Bidirectional Light Transport with Vertex Merging

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Motivation

Path tracing
Bidirectional path tracing
Progressive photon mapping

1 minute
Motivation

1 minute
Motivation

Bidirectional path tracing vs Progressive photon mapping
Bidirectional path tracing

Photon mapping

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

\[ I_j = \int_{\Omega} f_j(\bar{x}) \, d\mu(\bar{x}) \]

\[ \langle I_j \rangle = \frac{f_j(\bar{x})}{p(\bar{x})} \]

\[ p(\bar{x}) = p(x_0)p(x_1) \ldots p(x_k) \]
Bidirectional MC path sampling
Bidirectional MC path sampling
Bidirectional MC path sampling

Bidirectional path tracing

Photon mapping
Bidirectional MC path sampling

**Bidirectional path tracing**

\[ p_{VC}(\mathbf{x}) = p(x_0)p(x_0 \rightarrow x_1)p(x_3)p(x_3 \rightarrow x_2) \]

**Vertex merging**

\[ p_{VM}(\mathbf{x}) \approx p(x_0)p(x_0 \rightarrow x_1)p(x_3)p(x_3 \rightarrow x_2)p(x_2 \rightarrow x_2^*) \]
Vertex merging estimator

\[ \langle I \rangle = \frac{f_j(x)}{p_{VM}(x)} = \ldots = \Delta W(x_2) \frac{f_r(x_3 \leftrightarrow x_2, x_2^* \rightarrow x_1)}{\pi r^2} \Delta \Phi(x_2^*) \]

\( \equiv \) photon mapping estimator

\( \checkmark \) 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

...
Results

Same time (1 minute)
SIGGRAPH Asia 2011 Souvenirs

Stanford Bunny

NEW! Hong Kong Convention Centre

Utah Teapot
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
Bidirectional path tracing
Results

Progressive photon mapping

AA-340
Results

Our combination
Results

Relative contributions
Results

Our combination
## Results

### Order of convergence

<table>
<thead>
<tr>
<th></th>
<th>PT</th>
<th>BDPT</th>
<th>PPM</th>
<th>BDPT+VM</th>
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<tbody>
<tr>
<td></td>
<td>✓ $O(N^{-0.5})$</td>
<td>✓ $O(N^{-0.5})$</td>
<td>✗ $O(N^{-0.33})$</td>
<td>✓ $O(N^{-0.5})$</td>
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</table>

![Graph showing convergence rate](image)

**Legend:**
- **Our BDPT+VM**
- **PPM**
- **BDPT**
- **PT**
Summary

- 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
Challenges