A Practical and Efficient Approach for Correct Z-Pass Stencil Shadow Volumes

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Shadow Volumes

- Detect Silhouette Edges
- Extend to the infinity
  - Generating quads
- Volume in between the quads
Shadow Volumes
Hard Shadow Rendering

• Ray Tracing
  • [Appel 1968]

• Irregular Z-Buffer
  • [Johnson et al. 2005]

• Shadow Volumes
  • [Crow 1977]

Real time support is not widespread on current commodity hardware

Inconsistent performance
Shadow Volumes [Crow 1977]
Shadow Volumes [Crow 1977]
Z-Pass [Heidmann 1991]

1. Render Pass (Fill Depth Buffer)

2. Render Pass (Stencil)
   - Detect silhouette edges
   - Generate shadow volumes
   - Update stencil values with enabled depth test
Z-Pass [Heidmann 1991]

1. Render Pass (Fill Depth Buffer)

2. Render Pass (Stencil)
   - Detect silhouette edges
   - Generate shadow volumes
   - Update stencil values with enabled depth test

3. Render Pass (Shading)
   - Pixels with stencil value 0 are lit
Z-Pass Limitation

- Remark
  - What if the light source is in shadow?
Z-Pass Limitation

- Remark
  - What if the light source is in shadow?
- Fail case for Z-Pass
Z-Pass
Stencil Shadow Volumes

1. Render Pass (Fill Depth Buffer)

2. Render Pass (Stencil)
   • Detect silhouette edges
   • Generate shadow volumes
   • Update stencil values

3. Render Pass (Shading)
   • Pixels with stencil value 0 are lit
Z-Fail [Carmack 2000, Everitt & Kligard 2002]

- Cut shadow volumes against scene Bbox
- Create Caps
- We can count intersections to any point outside the Bbox
Z-Fail

- Depth Clamping
Z-Fail

- Can we count from any point?
Z-Fail

- Pick a point behind the far plane

- Count the shadow quads between visible point and the picked point.

- In practice: enabling inverse depth test
Z-Fail

1. Render Pass (Fill Depth Buffer)

2. Render Pass (Stencil) with depth clamp
   - Detect silhouette edges
   - Generate shadow volume
     - Render Front & Back Cap
   - Update stencil values
     - Enabled inverse depth test

3. Render Pass (Shading)
   - Pixels with stencil value 0 are lit
Z-Fail Limitations

1. Render Pass (Fill Depth Buffer)

2. Render Pass (Stencil) with depth clamp
   - Detect silhouette edges
   - Generate shadow volume
     - Render Front & Back Cap
   - Update stencil values
     - Enabled inverse depth test
     Excessive overdraw

3. Render Pass (Shading)
   - Pixels with stencil value 0 are lit
ZP+ [Horus et al. 2005]

1. Z-Pass shadow calculation
2. Render Pass (from light source)
   • Light source to near plane
   • Update all the stencil values
ZP+ [Hornus et al. 2005]

1. Render Pass (Fill Depth Buffer)

2. Render Pass (Stencil)
   a. From light source to near plane
      • Update stencil values
   b. From camera to scene
      • Detect silhouette edges
      • Generate shadow volumes
      • Update stencil values with enabled depth test

3. Render Pass (Shading)
   • Shade the pixels with 0 stencil
ZP+ Limitations

1. Render Pass (Fill Depth Buffer)

2. Render Pass (Stencil)
   a. From light source to near plane
      • Update stencil values
   b. From camera to scene
      • Detect silhouette edges
      • Generate shadow volumes
      • Update stencil values with enabled depth test

3. Render Pass (Shading)
   • Shade the pixels with 0 stencil

Implementation Complexity

Full screen size draw
++ZP [Eisemann et al. 2011]

1. Standard Z-Pass
2. Render Pass
   • Light source to camera
   • 1 pixel sized target
3. Depth Clamp
1. Render Pass (Depth)
2. Render Pass (Stencil)
   a. From light source to camera
      • 1 pixel render target
   b. From camera to scene (Z-Pass w/ depth clamping)
      • Detect silhouette edges
      • Generate shadow volumes
      • Update stencil values with enabled depth test
3. Render Pass (Shading)
   • Shade the pixels with 0 stencil
++ZP Limitations

1. Render Pass (Depth)

2. Render Pass (Stencil)
   a. From light source to camera
      • 1 pixel render target
   b. From camera to scene
      (Z-Pass w/ depth clamping)

3. Render Pass (Shading)
   • Shade the pixels with 0 stencil

Our approach combines these two passes

Draw call for the whole scene
Our Method
Atomic ZP

1. Render Pass (Depth)

2. Render Pass (Stencil) with depth clamp
   - Test triangle intersection with ray from light to camera and whether front facing
     - Increment the atomic counter
   - Detect silhouette edges
   - Generate shadow volumes
   - Update stencil values with enabled depth test

3. Render Pass (Shading)
   - If stencil value plus the atomic counter equals 0 the point is lit
Results

1. Render Pass (Fill Depth Buffer)

2. Render Pass (Stencil)
   a. From Light to * (ZP+ & ++ZP)
   b. From camera to scene
      • Detect silhouette edges
      • Render shadow quads
      • Update stencil values

3. Render Pass (Shading)
Results

- Z-Pass
- Z-Fail
- ZP+
- ++ZP
- Atomic ZP
Results

Citadel

Buddha
Conclusion

▪ Easy to implement, artifact free

▪ Avoids additional Render Pass (ZP+ & ++ZP)

▪ Avoids Rendering Hidden Geometry and Caps (Z-Fail)

▪ Performs on par with Z-Pass
  • 1 ray cast per light facing triangle overhead
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Questions?

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