HFTS: Hybrid Frustum-Traced Shadows in "The Division"

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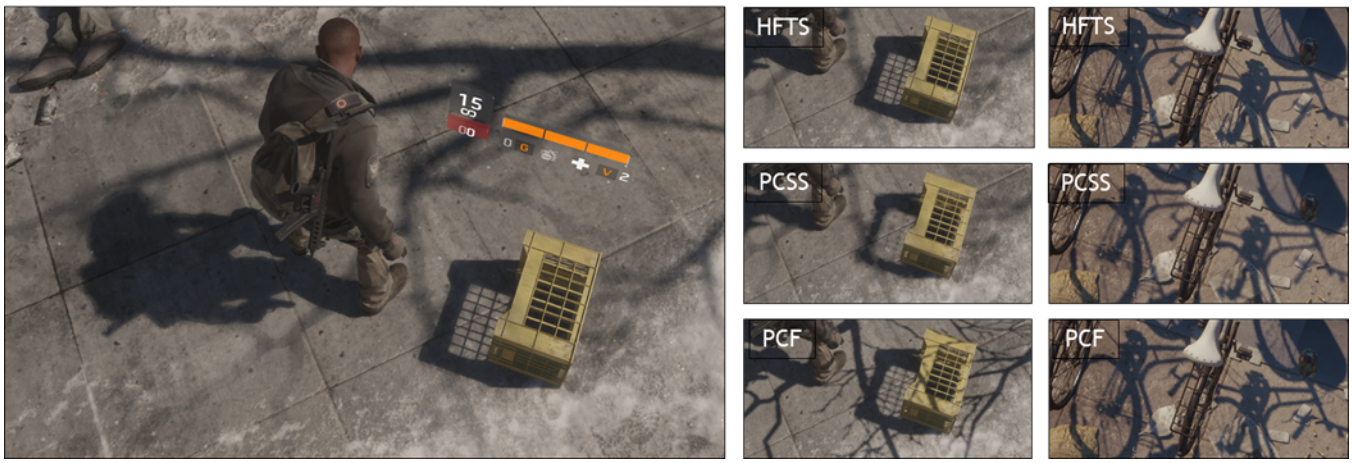

Figure 1: *Comparing hybrid frustum-traced shadows in* The Division *with production-quality percentage closer soft shadows and percentage closer filters. (Left) An in-game cityscape with insets (center) comparing the contact shadows generated by each technique. (Right) Another scene with tiny occluders; HFTS still gives good contact shadows while softening with distance to the occluder. Images courtesy of Ubisoft.*

Abstract

We present a hybrid irregular z-buffer shadow algorithm building on work by Story [2015] and Wyman et al. [2015] that allows soft shadows and is fast enough for use in shipping games, like *The Division*. Key novelties include an improved light-space partitioning scheme that speeds best- and average-case running times compared to using multiple cascades. We also extract a per-pixel distance to the nearest occluder to enable transitioning between irregular z-buffers and filtered shadow maps.

Keywords: irregular z-buffer, percentage closer soft shadows

Concepts: •**Computing methodologies** → **Visibility;**

1 Introduction

Irregular z-buffers [Johnson et al. 2005] compute accurate hard shadows at every pixel, essentially using a light-space A-buffer. Recent work by Wyman et al. [2015] showed hardware-accelerated irregular z-buffers (IZBs) scale much better when repurposing traditional shadow mapping techniques, like cascades, to do load balancing. However, using this approach to generate soft shadows (e.g., [Sintorn et al. 2008]) remains extremely inefficient, especially compared to common game techniques like percentage closer filtering (PCF) [Reeves et al. 1987] and percentage closer soft shadows (PCSS) [Fernando 2005].

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2 Hybrid Frustum-Traced Shadows

Our new hybrid frustum-traced shadows (HFTS) further improves the speed of irregular z-buffering, enabling use in production engines, and we transition to PCSS to provide soft shadows when the aliasing problems of shadow mapping are less objectionable.

Soft Shadows. Commonly used soft shadowing techniques like PCSS only approximate soft shadows, essentially by blurring a shadow map with dynamically-sized filters. We could similarly blur IZB shadows, but shadow map bias and aliasing are mostly problematic near contacts and existing techniques like PCSS work well for more distant occluders and have already been battle-tested. Our hybrid thus transitions between IZB shadows and PCSS shadows depending on distance to the occluder; near contacts we use IZB shadows, further away we use PCSS. A novel interpolation method using a shifted penumbra filter ensures PCSS results do not interfere with the frustum shadows near contact points.

Performance Improvements. Irregular z-buffers transform the aliasing of shadow mapping into irregular workloads (read: performance degradation). This can be addressed either by hardware that better handles irregular workloads or via software load balancing. It turns out that, by construction, techniques that reduce aliasing in shadow mapping can be used to perform load balancing for IZBs. Wyman et al. [2015] proposed using cascaded shadow maps, but this introduces some fixed-cost overheads, CPU-GPU communication, and partitions light-space to minimize visible aliasing. We discovered a two frustum light-space partitioning specifically designed to balance irregular provides much better performance.

3 Results

Our hybrid shadows have been integrated into NVIDIA's ShadowWorks library and shipped in Ubisoft's *Tom Clancy's The Division*. Below are some performance comparisons at 1920×1080 on a GeForce 980 GTX of a couple representative views.

Figure 2: *Three representative views from* The Division *gameplay used for performance timings. Images courtesy of Ubisoft.*

Figure 3: *Insets comparing techniques in the bike scene. Images courtesy of Ubisoft.*

Figure 4: *Insets comparing techniques in the worker and truck scenes. Note the scenes are dynamic, causing the blowing debris seen in the images. Images courtesy of Ubisoft.*

Shadow cost per frame All at 1920×1080	HFTS	PCSS	PCF
Bikes	8.1 ms	5.7 ms	2.9 ms
Sitting worker	7.9 ms	4.6 ms	2.8 ms
Truck	9.7 ms	5.5 ms	3.4 ms

References

FERNANDO, R. 2005. Percentage-closer soft shadows. In *ACM SIGGRAPH 2005 Sketches*.

JOHNSON, G. S., LEE, J., BURNS, C. A., AND MARK, W. R. 2005. The irregular z-buffer: Hardware acceleration for irregular data structures. *ACM Trans. Graph. 24*, 4 (Oct.), 1462–1482.

REEVES, W., SALESIN, D., AND COOK, R. 1987. Rendering antialiased shadows with depth maps. In *Proceedings of SIGGRAPH*, 283–291.

SINTORN, E., EISEMANN, E., AND ASSARSSON, U. 2008. Sample based visibility for soft shadows using alias-free shadow maps. *Computer Graphics Forum 27*, 4, 1285–1292.

STORY, J. 2015. Hybrid ray traced shadows. In *Game Developer Conference*.

WYMAN, C., HOETZLEIN, R., AND LEFOHN, A. 2015. Frustum-traced raster shadows: Revisiting irregular z-buffers. In *Proceedings of the Symposium on Interactive 3D Graphics and Games*, 15–23.