HISTORYGRAMS:
ENABLING INTERACTIVE GLOBAL ILLUMINATION IN
DIRECT VOLUME RENDERING USING PHOTON MAPPING

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Motivation
MOTIVATION


**Motivation**

[Ropinski et al. CG&A 2010]
**Motivation**

Our, multiple scattering  
[Ropinski et al. CG&A 2010]
PHOTON MAPPING

- Map intensity values to optical properties

Transfer function

Opacity

Intensity

0.4

0.8

0.2
PHOTON MAPPING

- Map intensity values to optical properties

Transfer function

Opacity

Intensity
PHOTON MAPPING

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Intensity

Opacity

0.4

0.2

0.8
PHOTON MAPPING

- Map intensity values to optical properties

![Diagram showing photon mapping concepts](Image)

Transfer function

- Opacity vs Intensity graph

- Points representing intensity values: 0.4, 0.2, 0.8
PROBLEM
**Problem**

Expensive to trace photons

- Expensive to gather photons
Expensive to trace photons
  • Optical property changes
  • Light changes
- Expensive to gather photons
  • Optical property changes
  • Light changes
Problem

Expensive to trace photons
  • Optical property changes
  • Light changes
- Expensive to gather photons
  • Optical property changes
  • Light changes
  • Camera changes
**Observation**

- Often local changes
HISTORYGRAMS
History of a photon

0.2

0.4

0.8
History of a photon

0.2

0.4

0.8
**History of a photon**

- Absorption
- Scattering
- Color
- Phase function/BRDF

0.2
0.4
0.8
History of a photon

- Absorption
- Scattering
- Color
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History of a photon

- Absorption
- Scattering
- Color
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0.4

0.8

0.2
HISTORY OF A PHOTON

- Absorption
- Scattering
- Color
- Phase function/BRDF
**History of a photon**

- Absorption
- Scattering
- Color
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![Diagram of photon history](image)

**Historygram**
**History of a Photon**

- Absorption
- Scattering
- Color
- Phase function/BRDF

Historygram
**History of a photon**

- Absorption
- Scattering
- Color
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Historygram

![Diagram showing the history of a photon with absorption, scattering, color, and phase function/BRDF](image)
**History of a Photon**

- Absorption
- Scattering
- Color
- Phase function/BRDF

**Historygram**

0.4

0.8

0.2
History of a Photon

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Historygram

0.2
0.4
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History of a Photon

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0.2
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Historygram
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**History of a Photon**

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**Historygram**

Intensity

0.4

0.8

0.2

0 0.33 0.67 1
**History of a Photon**

- Absorption
- Scattering
- Color
- Phase function/BRDF

**Historygram**

\[ \delta(x) \]

Intensity

0.2
0.4
0.8

\[ 0 \quad 0.33 \quad 0.67 \quad 1 \]
**History of a Photon**

- Absorption
- Scattering
- Color
- Phase function/BRDF

\[ \delta(x) \Rightarrow 001 \]
History of a Photon

- Absorption
- Scattering
- Color
- Phase function/BRDF

Historygram

\[ \delta(x) \Rightarrow 001 \]
**History of a Photon**

- Absorption
- Scattering
- Color
- Phase function/BRDF

### Historygram

\[ \delta(x) \rightarrow 010 \]

- Intensity

0.4 - 0.8 - 0.2
History of a Photon

- Absorption
- Scattering
- Color
- Phase function/BRDF

$\delta(x) \Rightarrow 010$

Intensity

<table>
<thead>
<tr>
<th>0</th>
<th>0.33</th>
<th>0.67</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**History of a Photon**

- Absorption
- Scattering
- Color
- Phase function/BRDF

### Historygram

<table>
<thead>
<tr>
<th>Intensity</th>
<th>0</th>
<th>0.33</th>
<th>0.67</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historygram</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Historygrams for View-Rays

- Transmittance:

$$T(x_i, x_j) = e^{-\int_{x_i}^{x_j} \tau(x') dx'}$$
**Historygrams for View-rays**

- **Transmittance:**

\[
T(x_i, x_j) = e^{-\int_{x_i}^{x_j} \tau(x') dx'}
\]
**Historygrams for View-Rays**

- **Transmittance:**

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Pipeline

Parameter change

Recompute invalid data

Create query Historygram

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Change Historygram</th>
<th>Recompute invalid data</th>
<th>Create query</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TF 1:

Opacity

Intensity

PIPELINE

S1 S2 S3 S4 S5

0.4

0.8

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Historygrams: Enabling Interactive Global Illumination in Direct Volume Rendering using Photon Mapping
**Pipeline**

TF 1:

TF 2:

Opacity

Intensity

Opacity

Intensity

TF 1:

TF 2:

Opacity

Intensity

 opacity

Intensity

$$S_1 \quad S_2 \quad 0.2 \quad S_3 \quad S_4 \quad S_5$$

0.4

0.8

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Historygrams: Enabling Interactive Global Illumination in Direct Volume Rendering using Photon Mapping
PIPELINE

TF 1:

Opacity

Intensity

TF 2:

Opacity

Intensity

δ(x)

0.4

0.8

S₁ S₂ 0.2 S₃ S₄ S₅

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**Pipeline**

TF 1:

```
Intensity
Opacity
```

TF 2:

```
Intensity
Opacity
```

Query Historygram (tracks changes):

```
1 1 0
```

0.4 0.8
**Pipeline**

TF 1:

```
Opacity

Intensity
```

TF 2:

```
Opacity

Intensity
```

Query Historygram (tracks changes)

```
1     1     0
```

\[ \delta(x) \]

Opacity

Intensity

0.4

0.8

\[ S_1 \quad S_2 \quad S_3 \quad S_4 \quad S_5 \]

Historygrams: Enabling Interactive Global Illumination in Direct Volume Rendering using Photon Mapping
RESULTS
RESULT - VISUAL

1.3x speedup
RESULT - VISUAL

2.4x speedup
RESULT - PERFORMANCE

(Higher is better)

Performance Speedup Using Histograms

- Single Scattering
- Multiple Scattering, 2 Bounces

Photons ( Millions )

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5

16 14 12 10 8 6 4 2
RESULT - PERFORMANCE

(Higher is better)
RESULT - PERFORMANCE

(Lower is better)

[Geforce GTX 570]
Limitations

- Partial volume effect
- Changing outer layers (skin, air)
CONCLUSION & FUTURE WORK

Conclusions

• Historygram data structure
• Efficient photon tracing and gathering without approximation
• Advanced material effects and multiple scattering

Future Work

• Photon beams
• Path tracing
THANK YOU!

Scientific Visualization Group
http://scivis.itn.liu.se

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