

VisibilityChunk: Average Directional Visibility for Importance Sampling

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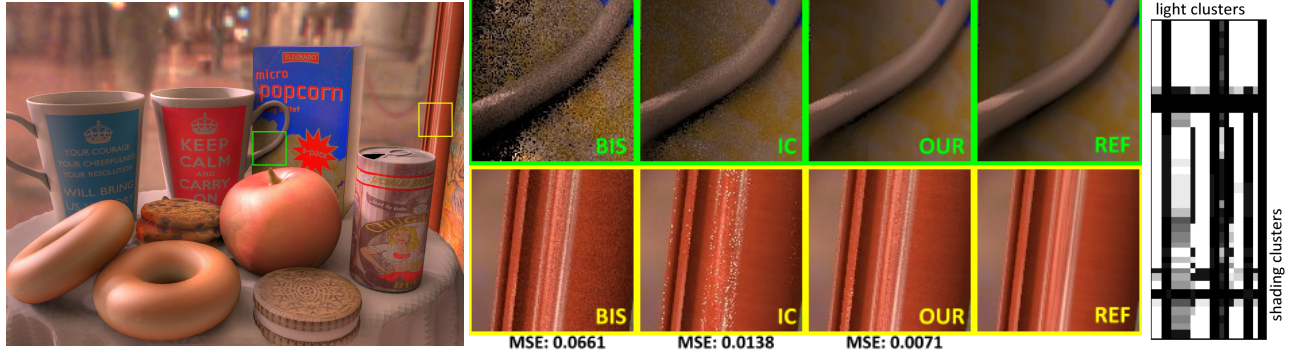


Figure 1: *LUNCH* (equal-time comparison, 200 sec.). Left: full image rendered by our approach. Middle: comparisons. From column 1 to column 4 are Bidirectional Importance Sampling (BIS) [Wang and Åkerlund 2009], Importance Caching (IC) [Georgiev et al. 2012], our approach, and reference images. Our method provides better noise reduction across the whole image, even with the presence of fine geometry. Right: The VisibilityChunk of the *LUNCH* scene (partial). The brightness indicates the average visibility between pairs of clusters.

1 Introduction

Monte Carlo ray tracing could suffer from noisy results due to large variance. Importance sampling is an effective strategy for reducing such variance. It requires to efficiently approximate the integral kernel of the rendering equation, a triple product of incident lighting, material properties and visibility. Among them, visibility is often ignored because its estimation demands expensive shadow ray casting or shadow map construction. Such neglect limits the effectiveness of importance sampling. This paper proposes an efficient method for estimating average visibility to improve the effectiveness of importance sampling.

We focus on rendering with the many-light formulation (or virtual point light method), which has received much attention in recent years. In previous importance sampling methods of this context, visibility is either completely omitted [Wang and Åkerlund 2009] or sparsely sampled [Georgiev et al. 2012] due to its expensive cost. The bidirectional importance sampling (BIS) approach proposed by Wang and Åkerlund [2009] only approximates lighting and BRDFs without taking visibility into account. It suffers from significant noise when the directions of strong lights or BRDF peaks are occluded. Georgiev et al. [2012] later proposed Importance Caching (IC) to address this problem. They computed and cached full lighting contributions, with visibility included, at sparse locations. The cached information is used as importance function for nearby shading points. Although achieving great variance reduction for flat regions, it fails to handle fine geometry (such as the frame of the oil painting in Fig 1), since fine geometry might not be sampled by the sparse caches.

2 VisibilityChunk

This paper proposes a new method, *VisibilityChunk*, to efficiently and effectively estimate average visibility. The method is based on the observation that visibility terms in the many-light transport matrix exhibit local structures if shading points and lights are properly clustered (Fig 1, right). We call a submatrix formed by a cluster of lights and a cluster of shading points a *VisibilityChunk* and estimate

its average visibility (the visibility ratio between the two clusters) by sampling lights and shading points. It has several advantages:

- It is usually sufficient to estimate the average value accurately with a small number of visibility samples.
- It makes the importance function more compact and improves performance for both construction and sampling. It also makes our algorithm more scalable to the number of lights.
- It provides a direct quality measure to visibility estimation, which can be used for further refinement of clustering.

We construct VisibilityChunks in a multi-pass manner. At the beginning, lights and shading points are clustered based on their geometric properties. This follows the observation that nearby shading points tend to behave similarly to a group of nearby lights. We then estimate the average visibility between each pair of light cluster and shading cluster with a small number of shadow rays. Based on the average visibility, light clusterings are locally refined for each shading cluster if necessary.

VisibilityChunk can be easily integrated into importance sampling. For each shading point, we locate the shading cluster it belongs to; retrieve the estimated visibility (the visibility ratio to each light cluster); and multiply it to the product of BRDF and illumination (which can be estimated by BIS). Fig. 1 demonstrates superior noise reduction of the proposed method compared to BIS and IC.

3 Conclusion and future work

We propose VisibilityChunk, a method for efficient computation and compact representation of the visibility function. It can be integrated into importance sampling for the many-light problem and provides more effective variance reduction. In the future, we would like to extend it to the temporal domain for rendering animations.

References

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- WANG, R., AND ÅKERLUND, O. 2009. Bidirectional importance sampling for unstructured direct illumination. *Computer Graphics Forum* 28, 2 (Apr.), 269–278.

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