Overview

- Hack
- Multiple depth layers
- 2.5D screen-space acceleration structure
- Multiple bounces in real-time
- Did I mention it’s a hack?
Overview

Render passes:

- Collection
- Hierarchy construction
- Traversal
Collection pass

- Collect multiple layers of geometry in a single pass
- We used Per-Pixel Linked-Lists (PPLL)
- Works just as well with depth-peeling based approaches
- Details omitted here, see paper for technical details
Hierarchy construction

Level 0:

- Merge intervals closer than parameter $\tau$ from $2 \times 2$ pixels
- Consecutively relax per hierarchy level: $\tau \times 2^{\text{level}}$
- $\tau$ is multiple of (world space) pixel width
Hierarchy construction

Level 1:

- Merge intervals closer than parameter $\tau$ from $2 \times 2$ pixels
- Consecutively relax per hierarchy level: $\tau \times 2^{\text{level}}$
- $\tau$ is multiple of (world space) pixel width
Hierarchy construction

Level 2:

- Merge intervals closer than parameter $\tau$ from $2 \times 2$ pixels
- Consecutively relax per hierarchy level: $\tau \times 2^{level}$
- $\tau$ is multiple of (world space) pixel width
Traversals: Multi-Layer SSR (MLSSR)

Level 0:

- Bresenham-style traversal, possibly striding
- Intersect ray with pixel depth intervals
- Applicable to one resolution
Traversal: Multi-resolution DDA

Level 1:

- DDA-style traversal, march ray on pixel grid
- Intersect ray with pixel depth intervals
- Applicable to multiple resolutions
Traversals: Multi-resolution DDA

Level 2:

- DDA-style traversal, march ray on pixel grid
- Intersect ray with pixel depth intervals
- Applicable to multiple resolutions

Hierarchical Multi-Layer Screen-Space Ray Tracing
Traversals: Multi-resolution DDA

Level 2:

- DDA-style traversal, march ray on pixel grid
- Intersect ray with pixel depth intervals
- Applicable to multiple resolutions

Hierarchical Multi-Layer Screen-Space Ray Tracing
Traversal: Multi-resolution DDA

Level 1:

- DDA-style traversal, march ray on pixel grid
- Intersect ray with pixel depth intervals
- Applicable to multiple resolutions
Traversing: Multi-resolution DDA

Level 0:
- DDA-style traversal, march ray on pixel grid
- Intersect ray with pixel depth intervals
- Applicable to multiple resolutions
Performance

- Everything bandwidth bound
- We used minimal material properties for the base level, modern physically based rendering might require more
- Will be focusing on hierarchy construction and traversal
Tau

- We found it to be very robust in [15, 35]
- Note the logarithmic x-axis
Traversal performance

Sponza, 1080p, GTX 1070, half-res trace:

San Miguel, 1080p, GTX 1070, half-res trace:
Quality

Geometry misses by virtue of traversal:

(Ours, MLSSR stride 1)  (MLSSR stride 4)
Quality

Quality increase from multiple depth layers:

(Single depth layer)  (Multiple depth layers)
Memory

Memory requirements for Sponza, 4 Layers, 5 Levels in MB:

<table>
<thead>
<tr>
<th>Resolution</th>
<th>PPLL</th>
<th>Deep G-Buffer</th>
<th>Hierarchy (worst-case)</th>
</tr>
</thead>
<tbody>
<tr>
<td>720p</td>
<td>96</td>
<td>42</td>
<td>40 (147)</td>
</tr>
<tr>
<td>1080p</td>
<td>217</td>
<td>95</td>
<td>89 (332)</td>
</tr>
</tbody>
</table>
## Memory

Memory requirements for Sponza, 4 Layers, 5 Levels in MB:

<table>
<thead>
<tr>
<th>Resolution</th>
<th>PPLL</th>
<th>Deep G-Buffer</th>
<th>Hierarchy (worst-case)</th>
</tr>
</thead>
<tbody>
<tr>
<td>720p</td>
<td>96</td>
<td>42</td>
<td>40 (147)</td>
</tr>
<tr>
<td>1080p</td>
<td>217</td>
<td>95</td>
<td>89 (332)</td>
</tr>
</tbody>
</table>

Population of hierarchy levels for $\tau = 25$ from 1 (blue) to 8 (red):

⇒ memory requirements lower than worst-case
Application: Ambient Occlusion

AO from 16 samples, Ours: 18.4ms, MLSSR: 12.1ms
Application: Shadow rays

Shadows from 3 point lights, Ours: 10.1ms, MLSSR: 24.4ms
Application: Reflections

1080p / 60fps / GTX 1070
Conclusion

Pros:
- Accelerated ray marching without trading image quality
- Faster than MLSSR for long rays
- Multiple bounces in real-time

Cons:
- Slower than MLSSR for short rays
- High memory footprint
Thanks!

1080p / 60fps / GTX 1070
Hierarchical Multi-Layer Screen-Space Ray Tracing

:wp
Hierarchical Multi-Layer Screen-Space Ray Tracing
Traversal performance
Sponza, 1080p, GTX 1070, full-res trace:

Hierarchical Multi-Layer Screen-Space Ray Tracing
Terminating long rays

Kill 0 rays: 6.0ms
Kill up to 1 ray: 5.4ms
Kill up to 4 rays: 4.7ms

(Difference x8)
Traversal: Bresenham

⇒ slight misses problematic when traversing the hierarchy
Traversal: Multi-resolution DDA
Collection performance

Sponza, 1080p, GTX 1070, collect

Our renderer is not quite up to date though..

Hierarchical Multi-Layer Screen-Space Ray Tracing