Deep Opacity Maps

Cem Yuksel and John Keyser
Texas A&M University
Deep Opacity Maps

Real-time semi-transparent shadows for hair
Outline

- Previous Work & Motivation
- Deep Opacity Maps
- Implementation
- Results
- Discussion
Previous Work

- Shadow Maps (Lance Williams, 1978)
  - Depth Map
  - Binary Decision
Previous Work

- Deep Shadow Maps (Lokovic and Veach 2000)
  - Multiple depths per pixel
  - Multiple opacities per pixel
  - Compress for efficiency
  - Offline
Previous Work

- Opacity Shadow Maps (Kim and Neumann 2001)
  - Opacity Layers
  - Interactive
  - Layering Artifacts!

Opacity Shadow Maps (256 layers)
Previous Work

- Opacity Shadow Maps (Kim and Neumann 2001)
  - Opacity Layers
  - Interactive
  - Layering Artifacts!
Previous Work

- Density Clustering (Mertens et al. 2004)
  - Per pixel layering
  - K-means clustering
  - Real-time
  - Inaccuracy Artifacts!
Motivation

- Deep Opacity Maps
  - Depth Map
  - Opacity Map
  - Real-time
  - Artifact Free!
Outline

- Previous Work & Motivation
- Deep Opacity Maps
- Implementation
- Results
- Discussion
Deep Opacity Maps

- Overview

Opacity Shadow Maps

Deep Opacity Maps
Deep Opacity Maps

- Overview
  - Pass 1: Depth Map
  - Pass 2: Opacity Map
  - Final frame rendering
Deep Opacity Maps

- **Pass 1:** Depth Map
  - $z_0$ per pixel
Deep Opacity Maps

- **Pass 2**: Opacity Map
  - Layers:
    - $z_0 \rightarrow z_0 + d_1$
    - $z_0 + d_1 \rightarrow z_0 + d_2$
    - $z_0 + d_2 \rightarrow z_0 + d_3$
    - …
  - $d_1, d_2, d_3…$ are user defined
Deep Opacity Maps

- **Layer Sizes**
  - $d_1$
  - $d_2 - d_1$
  - $d_3 - d_2$
  - ...
  - can be different!
Deep Opacity Maps

- Layer Sizes
  - $s = d_1$
  - Alternatives:
    - $s, s, s, s, \ldots$ (constant)
    - $s, 2s, 4s, 8s, \ldots$ (powers of 2)
    - $s, s, 2s, 3s, 5s, \ldots$ (Fibonacci)
    - $s, 2s, 3s, 4s, \ldots$ (linear)
Deep Opacity Maps

- Beyond the last layer
  - Ignore?
    - Won’t cast shadows
  - Add to the last layer?
    - Cast shadows on themselves
  - Increase the last layer size?
    - Reduce accuracy

Transmittance beyond the last layer should be close to zero anyway!
Outline

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Implementation

- Depth Map
  - can be **8-bit**, 16-bit, or 32-bit

- 3 opacity layers
  - **Single Texture**
    - **R**: depth \((z_0)\)
    - **G**: layer 1 opacity
    - **B**: layer 2 opacity
    - **A**: layer 3 opacity
Implementation

- 7, 11, 15... opacity layers
  - **Multiple Draw Buffers**
    - $R_1$: depth ($z_0$)
    - $G_1$: layer 1 opacity
    - $B_1$: layer 2 opacity
    - $A_1$: layer 3 opacity
    - $R_2$: layer 4 opacity
    - $G_2$: layer 5 opacity
    - $B_2$: layer 6 opacity
    - $A_2$: layer 7 opacity
    - ...

Texture 1

Texture 2
Outline

- Previous Work & Motivation
- Deep Opacity Maps
- Implementation
- Results
- Discussion
Results

(10K strands – 150K lines)

- **Opacity Shadow Maps**
  - 16 layers (81 fps)
  - 128 layers (2.3 fps)

- **Density Clustering**
  - 4 layers (73 fps)

- **Deep Opacity Maps**
  - 3 layers (114 fps)
Results

(15K strands – 1M lines)

Opacity Shadow Maps
8 layers
(88 fps)
Opacity Shadow Maps
256 layers
(0.6 fps)
Density Clustering
4 layers
(47 fps)
Deep Opacity Maps
3 layers
(74 fps)
## Results

(10K strands – 1.5M lines)

<table>
<thead>
<tr>
<th>Method</th>
<th>Layers/Settings</th>
<th>Frames per Second</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opacity Shadow Maps</td>
<td>8 layers</td>
<td>65 fps</td>
</tr>
<tr>
<td>Opacity Shadow Maps</td>
<td>256 layers</td>
<td>0.5 fps</td>
</tr>
<tr>
<td>Density Clustering</td>
<td>4 layers</td>
<td>37 fps</td>
</tr>
<tr>
<td>Deep Opacity Maps</td>
<td>3 layers</td>
<td>50 fps</td>
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</tbody>
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<td>Deep Opacity Maps</td>
<td></td>
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</tbody>
</table>
Results

- Deep Opacity Maps

3 layers

3 LARGER layers
Results

- Deep Opacity Maps

3 layers

7 layers
Results

Deep Opacity Maps + Shadow Maps
Outline

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- Implementation
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- Discussion
Discussion

- Direct illumination (no shadow) captured correctly
- Concentrate accuracy to where the shadow begins
- Interpolation is moved to within hair volume
- Layering artifacts are hidden
- Fewer layers (less memory)
- 2 pass shadow generation (fast)
Discussion

- Flickering?

Staircase Artifacts!
Discussion

- Flickering?
  - Same as shadow maps

![Shadow Maps](image)

- single look-up
- multiple look-up
Discussion

single look-up

multiple look-up
Conclusion

- Deep Opacity Maps method
  - is simple,
  - is faster,
  - uses less memory,
  - looks better!

- Use it!

- Questions?