Advanced Geometrically Correct Shadows for Modern Game Engines

Jon Story, 16 March 2016

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Agenda

- Problems with Shadows?
- Frustum Tracing
- Irregular Z-Buffer
- Dynamic Reprojection
- Conservative Rasterization
- Anti-Aliasing
- Hybrid Frustum Traced Shadows
- Comparison Screenshots
- Performance
- GFSDK Shadow Lib v3.0



Problems with Shadows?







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Aliasing due to insufficient shadow map texels 32

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0.4 km : Establish Base of Operations

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DZ Player bracket: 1 - 14

0.6 km : Establish Base of Operations

Detachment due to z-bias factor

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Filter interferance from overlapping blockers





Demo: Tom Clancy's The Division







Frustum Tracing







What's the difference between ray tracing and frustum tracing?







Ray Tracing



• Store primitives in some structure

• Perform ray triangle intersection test for all appropriate triangles







Frustum Tracing

• Construct 4 planes for each light space primitive

• Perform point-in-frustum test for the list of screen pixels mapped to a given light space texel

* [Chris Wyman - i3D 2015]







Irregular Z-Buffer







Irregular Z-Buffer

•Mapping light space to screen space...









Constructing the Irregular Z-Buffer

Screen Space List Nodes



Fixed memory footprint!

* [Chris Wyman - i3D 2015]

G©C



Visualizing the Irregular Z-Buffer

List length that each screen pixel is a member of





* [Chris Wyman - i3D 2015]



gameworks.nvidia.com



Pipeline Stage: Irregular Z-Buffer









Pipeline Stage: Frustum Tracing



Dynamic Reprojection







Very long lists?

•A major problem with the irregular z-buffer approach

- Causes very low occupancy
- •A single light texel can map to a very large area of the screen
- •SDSM can certainly be used to help alleviate this, but:
 - Requires a CPU read back
 - Frustum / occlusion culling needs to be done at render time
 - Stability issues
- •A more targeted approach would be to directly detect long lists
 - Dynamically reproject those problem areas





Pipeline Stage: Heat Map







Pipeline Stage: Dynamic Reprojection







Pipeline Stage: Irregular Z-Buffer







Pipeline Stage: Frustum Tracing





Full screen pass counts number of screen pixels mapped to a given light space texel

Visualized here as a near map. long ists area in light space





Benefits of Dynamic Reprojection

- Improves existing light space mapping for frustum tracing
 - Could be used to improve standard shadow maps?
- Reprojection is computed on the GPU
 - No CPU read back is required
 - Easy to integrate with existing cascades
- Reprojection only occurs when long lists are detected
- Drastically improves baseline performance of frustum tracing





Conservative Rasterization







Requires Conservative Rasterization

- Ensures that every pixel touched by a primitive is rasterizered
- •Enabled in DirectX 12 and in DirectX 11 at FEATURE_LEVEL_11_3
 - D3D11_RASTERIZER_DESC2
 - D3D12_RASTERIZER_DESC
- •Also through NvAPI it works on Windows 7 and above!
- Supported by Maxwell and above











Software Conservative Rasterization

•Use the GS to dilate a triangle in clip space

•Generate AABB to clip the triangle in the PS

•See GPU Gems 2 - Chapter 42









Anti-Aliasing



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Anti-Aliasing?

• Perform sub-pixel accurate frustum tests?

- Perfectly possible to achieve
- Yields really stable results
- But comes at an additional cost
- Simple trick apply a screen space AA technique
 - FXAA
 - Great results
 - Very cheap
 - Possibly free if you already use screen space AA





Anti-Aliasing









Shadow Map







Frustum Traced







Hybrid Frustum Traced Shadows (HFTS)







Hybrid Approach

• Combine frustum traced shadow with PCSS

- •Blocker distance can be used as an interpolation factor
- •As blocker distance approaches zero, frustum traced result is prevalent
- •Only first cascade has frustum tracing applied



Lerp factor

L = saturate(BD / WSS * PHS)

L: Lerp factor BD: Blocker Distance WSS: World Space Scale PHS: Percentage of Hard Shadow

HFTS = lerp(FT, PCSS, L)

HFTS: Hybrid Shadow FT: Frustum Traced Hard Shadow (0 or 1) PCSS: PCSS Soft Shadow (0 to 1)

* [Jon Story – GDC 2015]



HFTS - Standard Filter



Needs a Shifted Penumbra Filter

•Shadow map result would not be contained within the frustum traced result

• Would lead to ugly artifacts during interpolation



* [Jon Story – GDC 2015]











Pipeline Stage: HFTS







Comparison Screenshots









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0.4 km : Establish Base of Operations

Quality: HFTS¹

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DZ Player bracket: 1 - 14

0.6 km : Establish Base of Operations

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Detachment

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Too soft

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DZ Player bracket: 1 - 14

0.6 km : Establish Base of Operations

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Filter interferance 158 00

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DZ Player bracket: 1 - 14

0.6 km : Establish Base of Operations

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Quality: HFTS







DZ Player bracket: 1 - 14

0.9 km : Establish Base of Operations

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Quality: HFTS

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0.5 km : Establish Base of Operations

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Checkpoint
44 m : Signal for JTF assistance

Quality: HFTS



0.4 km : Establish Base of Operations

Aliasing

Quality: High ⁰¹

Detachment

32

Too soft



0.4 km : Establish Base of Operations

Quality: PCSS 01

Detachment

Aliasing

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Too soft

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0.4 km : Establish Base of Operations

Quality: HFTS⁰¹

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Performance



















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GFSDK Shadow Lib v3.0







GFSDK Shadow Lib v3.0

- •Lots of shadow techniques (PCF, PCSS, RT, HRTS, FT, HFTS)
- Handles spot and directional lights with cascades
- Offers SDSM or user defined cascades
- Industry leading shadow quality
- •Why not HFTS your game...?



Special Thanks

• Anders Holmquist and team at MASSIVE

References

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Questions?

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