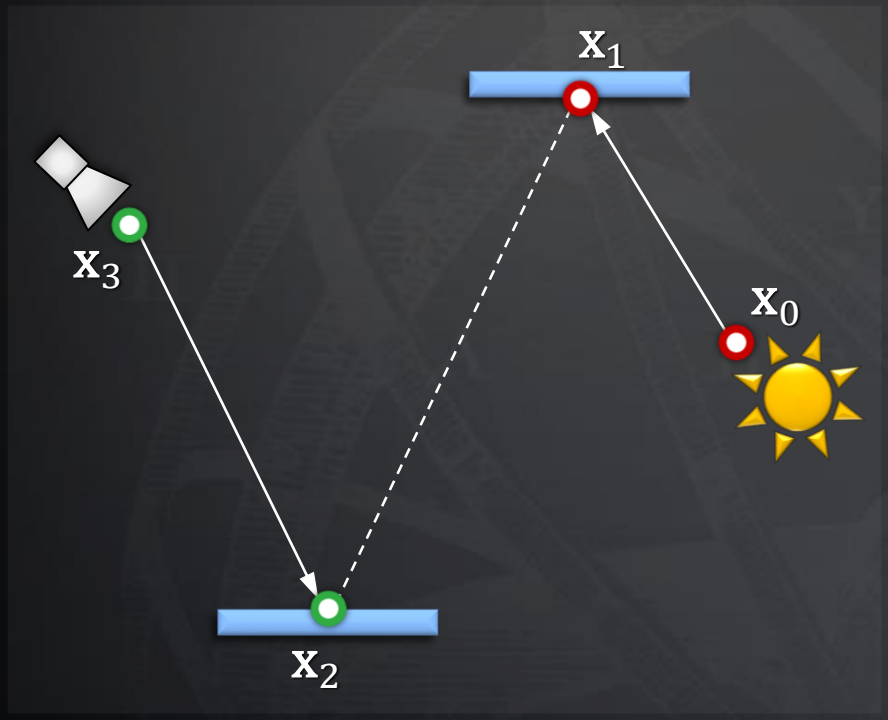
Bidirectional MC path sampling



Bidirectional path tracing

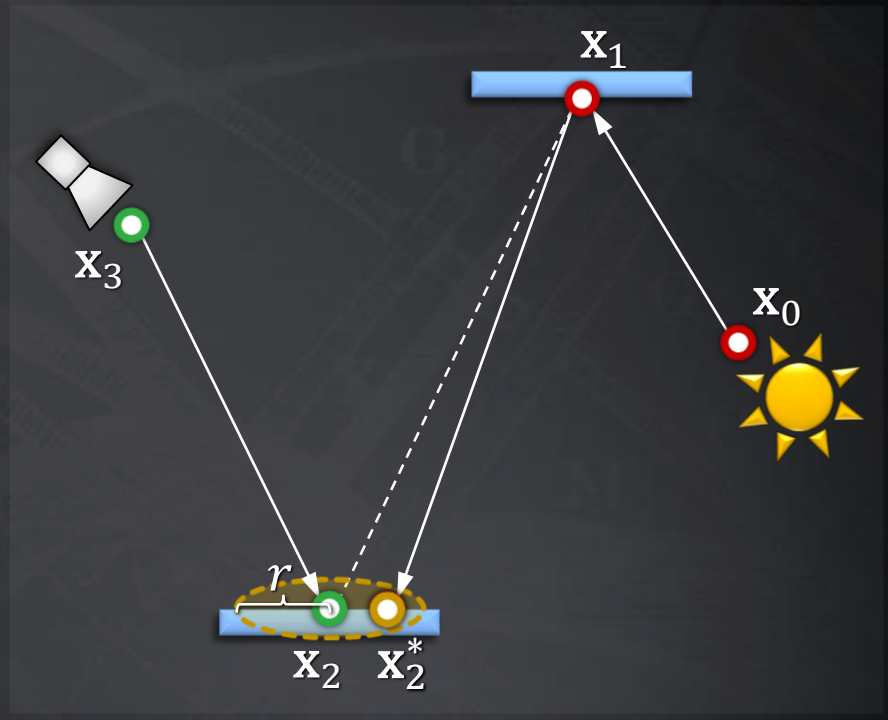
Photon mapping

Bidirectional MC path sampling



Bidirectional connecting

$$p_{VC}(\bar{\mathbf{x}}) = p(\mathbf{x}_0)p(\mathbf{x}_0 \to \mathbf{x}_1)\, p(\mathbf{x}_3)p(\mathbf{x}_3 \to \mathbf{x}_2)$$



Vertex merging

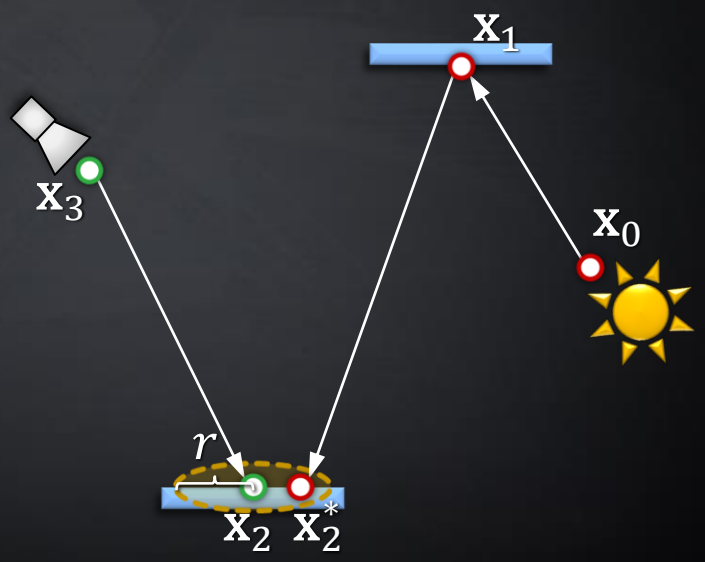
$$p_{VM}(\bar{\mathbf{x}}) \simeq p(\mathbf{x}_0)p(\mathbf{x}_0 \to \mathbf{x}_1)\, p(\|\mathbf{x}_2 - \mathbf{x}_2^*\|^2 < r)\, p(\mathbf{x}_3)p(\mathbf{x}_3 \to \mathbf{x}_2)$$

Vertex merging estimator

Light vertex
Camera vertex

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

- No density estimation!

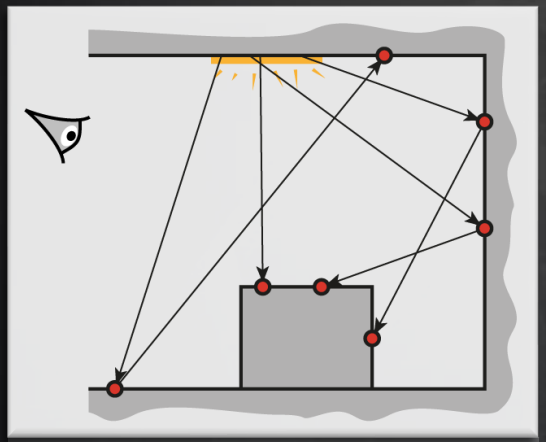


Sampling techniques

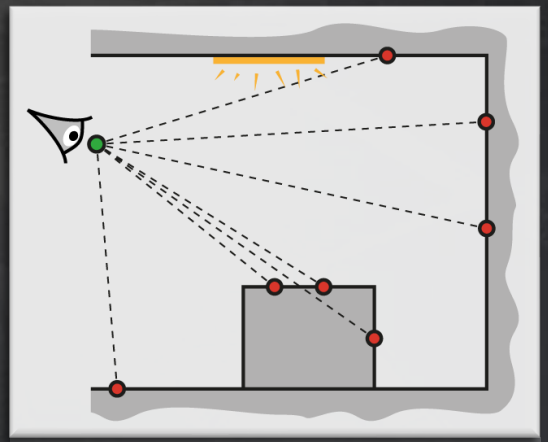
Unidirectional	2 ways
Vertex connection	4 ways
Vertex merging	**5 ways**
Total	**11 ways**

Vertex connection and merging

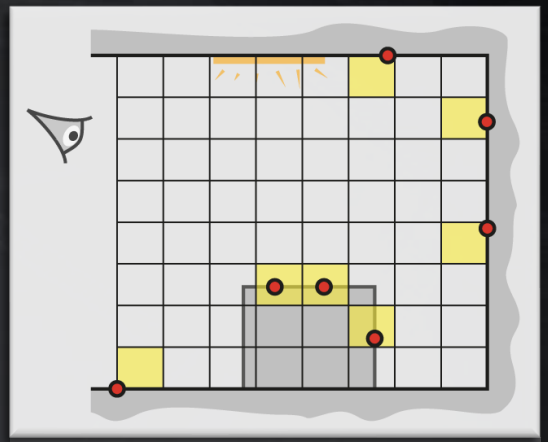
Stage 1: Light sub-path sampling



a) Trace sub-paths

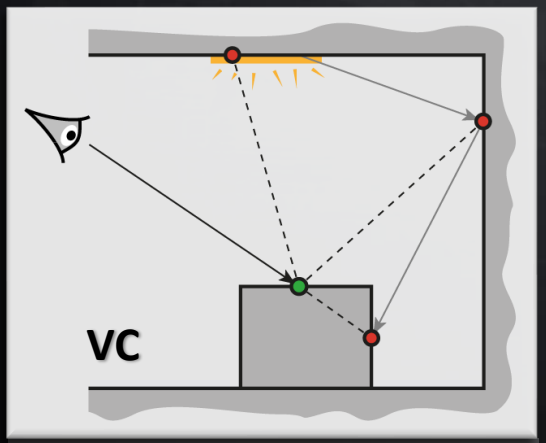


b) Connect to eye

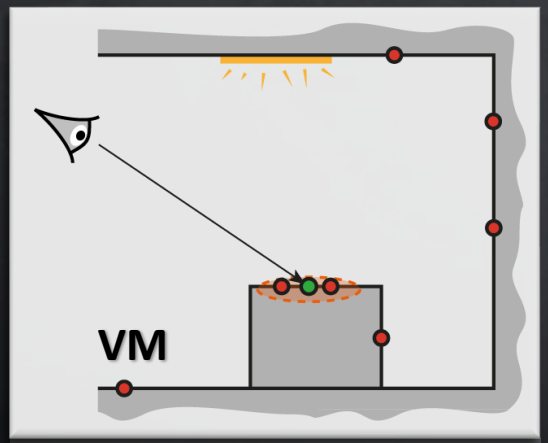


c) Build search structure

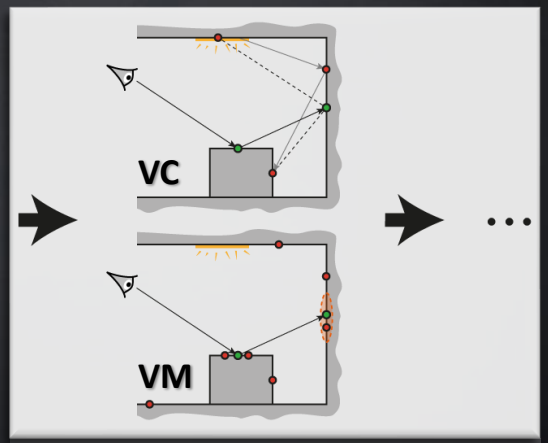
Stage 2: Eye sub-path sampling (reduced radius at each iteration)



a) Vertex connection

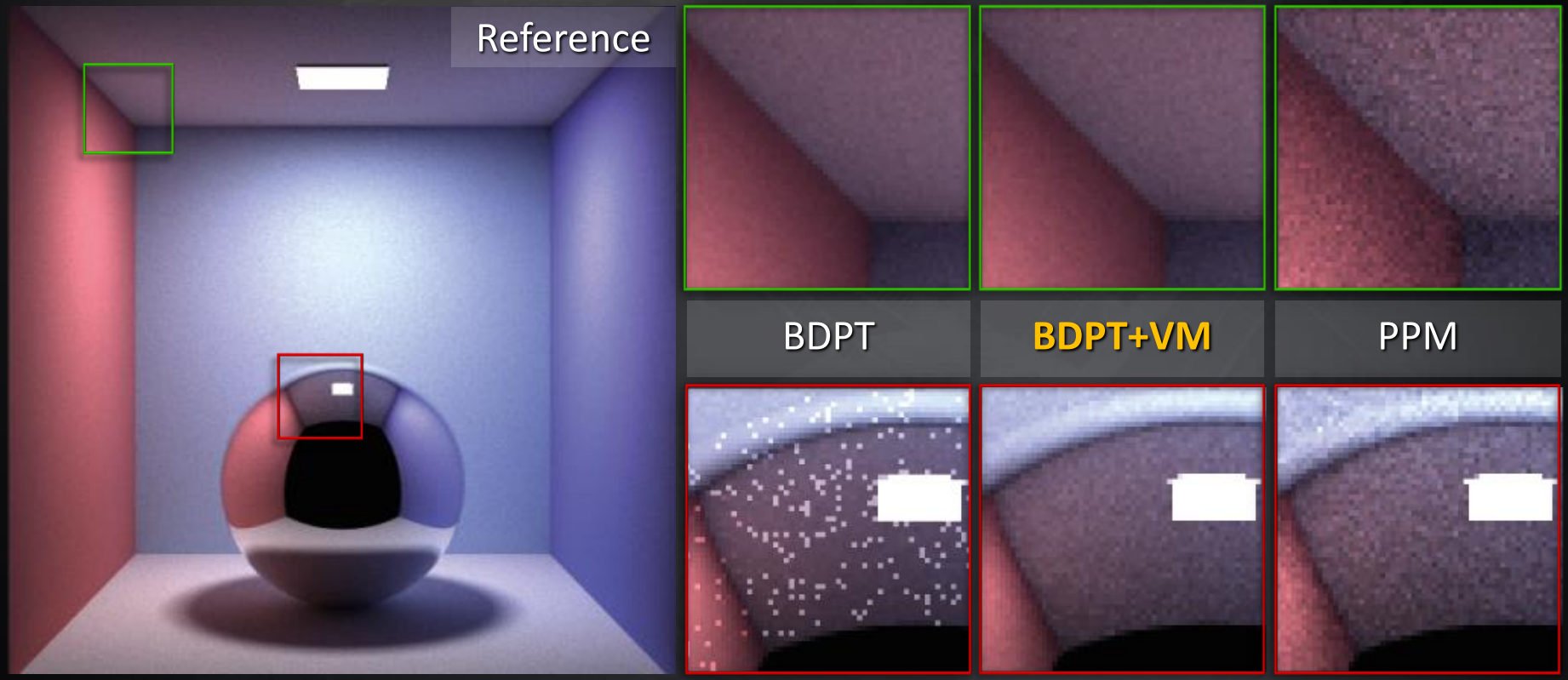


b) Vertex merging



c) Continue sub-path

Results



Same time (1 minute)


PT
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Souvenirs
Stanford Bunny
NEW! Hong Kong Convention Centre
Utah Teapot
BDPT
SIGGRAPH Asia 2011
Souvenirs
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Utah Teapot
PPM
SIGGRAPH Asia 2011
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Utah Teapot
VM
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VM


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Utah
Teapot
VM+BDPT

Results

Path tracing

Results

Bidirectional path tracing

Results

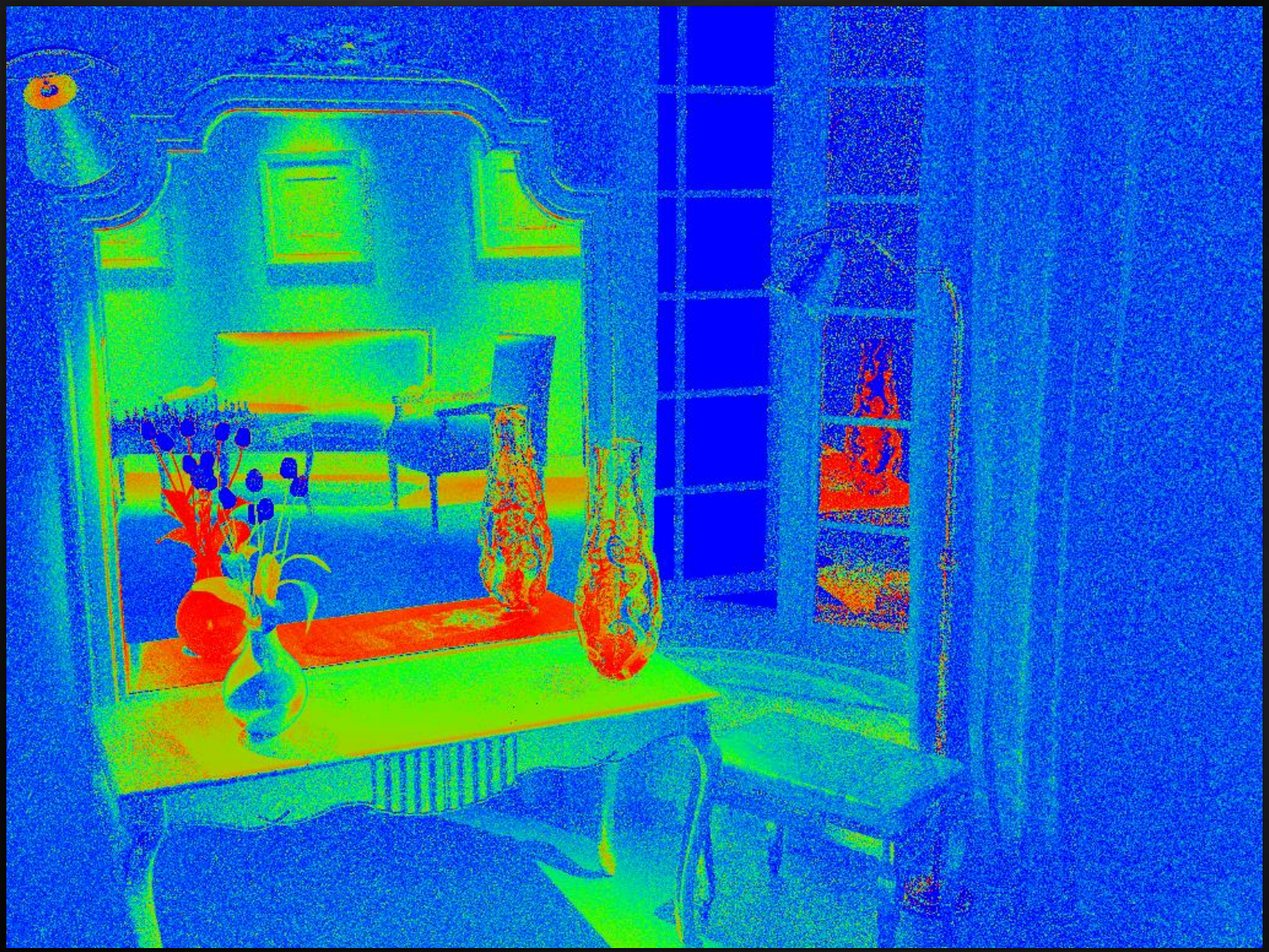
Progressive photon mapping

Results

Our combination

Results

Relative contributions

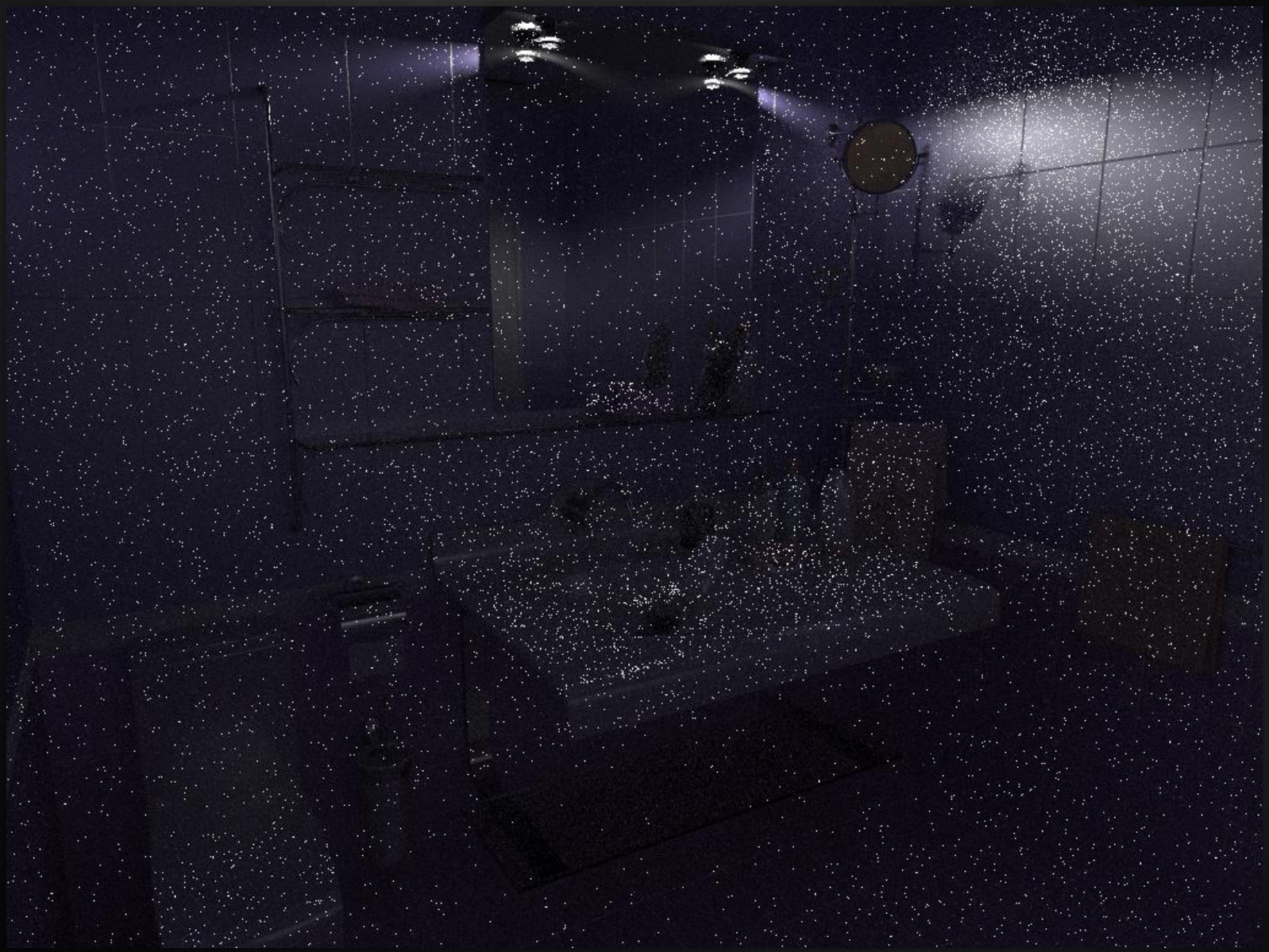


Results

Our combination

Results

Path tracing



Results

Bidirectional path tracing

Results

Progressive photon mapping

Results

Our combination

Results

Relative contributions

Results

Our combination

Results

Path tracing

Results

Bidirectional path tracing

Results

Progressive photon mapping

Results

Our combination

Results

Relative contributions

PPM

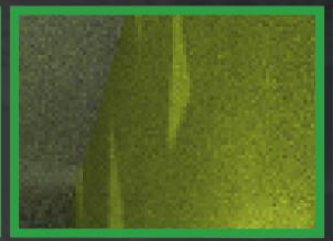
BPT

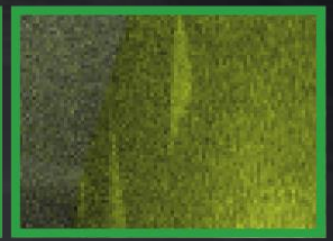
Results

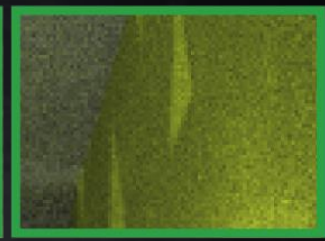
Our combination

Results

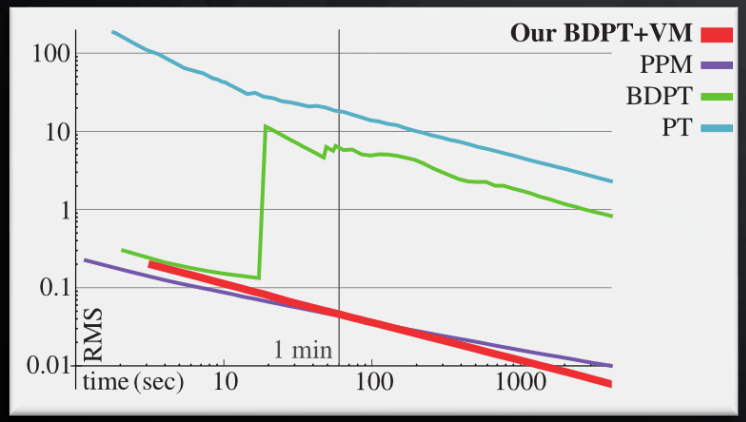
Order of convergence







PT	BDPT	PPM	BDPT+VM
✓ $O(N^{-0.5})$	✓ $O(N^{-0.5})$	✗ $O(N^{-0.33})$	✓ $O(N^{-0.5})$

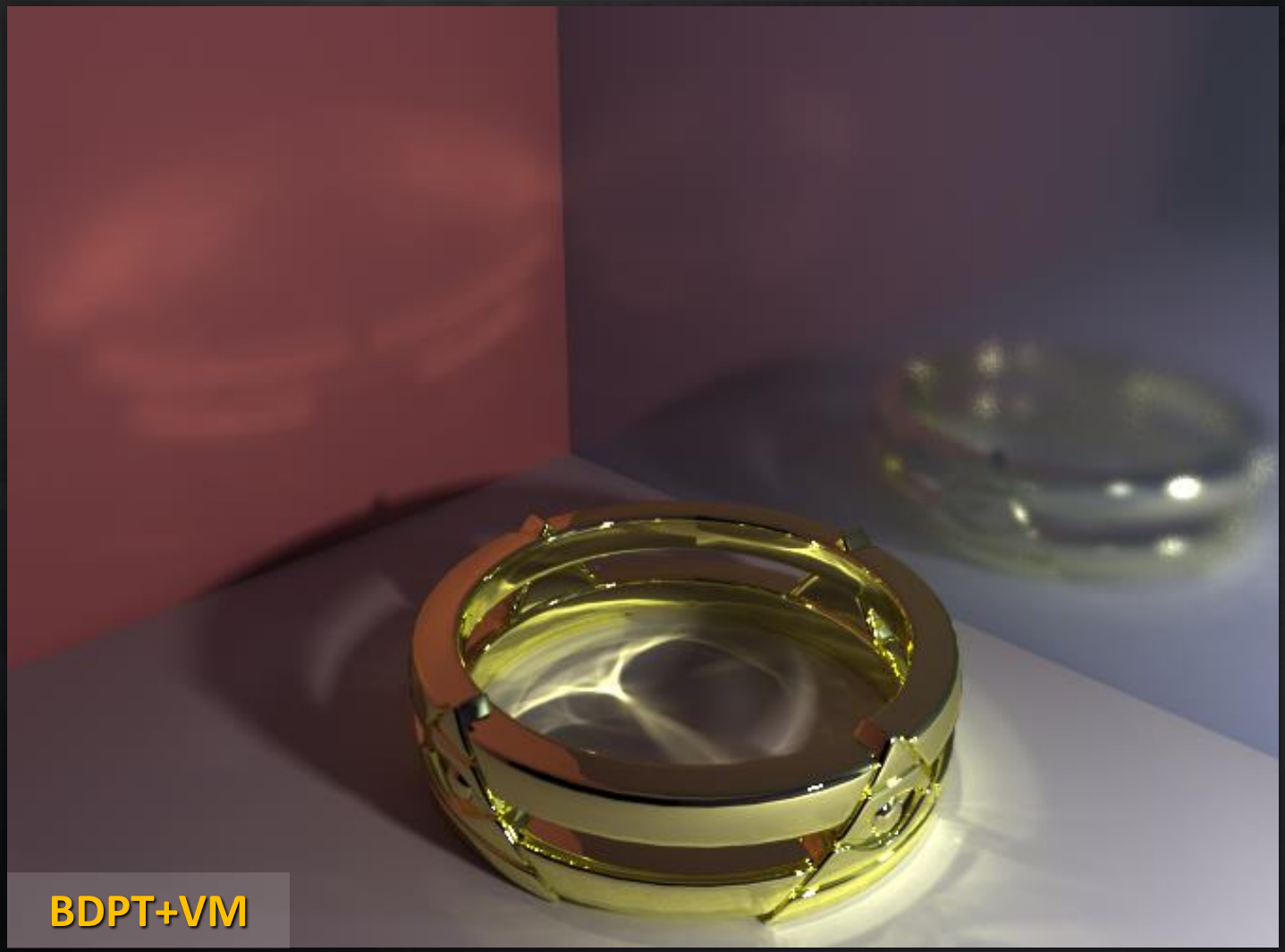


Summary

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

Challenges

Challenges



Challenges

Challenges