Point-Based Global Illumination Directional Importance Mapping

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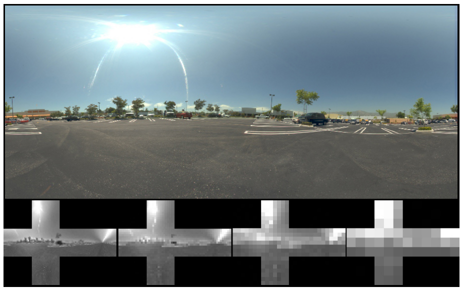

(a) Example of an environment map and its associated mip-mapped importance cube-map.

(b) Scene rendered with high dynamic range environment-map shown in (a).

(c) Indirect diffuse and glossy reflections of the point-based fire onto the street geometry.

1 Introduction

Point-based global illumination (PBGI) is a popular technique used in film production to render complex scenes. It thrives by efficiently handling soft lighting effects caused by diffuse and glossy indirect illumination. Furthermore, it elegantly incorporates direct illumination from distant image-based environment-maps. However, PBGI's efficiency degrades rapidly as the high dynamic-range (HDR) nature of the illumination increases or/and as the glossy reflections become sharper. In this talk, we introduce an improved PBGI cut picking algorithm, which uses directional importance mapping. We show that this technique drastically improves quality and render time when solving these difficult illumination effects.

2 Overview

As described in [Christensen 2008] and [Kontkanen et al. 2011], PBGI operates on a dense point representation of the scene. First, the points are diffusely shaded and organized in an octree, where each octree node describes the light reflected from the corresponding cluster of points to any direction. Each micropolygon visible in the image is then shaded by first selecting a set of octree nodes that define a suitable level of detail (LOD), which we call a cut. The radiance reflected from the nodes in the cut is then accumulated using a cube-map rasterizer centered around the micropolygon, thereby resolving occlusion. The resulting cube-map can be composited over a pre-rendered cube-map of the distant environment-map. Finally the cube-map is convolved with the bi-directional reflectance distribution function (BRDF) of the surface.

Our work focuses on handling difficult situations that arise when directional spikes of illumination are present in the scene, as in Figures (b) and (c). In this context, the PBGI cut picking algorithm is ineffective, as it achieves a level of detail that is directionally of equal quality ([Christensen 2008] section 3.3). Our approach is to improve the algorithm by using an LOD refinement quality threshold that varies directionally, according to a directional importance map. In the two following examples, we review how the directional importance map is built and used.

To handle complex **HDR distant environment maps**, we wish to pick smaller point clusters in directions that correspond to bright pixels in the environment map. This is desired to improve the quality of the corresponding shadows, which can otherwise look blocky and cause temporal aliasing. To this effect, we pre-compute a mip-mapped importance cube-map, with pixel values set proportionally to the environment map's luminance. See an example in Figure (a). The cut picking algorithm is then modified as follows. We first evaluate the direction and solid angle subtended by the cluster of a given octree node. The solid angle is first used to select the appropriate mipmap level and that importance cube-map is sampled in the cluster direction. The resulting importance is then used to modulate the solid angle threshold, used as cut picking refinement criteria for this node. Various function choices are possible to adjust this threshold. We choose to interpolate between the value set by the user and the solid angle subtended by the smallest pixel of the cube-map rasterizer.

In the case of **glossy reflections**, we wish to pick smaller point clusters in directions that correspond to narrow BRDF lobes. This is in order to improve the quality of sharper reflections, which can otherwise cause blocky artifacts. We first define the BRDF lobe bounding cone of directions as follows. We use the ideal specular reflection direction as the cone axis and use a conservative estimate of the size of the lobe to derive the bounding cone half-angle. Then, our importance function maps directions to increased importance when the cluster subtended solid angle intersects the BRDF lobe's bounding cone of directions. When this happens, we simply wish to map the importance to be inversely proportional to the BRDF bounding cone half-angle. Again, we choose to interpolate the cut picking refinement solid angle threshold according to the half-angle, between the user setting and the solid angle of the smallest pixel of the cube-map rasterizer.

3 Results

Figure (b) and (c) show two production scenes from the DreamWorks Animation movie *"Madagascar 3: Europe's Most Wanted"*, that were rendered using the directional importance mapping methods described in this talk. They illustrate how our technique improves PBGI to handle soft diffuse, glossy, and sharper interreflections and shadows. Rendering scene (b) without using directional importance mapping at a similarly acceptable quality is over $3\times$ slower. Attempting the same comparison with scene (c) was impractical, because picking a high cluster level-of-detail in all directions, produces cuts that are excessively large with this type of heavy environment.

References

CHRISTENSEN, P. H. 2008. Point-based approximate color bleeding. Tech. Rep. 08-01, Pixar.

KONTKANEN, J., TABELLION, E., AND OVERBECK, R. S. 2011. Coherent out-of-core point-based global illumination. *Computer Graphics Forum (EGSR '11) 30*, 4, 1353–1360.

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