Interactive indirect lighting computed in the Cloud

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Figure 1: *Direct-only vs. both direct and indirect in two systems. Cloud indirect computed and encoded in (left two) lightmaps and (right two) voxels. Please see the video for dynamic lighting.*

Abstract. In this talk we present two different ways to map indirect lighting computation onto the new "pipeline" represented by the Cloud. Some of this new pipeline is familiar, but some is quite different. Given the vast space of possible hardware configurations and the many known algorithms for light transport, we explore two quite different approaches to indirect lighting and empirically examine their performance on the Cloud. As this examination is largely empirical, we use test scenes with significant geometric and texture complexity. We present detailed optimizations and measurements of bandwidth and latency performance. We further examine the amortization of indirect lighting across multiple users, a key potential benefit of Cloud-based systems.

The Cloud. The evolution of distributed computing has a long and complex history. "The Cloud" is not so much a technological change as a change in scope and expectations: a variety of clients including phones, tablets, and PCs should be supported, and a certain level of seamlessness is expected. The presence of mobile clients introduces an asymmetry in the relative computational power of the client and server.

Games. The symbiotic relationship between gamers, hardware vendors, and game developers has driven a co-evolution of better imagery on better hardware. Recent games have added indirect lighting as part of this improvement in imagery and it is an active area of development in the games industry [Martin and Einarsson 2010]. The challenge of providing users with this improved visual quality despite the limitations of low-power mobile clients suggests a distributed solution: compute indirect lighting on a server. Many modern multi-player game architectures already include a server as part of the system architecture. The technological landscape of games in the Cloud is summarized nicely in the recent article by Shi et al. [2012].

A light-map based approach. Our first system uses irradiance lightmaps [McTaggart 2004] computed dynamically and progressively on the server, and these lightmaps are sent across the network to the client. We take care to make these lightmaps compatible with the H.264 compression standard in order to use dedicated hardware on both client and server, greatly improving the speed and latency of lightmap transmission. The client computes the direct lighting interactively and composes this with whatever lightmaps it has at the time. Because the direct and indirect lighting are decoupled, the client experiences no stalls due to latency, but it instead has a "lag" between direct and indirect lighting. We will demonstrate this system with different amounts of lag, and we measure this lag on real systems "in the wild" (e.g., an internet connection across a significant geographic distance). We also examine the bandwidth requirement of our system.

A voxel-based approach. Our second system uses a voxel-based approach [Crassin et al. 2011] to compute and store the indirect lighting. This is a larger data structure than lightmaps, but does not require a UV-parameterization of the scene. Because of its larger size, this data structure is not suitable for transmission to the client. Instead the final images are computed on the Cloud and are streamed as video to the client. This has the advantages of being able to support very low-power clients, as well as being able to take advantage of multiple and diverse nodes within the server. It has the disadvantage of requiring lower latency for acceptable user experience. This system is also demonstrated under various latency conditions.

Summary. We will provide what is to our knowledge the first demonstration of interactive graphics with indirect lighting computed on the Cloud. This involves many technical details that do not come up in traditional systems, and provides an empirical demonstration of of the perceptual effect of latency between direct and indirect lighting. We hope this will inspire much discussion and interest in both the research and production communities.

References

CRASSIN, C., NEYRET, F., SAINZ, M., GREEN, S., AND EISEMANN, E. 2011. Interactive indirect illumination using voxel cone tracing. *Computer Graphics Forum 30*, 7.

MARTIN, S., AND EINARSSON, P. 2010. A real-time radiosity architecture for video games. *SIGGRAPH 2010 courses*.

MCTAGGART, G. 2004. Half-life 2/Valve Source shading. In *Direct3D Tutorial Day, Game Developers Conference*.

SHI, S., NAHRSTEDT, K., AND CAMPBELL, R. 2012. A real-time remote rendering system for interactive mobile graphics. *ACM Trans. Multimedia Comput. Commun. Appl. 8*, 3s.

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