Deep Opacity Maps

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Deep Opacity Maps

Real-time semi-transparent shadows
for hair

Outline

EUROGRAPHICS 2008

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

Previous Work

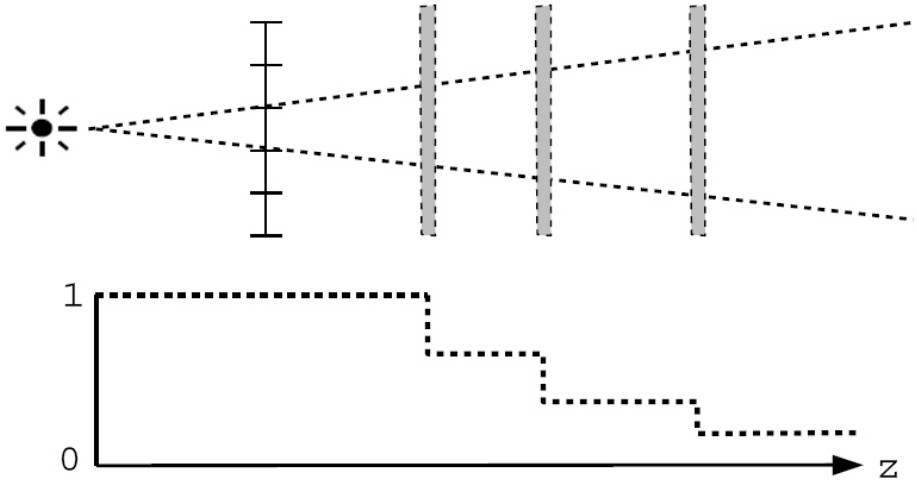
EUROGRAPHICS 2008

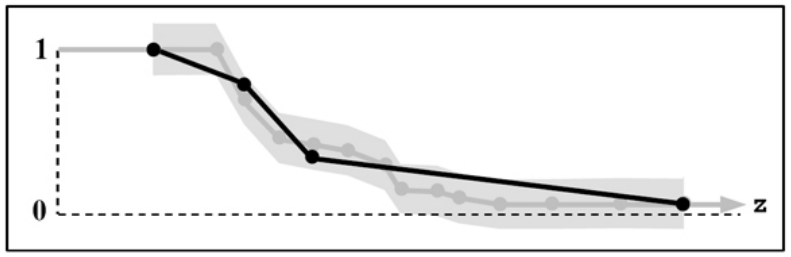
- Shadow Maps (Lance Williams, 1978)
  - Depth Map
  - Binary Decision

Previous Work

EUROGRAPHICS 2008

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

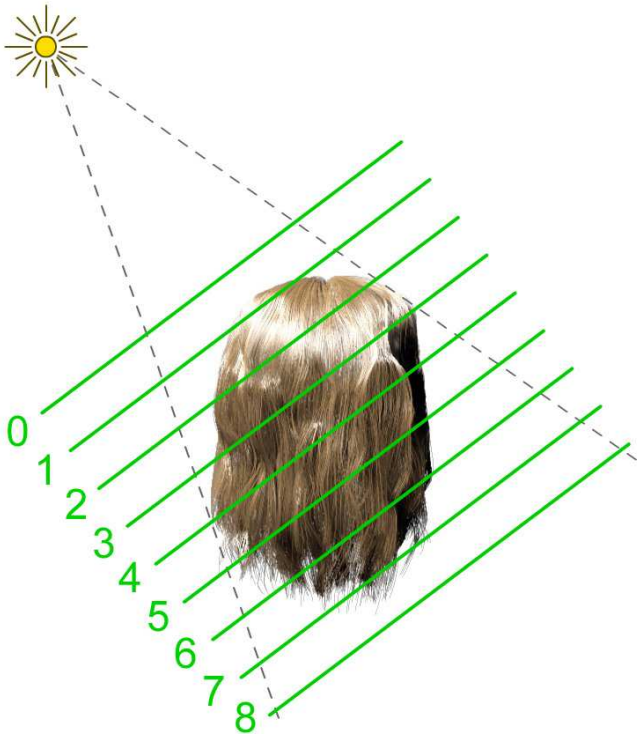


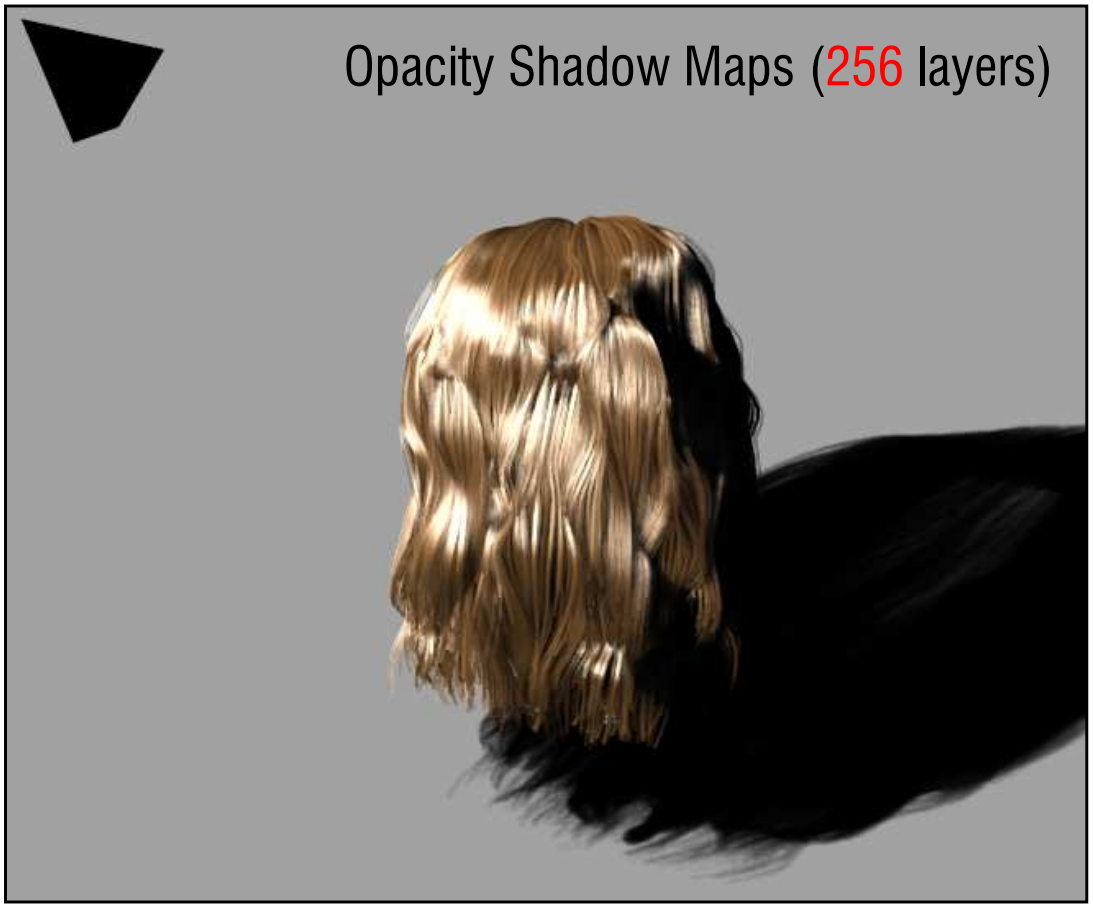


Previous Work

EUROGRAPHICS 2008

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





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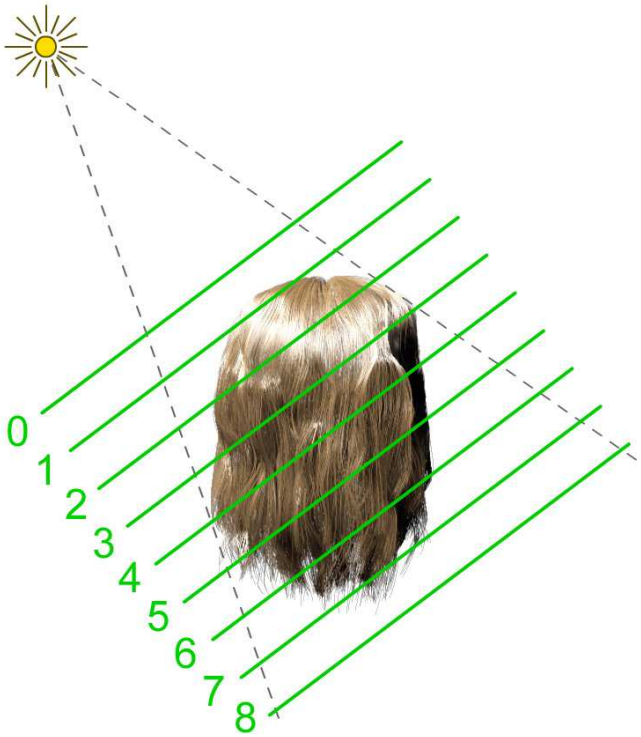
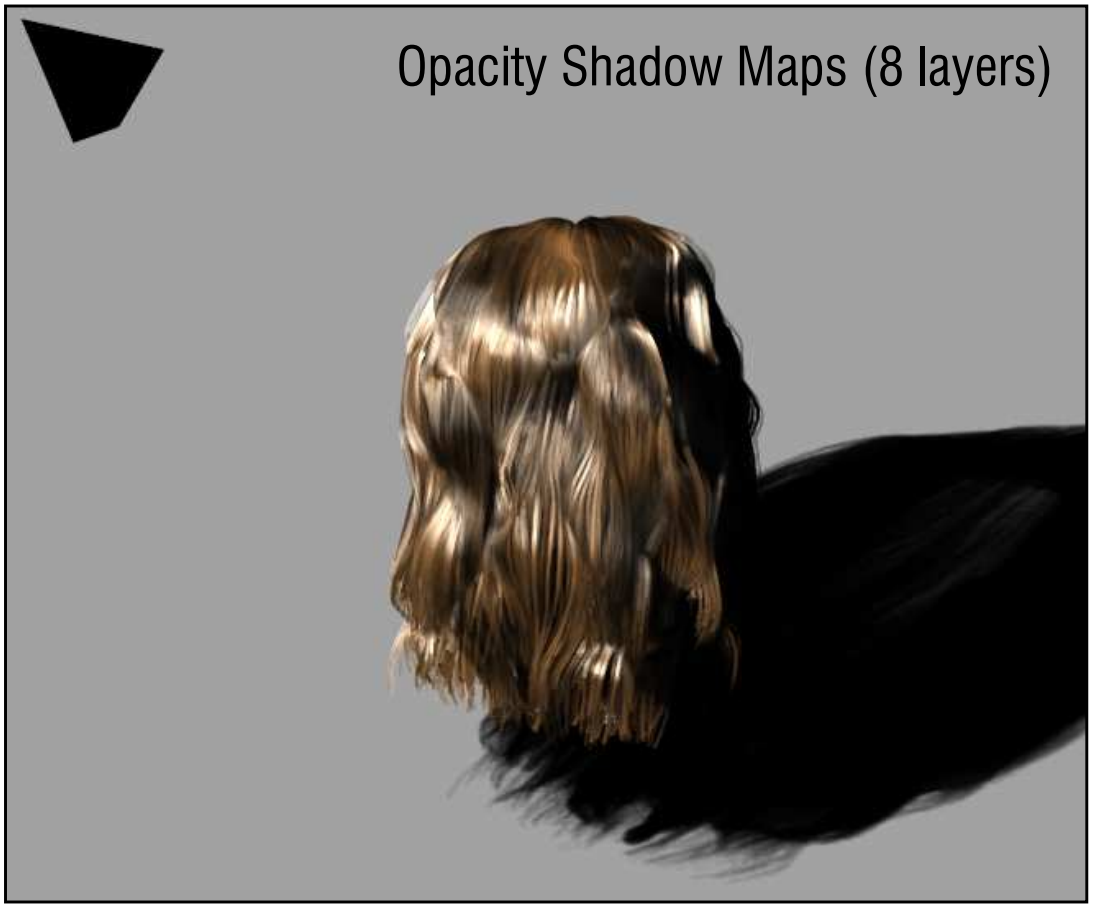
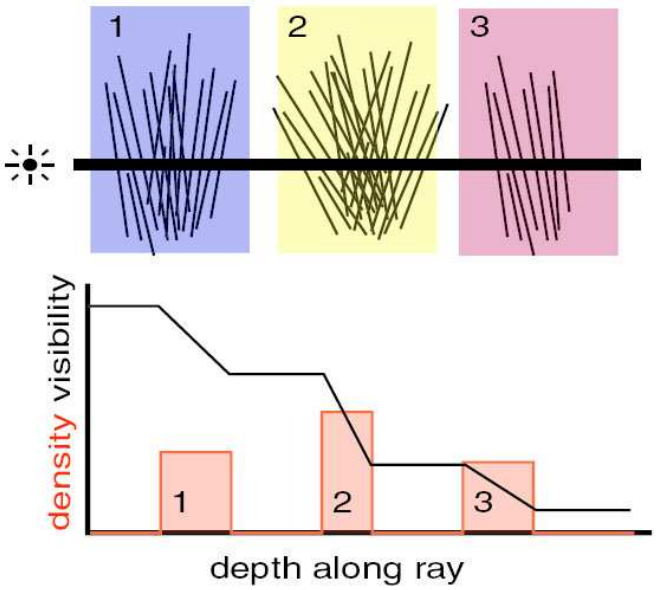


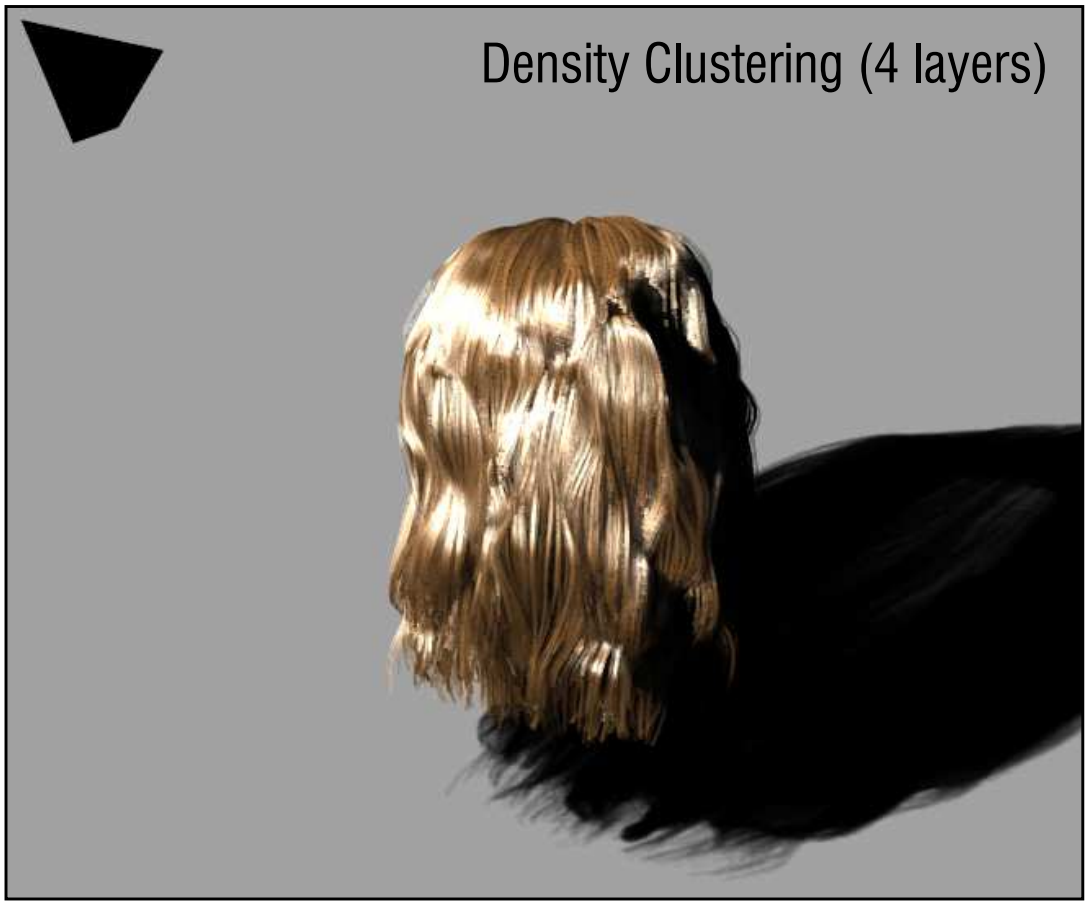


Previous Work

EUROGRAPHICS 2008

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

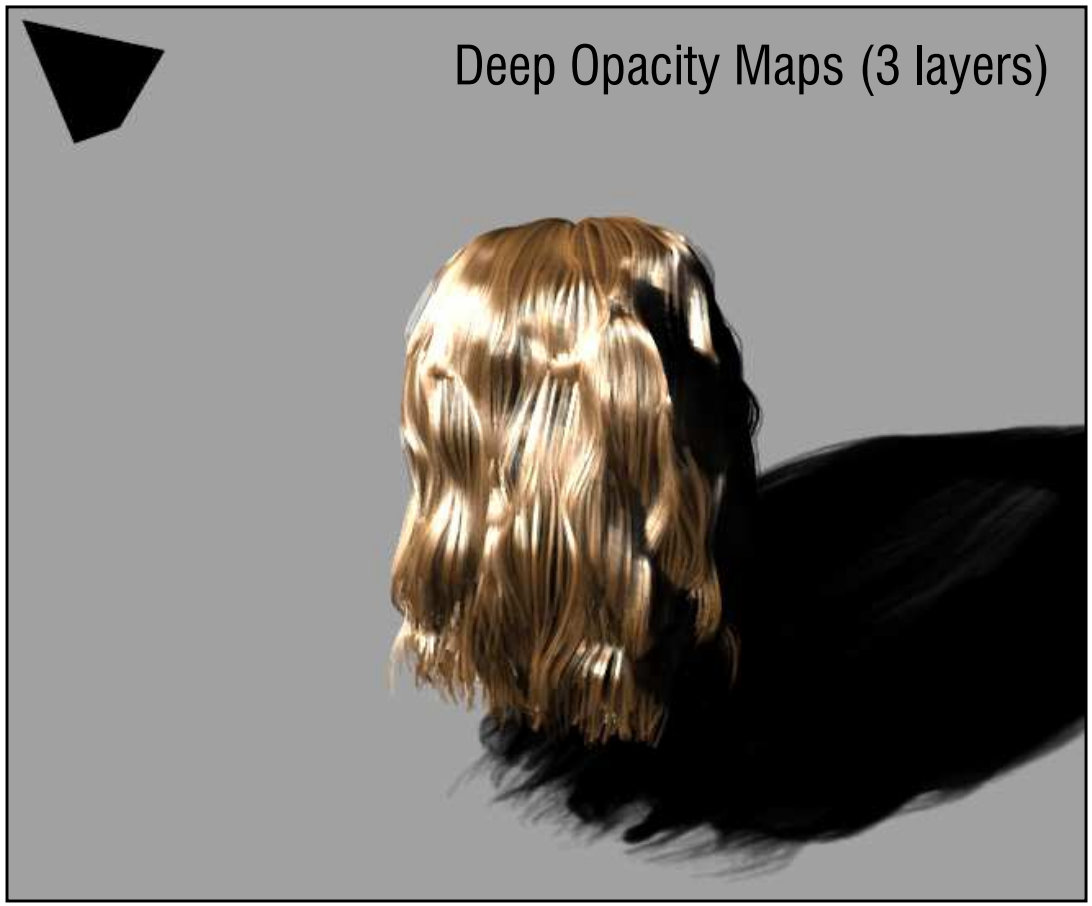




Motivation

EUROGRAPHICS 2008

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



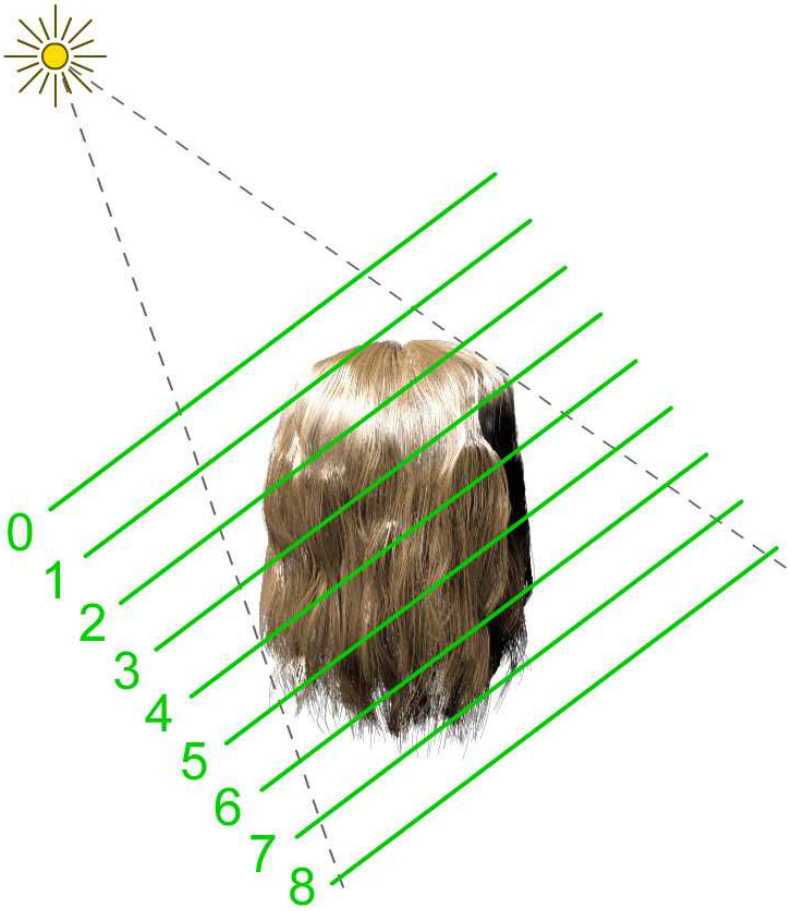
Outline

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

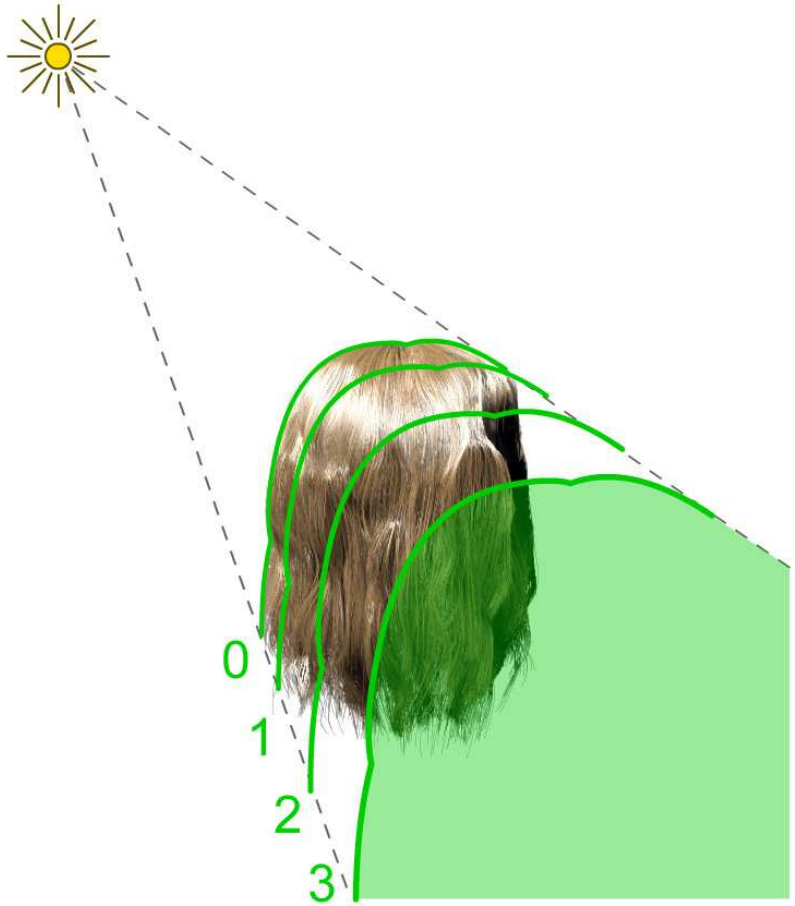
Deep Opacity Maps

EUROGRAPHICS 2008

- Overview



Opacity Shadow Maps



Deep Opacity Maps

Deep Opacity Maps

EUROGRAPHICS 2008

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

Deep Opacity Maps

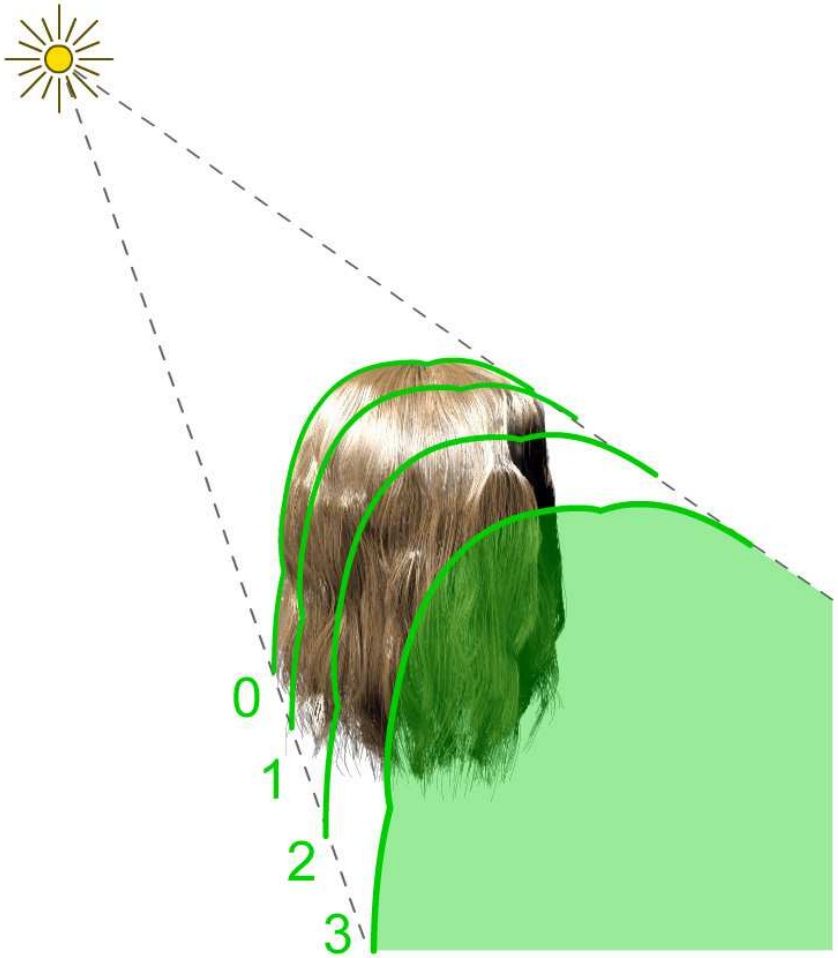
EUROGRAPHICS 2008

- **Pass 1:** Depth Map
  - z_0 per pixel

Deep Opacity Maps

EUROGRAPHICS 2008

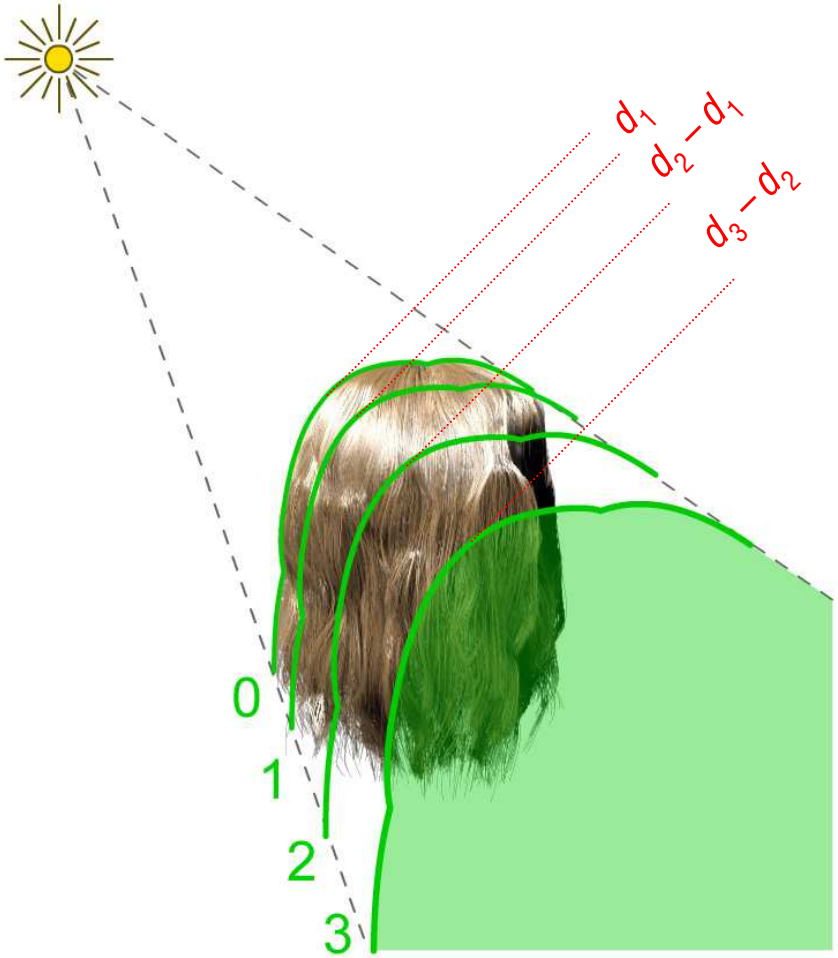
- **Pass 2:** Opacity Map
  - Layers:
  - $z_0 \rightarrow z_0 + d_1$
  - $z_0 + d_1 \rightarrow z_0 + d_2$
  - $z_0 + d_2 \rightarrow z_0 + d_3$
  - …
  - $d_1, d_2, d_3 \ldots$ are user defined



Deep Opacity Maps

EUROGRAPHICS 2008

- Layer Sizes
  - d_1
  - $d_2 - d_1$
  - $d_3 - d_2$
  - …
  - can be different!



Deep Opacity Maps

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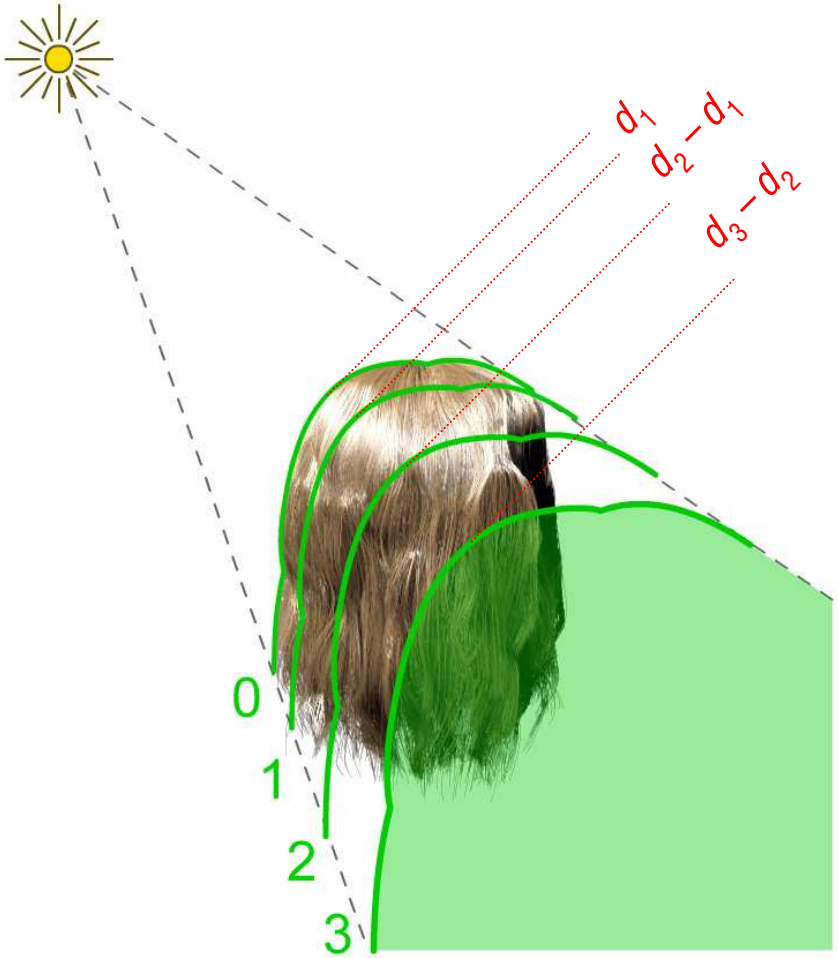
- Layer Sizes
  - $s = d_1$
  - Alternatives:
    - s, s, s, s, … (constant)
    - s, 2s, 4s, 8s, … (powers of 2)
    - s, s, 2s, 3s, 5s, .. (Fibonacci)
    - **s, 2s, 3s, 4s, … (linear)**

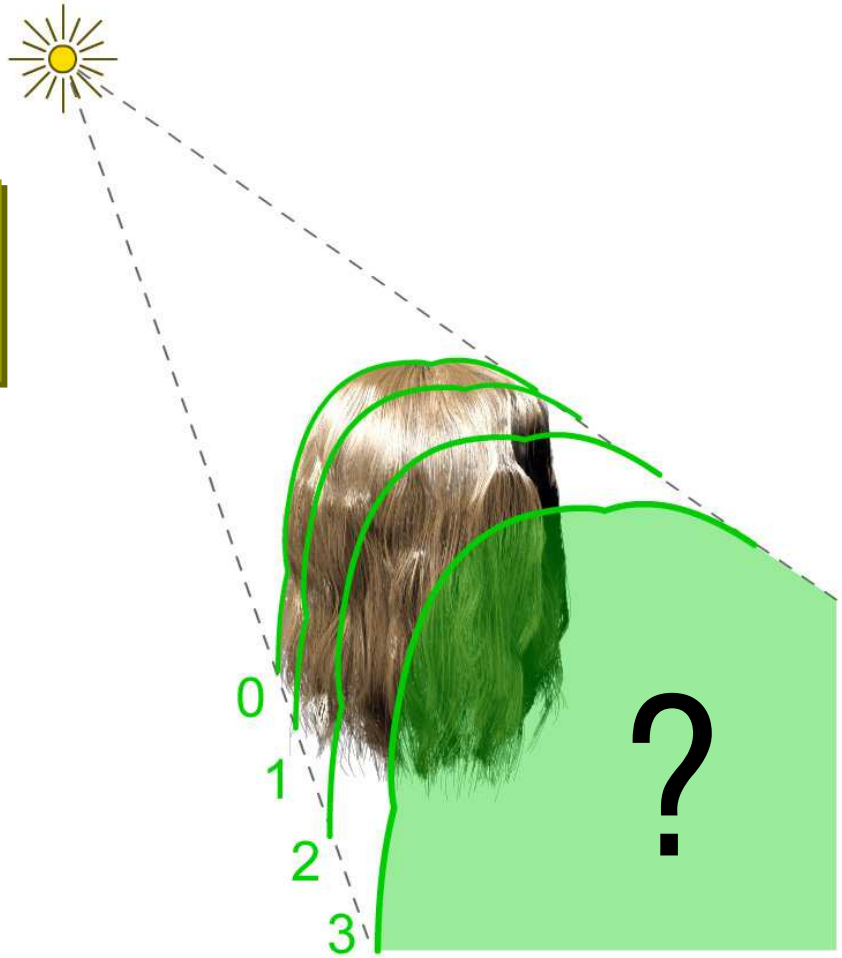


Deep Opacity Maps

EUROGRAPHICS 2008

- 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!



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Implementation

EUROGRAPHICS 2008

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

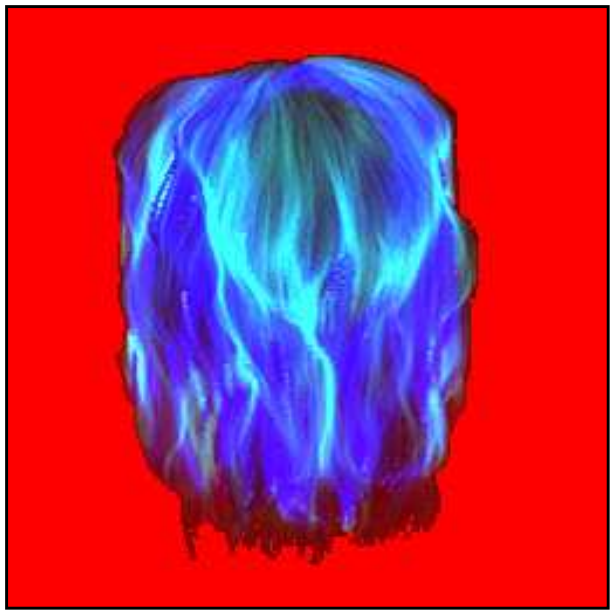
- 3 opacity layers
  - **Single Texture**

    R: depth (z_0)

    G: layer 1 opacity

    B: layer 2 opacity

    A: layer 3 opacity



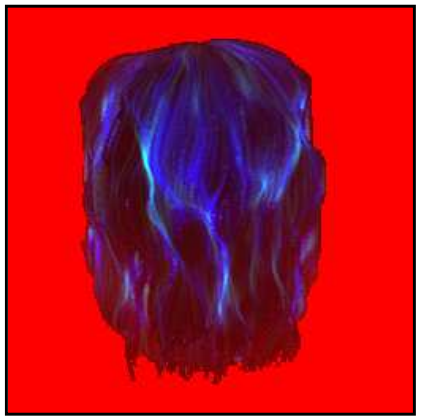
Implementation

EUROGRAPHICS 2008

- 7, 11, 15… opacity layers
  - **Multiple Draw Buffers**

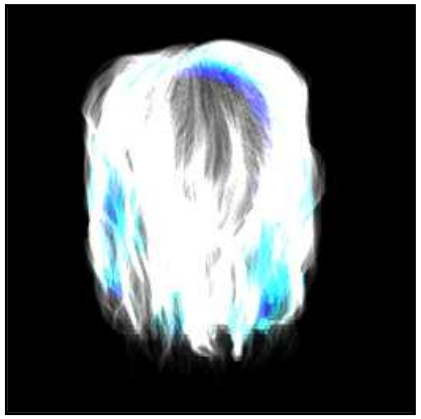
$\mathbf{R}_1$: depth (z_0)
$\mathbf{G}_1$: layer 1 opacity
$\mathbf{B}_1$: layer 2 opacity
$\mathbf{A}_1$: layer 3 opacity

Texture 1



$\mathbf{R}_2$: layer 4 opacity
$\mathbf{G}_2$: layer 5 opacity
$\mathbf{B}_2$: layer 6 opacity
$\mathbf{A}_2$: layer 7 opacity

Texture 2



…

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Results

(10K strands – 150K lines)

EUROGRAPHICS 2008

Opacity Shadow Maps 16 layers (81 fps)	Opacity Shadow Maps 128 layers (2.3 fps)	Density Clustering 4 layers (73 fps)	**Deep Opacity Maps** **3 layers** **(114 fps)**

Results

(15K strands – 1M lines)

EUROGRAPHICS 2008

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)**

Density Clustering

Deep Opacity Maps

Results

(10K strands – 1.5M lines)

EUROGRAPHICS 2008

Opacity Shadow Maps
8 layers
(65 fps)

Opacity Shadow Maps
256 layers
(0.5 fps)

Density Clustering
4 layers
(37 fps)

Deep Opacity Maps
3 layers
(50 fps)

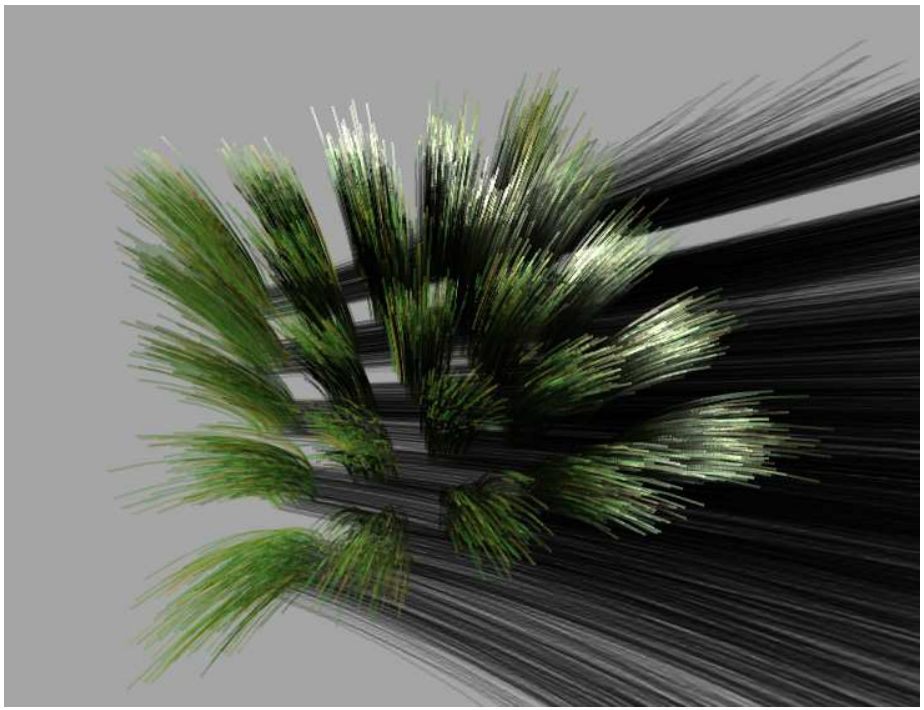
Density Clustering

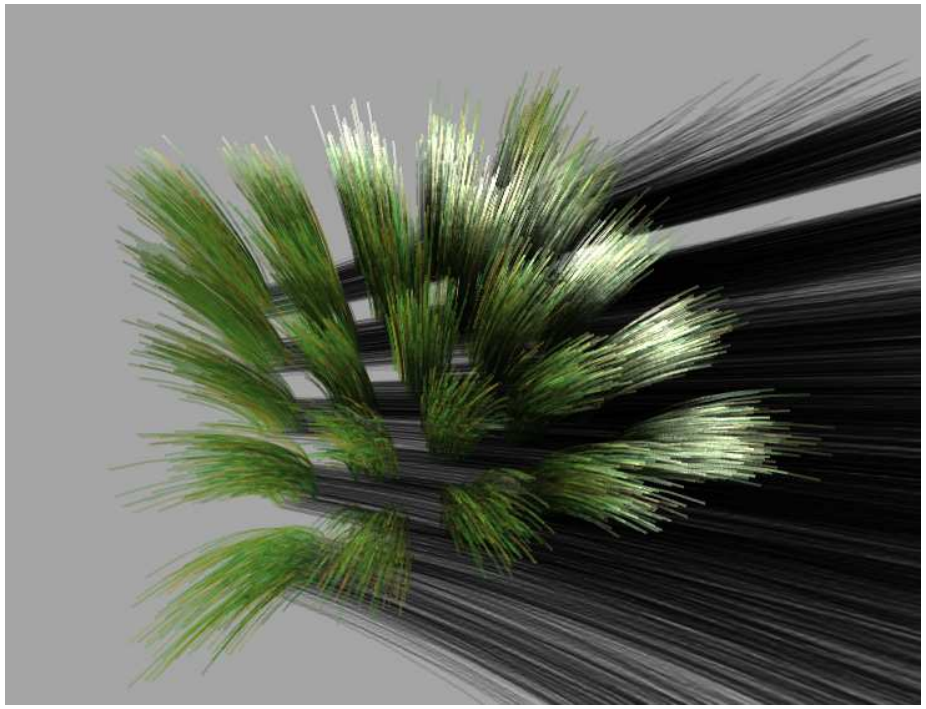
Deep Opacity Maps

Results

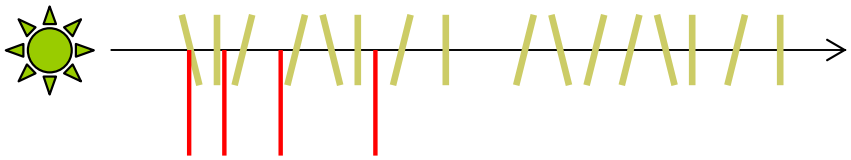
EUROGRAPHICS 2008

- Deep Opacity Maps

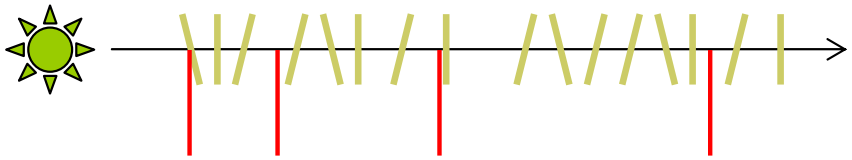




3 layers



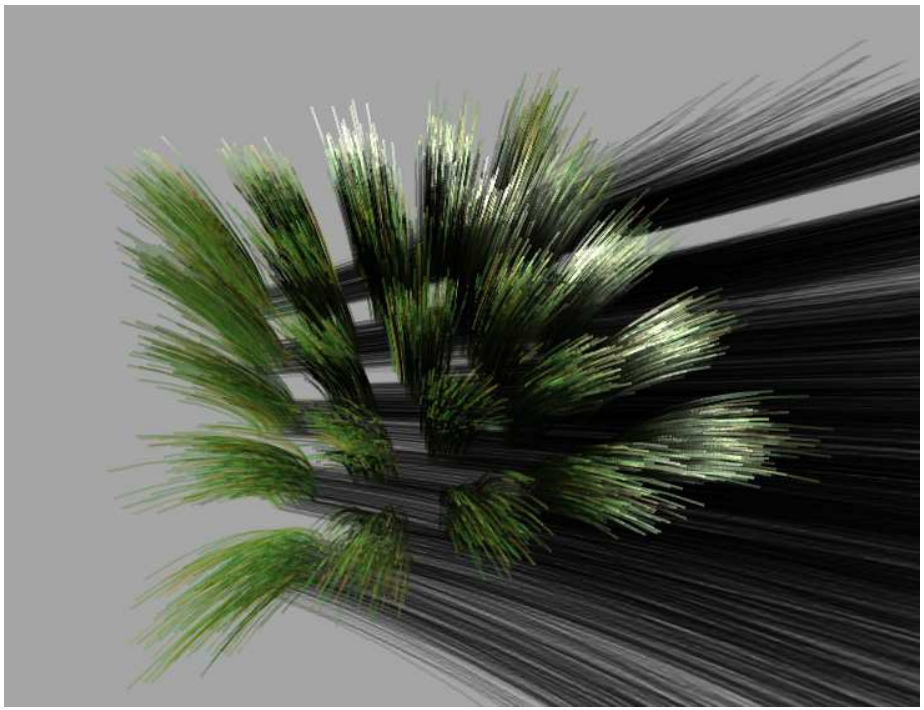
3 LARGER layers

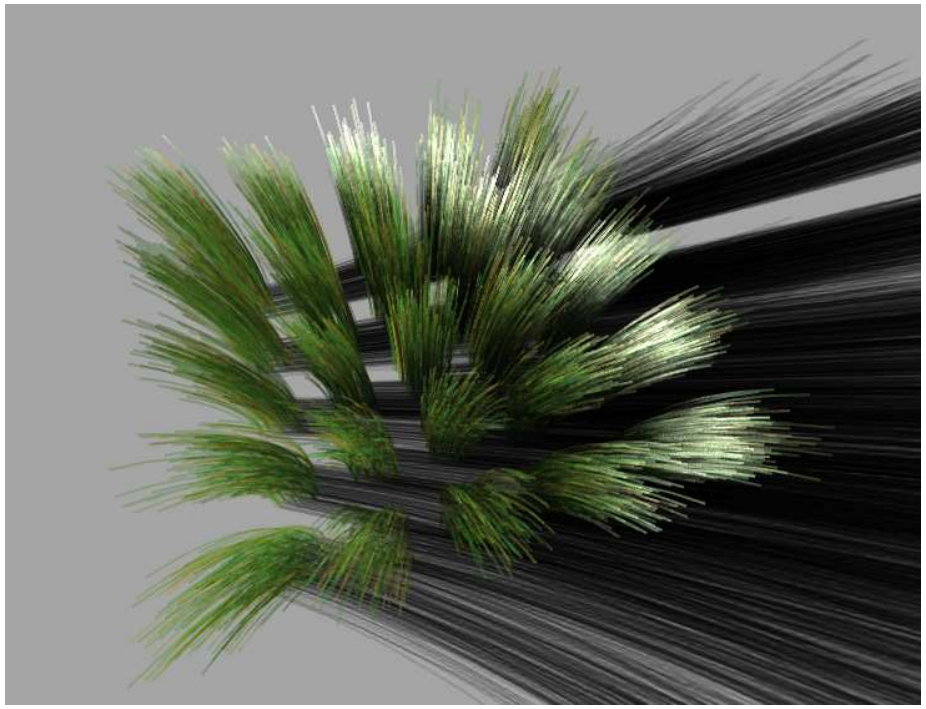


Results

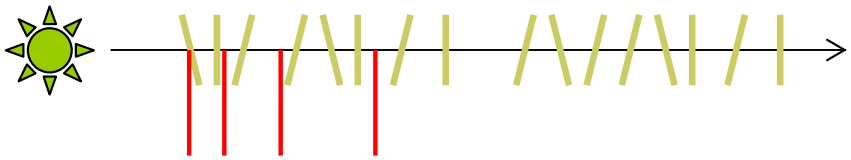
EUROGRAPHICS 2008

- Deep Opacity Maps

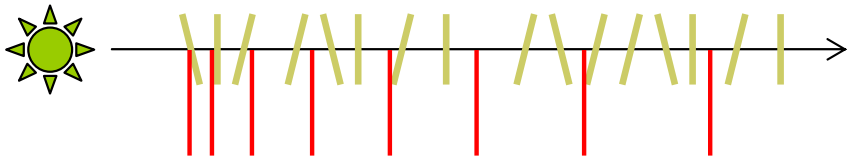




3 layers



7 layers



Results

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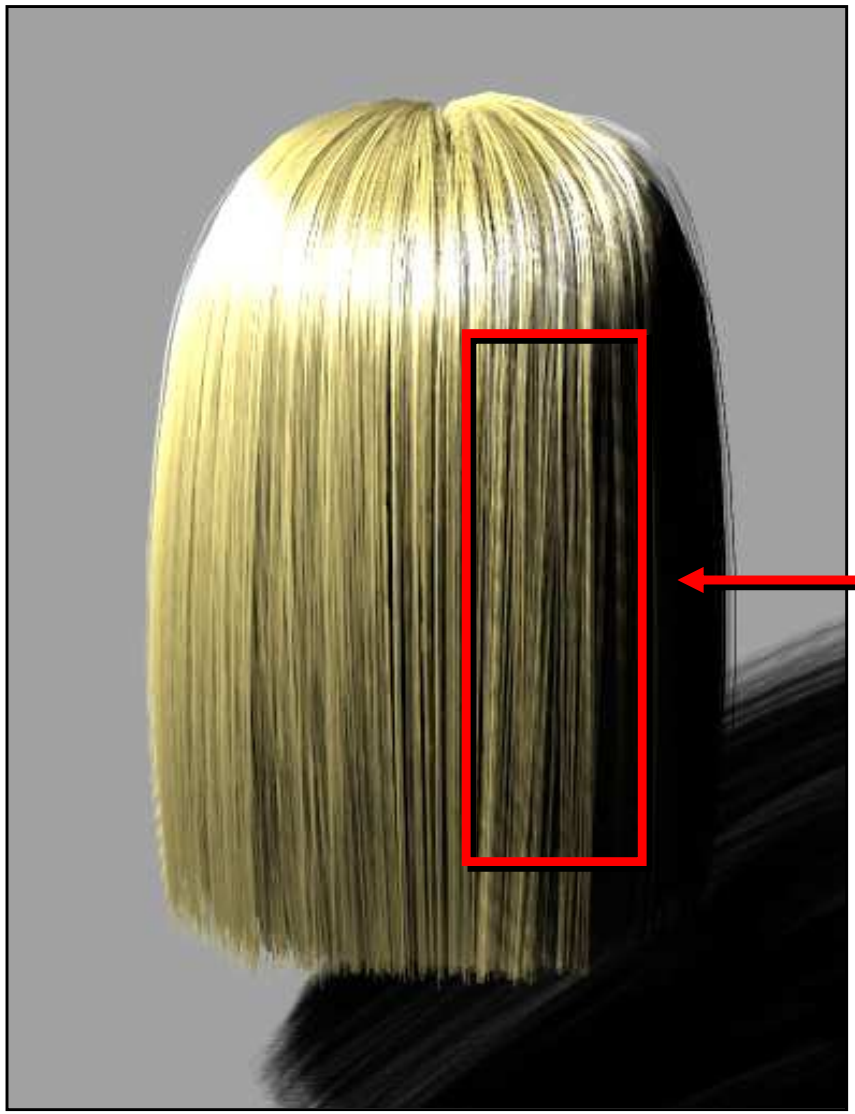
Discussion

- 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

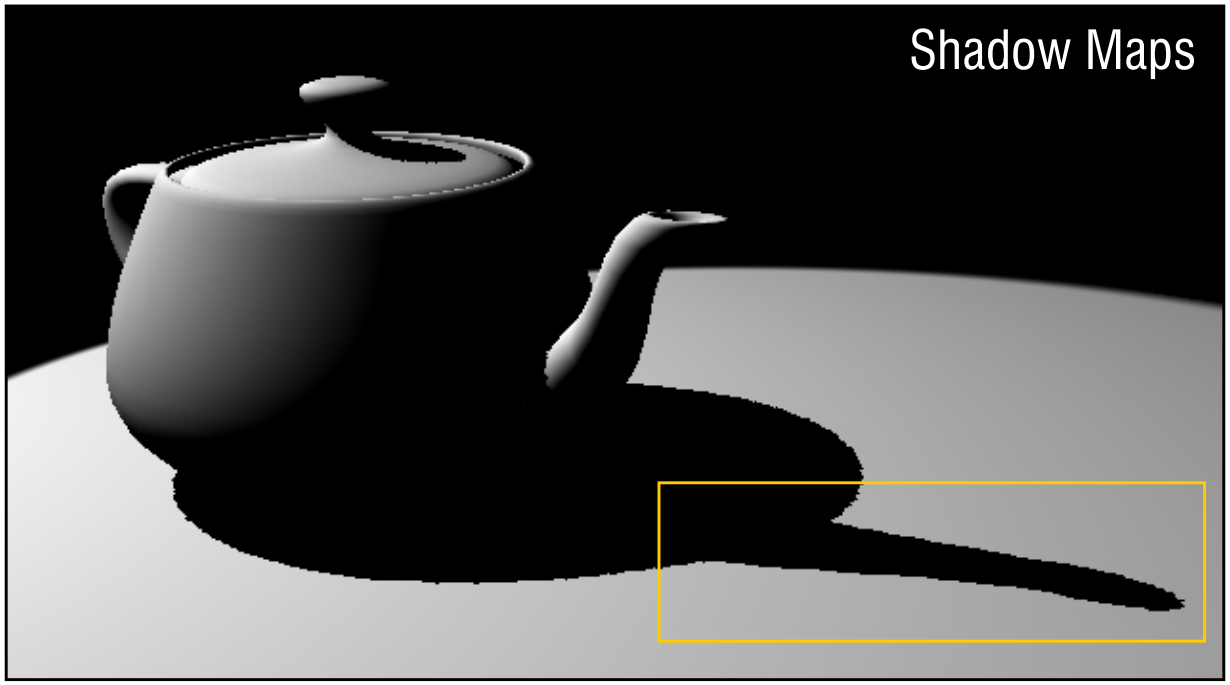
- Flickering?



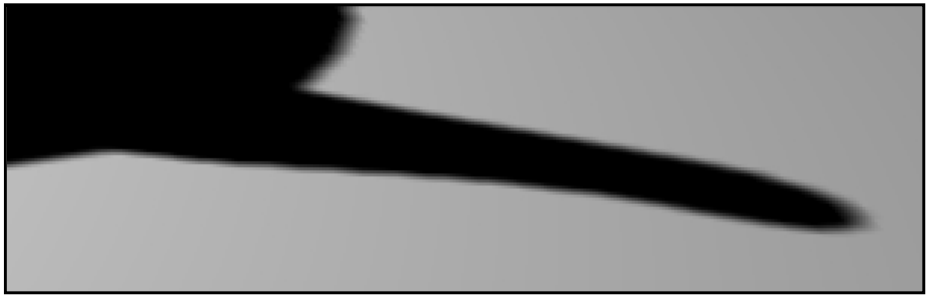
Discussion

EUROGRAPHICS 2008

- Flickering?
  - Same as shadow maps



single look-up



multiple look-up

Discussion

single look-up

multiple look-up

Conclusion

EUROGRAPHICS 2008

- Deep Opacity Maps method
  - is simple,
  - is faster,
  - uses less memory,
  - looks better!
- Use it!
- Questions?