Fast Multi-image-based Photon Tracing with Grid-based Gathering

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Abstract

We developed a real-time solution for approximate global illumination, where the temporal cost in complex scenes is dramatically reduced. Our approach initially traces photon-rays with multiple cube-maps, and then gathers the irradiance of photons using uniform grids filled with low-order spherical harmonics. Numerous global illumination effects can be rendered efficiently in our framework.

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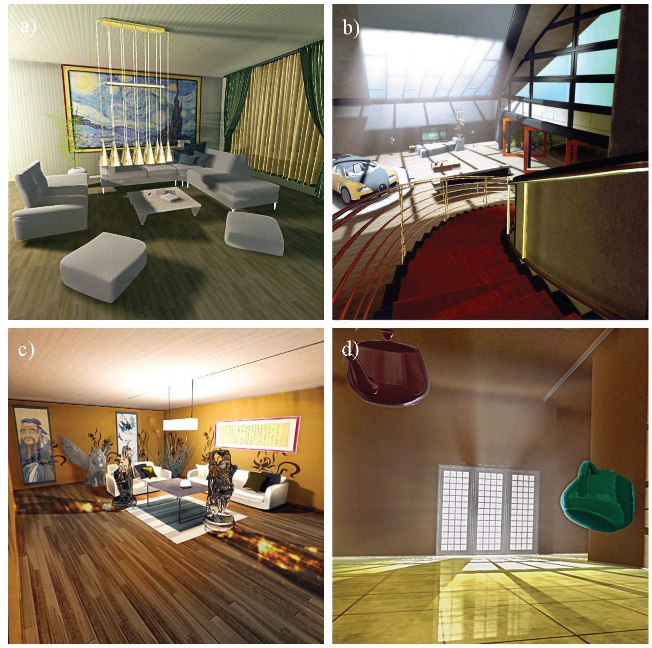

Figure 1: *Without pre-computation, our technique renders dynamic global illumination effects in a complex scene in real-time ($19 \sim 56Hz$ on a GTX480).*

1 Problem Formation

Ray-tracing and light-gathering are the two key steps in photon mapping. Recent method focusing on multi-image-based photon mapping [Yao et al. 2010] works well in simple scenes, but has serious limitations in complex ones due to: a) they intersect a photon-ray iteratively with distance imposters (cube maps), where, however, the initialization can be far from accurate, which leads the iterative refinement to be failed (Figure 1); b) they intersect a photon-ray with all the distance imposters in the scene, which is costly and unnecessary; c) the method for radiance estimation called splatting, is not efficient when there are large amount of photons, since splatting millions of photons will need the rasterization of billions of pixels.

2 Technical Approach

In the ray-tracing phase, to initialize a more accurately, we introduce a cascaded partition and ray-casting scheme. The searching space of the intersection point is uniformly divided. We then cast a ray in each subdivided space and minimize an energy across the searching space. The intersection with minimal energy will be chosen as the initialized point. This approach has been proven to be much more accurate than previous methods. We then find an exact solution from this initialization following the work proposed by Szirmay-Kalos et al. [2005]. Only two cube maps are accessed in our method by each photon-ray, which makes our performance in the ray-tracing phase an order of magnitude higher than the existing methods.

In the radiance gathering phase, the radiance of each photon is represented with a spherical harmonics (SH) vector, which is later injected and accumulated into two types of uniform grids covering the scene. One grid called the light-gathering volume, or LGV, is a 3D grid used to gather smoothed (low-frequency) light such as diffuse lighting. Since gathering higher frequency details such as caustics needs a higher resolution grid, which is more efficient to be in 2D rather than in 3D, we propose a high-resolution 2D grid to gather the more detailed light, called screen-space LGV (SSLGV). After injecting the radiance of photons into the two grids, we propagate the radiance in the grids following the light propagation framework proposed by Kaplanyan et al. [2010], which is actually equivalent to radiance gathering. Finally we use the gathered radiance in the grids to illuminate the scene.

3 Limitations for Future Works

The artifacts pervasive in existing lattice-based methods are temporal discontinuity and light bleeding. Besides, the rendering quality of some flattened "middle"-frequency caustics is still very photon-dependent where tracing billions of photons is still unavailable in real-time applications.

References

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