Illumination-driven Light Probe Placement

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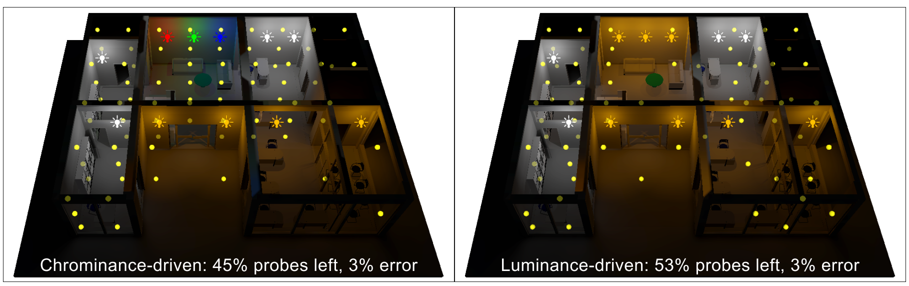

Figure 1: *An example scene showcasing the light probes that remained after applying our simplification procedure over an initial regular grid, under two lighting configurations. The resulting set can preserve either any subtle chrominance variations (left) or luminance transitions (right), without significantly altering the (encoded) global light field.*

Abstract

We introduce a simplification method for light probe configurations that preserves the indirect illumination distribution in scenes with diverse lighting conditions. An iterative graph simplification algorithm discards the probes that, according to a set of evaluation points, have the least impact on the global light field. Our approach is simple, generic and aims at improving the repetitive and often non-intuitive and tedious task of placing light probes on complex virtual environments.

CCS Concepts

• ***Computing methodologies*** $\rightarrow$ ***Rendering;***

1. Introduction

The production of high-quality synthetic images with physically-correct visual fidelity is considered one of the most computationally demanding problems in computer graphics, mainly due to the intractable cost of global illumination estimation over arbitrarily complex light transport paths. The encoding, and subsequently, caching and reconstruction of energy transport at sparse locations using virtual *light probes* has proved to be an effective solution for the plausible representation of most common indirect lighting phenomena, especially in interactive applications and commodity hardware. Research on light probe placement has focused on mitigating issues related to interpolation and spatial coverage [Cup12], erroneous interpolation (light leaking) [SL17] and efficient encoding [VPG14]. Two simplistic solutions are to place the probes manually and lay them out in a grid-like structure, which are slow to set up and costly to maintain, respectively. More elegantly, Wang et al. [WKKN19] proposed guiding the placement by geometric visibility features, but disregarded in the process the final lighting.

In this work, we present a simple mechanism for the simplification of a previously-computed, high-quality dense light probe arrangement, while minimising resulting radiance errors and retaining probes, which are deemed visually important. Our technique is agnostic to the original positioning, interpolation and radiance encoding scheme used, allowing any existing positioning approach to be employed as input or as part of the simplification process.

2. Method Overview

Our approach is based on the idea of generating a dense light field, computing the received energy on a set of reference evaluation points and, finally, pruning the least important probes according

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to a set of criteria, so that the smallest probe set with the minimum perceived error is retained. This operation is split in two stages, Setup and Simplification, as illustrated in Figure 2.

In the Setup stage, a large number of light probes (LP), much higher than the expected sparse output, is automatically distributed according to a user-selected space-filling strategy (grid, Poisson distribution, etc.) and their radiance field is computed. The LPs are then spatially connected to form an undirected graph. Then, a set of key evaluation points (EP) are scattered in the scene, also with a user-selected space-filling strategy, to sample the cached light field. Ideally, EPs should be concentrated near potential paths of dynamic geometry and regions visible to the moving user. Finally, the incident energy for each EP is computed, by sampling its k-nearest probes, and stored as a *reference* to guide the next step.

The Simplification stage aims at preserving the most important LPs with respect to the reference radiance measurements at the EPs. This is performed by iteratively removing the LP that introduces the smallest error and restructuring the graph connectivity (outer loop in Fig. 2-bottom), until the terminating conditions are met. For each LP tested in this process, the LP is first removed and the probe graph connectivity is recalculated. Then, the radiance at every EP is evaluated and an error with respect to the reference radiance is calculated, according to the selected illumination criterion. Finally the LP and its connections are restored and the next LP is tested (inner loop in Fig. 2-bottom).

Illumination criteria. In practical scenarios, we observed that luminance and chrominance are not always equally important in the effective use of indirect lighting. To this end, we transform the reconstructed radiance values to a luminance/chrominance space (YCoCg [MS03]). The error is the mean absolute percentage error between the reference and candidate values. We measure two different user-selectable quantities per colour component on the EPs: either radiance in individual sampling directions or average. We weight the colour components according to importance (w_Y, w_C) as follows: a) Chrominance-based: $w_Y = 0.1, w_C = 0.45$, when colour bleeding is more important, and b) Luminance-based: $w_Y = 1.0, w_C = 0.0$, to retain a higher probe density at regions with high luminance transitions.

Terminating conditions. The Simplification loop continues until either one of the following conditions are met: a) the expected LP number is reached or b) the error tolerance is exceeded.

3. Implementation and Evaluation.

We have developed a cross-platform prototype of our work as a component in Unity's game engine. This allowed us to exploit its light probe baking system, and the tetrahedral tessellations [Cup12] system for the graph, connectivity and interpolation of light probes. To better guide LP placement, we support proxy volumes, multiple light probe groups and a variety of initial population distributions. A preliminary version of the prototype is also available in `https://github.com/cgaueb/light_probe_placement`.

We tested our approach on scenes of different radiometric complexity and observed that we obtained sufficient light probe count reduction under diverse lighting conditions and constraints, as illustrated in the simple example of Figure 1.

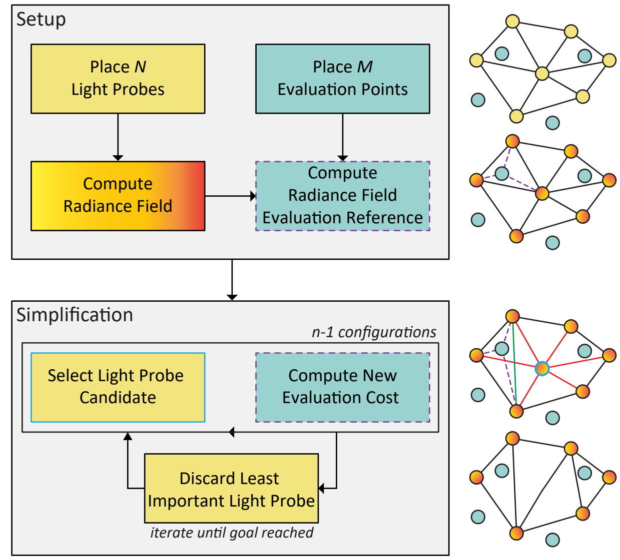

Figure 2: *Our method consists of two common steps: "Setup" and "Simplification" (left). A simplistic graphical example is also offered to demonstrate the workflow of this approach (right).*

4. Limitations and Future Work

Our research is still ongoing and can be greatly improved and extended in the future. The main limitation of our simplification method is the high processing times required when light probe and evaluation point sizes increase significantly. To accelerate this, we can exploit the spatial locality of the light probe influence to reconstruct connectivity locally as well as remove multiple probes simultaneously. Finally, a global optimiser can be added as a last step, further refining the final configuration of the reduced LP set.

Acknowledgements

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