Adaptive Ray-bundle Tracing with Memory Usage Prediction: Efficient Global Illumination in Large Scenes

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LIGHT MAPS FOR LARGE SCENES

45.3 M texel light maps
Scene with 4.9 km in diameter (3.7 M triangles)
Computation time: 1396 secs (2000 sample directions)
(GPU: NVIDIA GeForce GTX 580 1.5GB memory)
INTRODUCTION

1. Introduction
2. Adaptive Tiling for Ray-bundles
3. Experimental Results & Future Work
RAY-BUNDLE TRACING

- Set of parallel rays for a sample direction [Sbert96]
- Implemented with GPU rasterization [Szirmay-Kalos98, Hachisuka05]
  - Benefits: HW acceleration, tessellation etc.
- Multi-fragment problem is identical to OIT
  - Per-pixel linked-list [Yang10]
Limited Memory Capacity of GPUs

Ray-bundle tracing is weak in large scenes

- Uniformly distributed rays
- Inhomogeneous light map density
- High-resolution ray-bundle buffer is required

- Memory usage is unknown before rendering
- Excessive memory has to be allocated
**Uniform Tiling** [Thibieroz11]

- Proposed for real-time linked-list OIT
  - Split a render target into smaller tiled regions
  - Each tile is rendered separately
- Unsuitable for off-line rendering
  - Overflow is still unpredictable
  - Scene-dependent parameter tuning

![1 render target](image1)

![8x8 render targets](image2)
Our Contributions

- Memory usage prediction for linked-list ray-bundles
- Adaptive tile subdivision using the above prediction
  - Reduce the risk of memory overflow & light leaking error
  - Avoid over-splitting
  - Less parameter tuning

Uniform tiling  Our adaptive tiling
ADAPTIVE TILING FOR RAY-BUNDLES

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ADAPTIVE TILING

- Based on adaptive shadow mapping [Fernando01]
  - Quadtree-based tile subdivision
  - According to a low-resolution scene analysis
- Analysis for memory usage prediction is also added
  - The overflow risk is reduced dramatically
    - It is not completely eliminated, however
**Importance & Fragment Count Analysis**

- Render two mipmaps from the ray-bundle direction.
- Pixels as quadtree nodes (resolution: $2^n$).

![Diagram showing the process of rendering importance and fragment count mipmaps](image-url)
Recursive Tile Subdivision

- Start from the top mip level (root of the quadtree)
- A tile is subdivided when overflow is predicted

Subdivision condition
for each tile

Required ray-bundle pixel count
computed with importance mipmap

Estimated upper bound
computed with fragment count mipmap
EXPERIMENTAL RESULTS & CONCLUSIONS

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NO TILING

2000 sample directions
Ray-bundle resolution: $1024^2$
Node buffer size: 5M nodes
Analysis resolution: $1024^2$

100 secs
MSE: 2.0435e-2
overflow ratio: 0%

Ground truth

GPU: NVIDIA GeForce GTX 580 with 1.5GB memory
35x35 Uniform Tiling

1381 secs
MSE: 3.3344e-3
overflow ratio: 6.96%

2000 sample directions
Ray-bundle resolution: 1024²
Node buffer size: 5M nodes
Analysis resolution: 1024²

GPU: NVIDIA GeForce GTX 580 with 1.5GB memory
OUR Adaptive TILING
(172.7 tiles / direction)

2000 sample directions
Ray-bundle resolution: $1024^2$
Node buffer size: 5M nodes
Analysis resolution: $1024^2$

1396 secs
MSE: $2.5349e^{-4}$
overflow ratio: $1.27e^{-2}$%

GPU: NVIDIA GeForce GTX 580 with 1.5GB memory
### Computation Times per Sample Direction

2% overhead

<table>
<thead>
<tr>
<th>Analysis Rendering</th>
<th>7.9</th>
<th>13.3</th>
<th>2.4</th>
<th>7.5</th>
<th>12.5</th>
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<tbody>
<tr>
<td>Mipmapping</td>
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<td>0.3</td>
<td>0.2</td>
<td>0.3</td>
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<tr>
<td>Tile Subdivision</td>
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<tr>
<td>GPU-CPU Data Copy</td>
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<td>0.8</td>
<td>0.6</td>
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<td>0.7</td>
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<td>Ray-bundle Creation</td>
<td>291.6</td>
<td>405.7</td>
<td>69.9</td>
<td>269.8</td>
<td>418.9</td>
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<td>Light Map Update</td>
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<td>274.7</td>
<td>63.8</td>
<td>217.4</td>
<td>286.9</td>
</tr>
</tbody>
</table>

(ms)

GPU: NVIDIA GeForce GTX 580 with 1.5GB memory
CONCLUSIONS

○ Adaptive tiling for linked-list ray-bundles
  • A tiles is subdivided when overflow is predicted
  • The risk of memory overflow is reduced dramatically
  • Less parameter tuning

○ Memory usage prediction
  • Using the fragment count mipmap

○ Demonstrated baking light maps of large scenes
  • With a limited memory capacity
FUTURE WORK

- Improving the analysis accuracy
  - Supersampling
  - Conservative rasterization [Hasselgren05]

- Ray-bundle warping
  - Rectilinear texture warping [Rosen12]

- Real-time linked-list OIT
  - For an arbitrary node buffer size
THANK YOU