An Efficient Hybrid Shadow Rendering Algorithm

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Not Another Talk on Shadows?!

Main ideas:
- combination of shadow maps + shadow volumes
- computation masks
Classic Shadow Algorithms

Shadow maps (Williams 1978)
- fast and simple
- undersampling artifacts
- lots of recent research!

Shadow volumes (Crow 1977)
- object-space
- accurate
- accelerated by stencil buffer
- high fillrate consumption!
Fillrate Problem

Lots and lots of fillrate!
- rasterization
- stencil updates

Why?
- polygons have large screen area
- polygons overlap
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But is this really a problem?
But Is This *Really* A Problem?

Case study: Doom 3 engine (id Software)
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- bump mapping
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- bump mapping
- per-pixel surface shading
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“Shadowing accounts for about half of the game’s rendering time.”

— John Carmack
Two Observations
Two Observations (shadow maps)

Shadow-map aliasing is ugly
But — only noticeable at shadow silhouettes
Two Observations (shadow volumes)

Shadow volumes are accurate everywhere
But — accuracy is only needed at silhouettes

few silhouette pixels
Hybrid Approach

Decompose the problem:
- use shadow volumes at silhouettes
- use shadow maps everywhere else
Algorithm

1. [Image 1]

2. [Image 2]

3. [Image 3]

4. [Image 4]
Algorithm

1. create a shadow map
2. create a shadow map
3. create a shadow map
4. create a shadow map

create a shadow map
Algorithm

1. Find silhouette pixels

2. Find silhouette pixels

3. 

4. 

find silhouette pixels
Algorithm

1. apply shadow volumes

2. only at silhouette pixels
Algorithm

1.  
2.  
3. apply shadow maps everywhere else
4.  

apply shadow maps everywhere else
Algorithm Details

Questions:

- how to find silhouette pixels?
- how to rasterize only silhouette pixels?
Find Silhouette Pixels

Silhouette pixels

Look for depth discontinuities

Use nearest 2x2 depth samples of the shadow map
Find Silhouette Pixels (example)

shadow map query point

Check results:
- 2 in shadow
- 2 visible

Disagreement!
- silhouette pixel
Restricted Rasterization

Use a mask to limit rasterization:
- tag silhouette pixels in framebuffer
- mask off all other pixels
We need a **computation mask**

- user-specified mask
- hardware early pixel rejection
- reduces rasterization, shading, memory bandwidth

**Diagram:**

- Rasterizer
- Shading
- Pixel tests
- Normal pixel rejection
- Framebuffer

**Notes:**

- Early pixel rejection (e.g. per tile of 4x4 pixels)
Hardware Support

Current hardware doesn’t have computation mask

- but — hardware already has early z culling!
- minimal changes needed for native mask support
- our implementation uses a **simulated** mask
Results

- 2.6 GHz Pentium 4
- NVIDIA GeForce 6 (**NV40**) + crazy blue power supply
Hybrid Algorithm Example

standard shadow map

Aliased shadow of a ball
Hybrid Algorithm Example

Blue and red regions handled by shadow maps

visualization
Hybrid Algorithm Example

Blue and red regions handled by shadow maps

Black and green regions handled by shadow volumes
Hybrid Algorithm Example

standard shadow map  hybrid algorithm
Test Scenes
Shadow maps
Silhouettes
Shadow volumes
Time: 48 ms

Hybrid
Time: 19 ms
Artifacts

Low-resolution shadow map → discretization errors
Misclassified silhouette pixels → missing features
Difficult cases: fine geometry
Example of Missing Features

<table>
<thead>
<tr>
<th>result</th>
<th>visualization</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="256x256" /></td>
<td><img src="image2.png" alt="256x256" /></td>
</tr>
<tr>
<td><img src="image3.png" alt="1024x1024" /></td>
<td><img src="image4.png" alt="1024x1024" /></td>
</tr>
</tbody>
</table>
Algorithm designed to help *fillrate-bound* applications:

- requires an extra rendering pass
- 30% to 100% speedup in our test scenes
- performance depends a lot on culling hardware

More details in the paper and web page ...

- tradeoff analysis
- comparison to related work
- implementation details
- more performance and image comparisons
Summary

Hybrid shadow algorithm

Screen-space decomposition:
- most pixels use fast (but inexact) algorithm
- a few pixels use accurate (but expensive) algorithm
Computation Masks

Why?

- pixels are not created equal
- programmer marks “interesting” pixels
- fast reject all other pixels
- not just for shadows!
- useful in general for multipass algorithms
- hardware is (mostly) already there
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