A Median Cut Algorithm for Light Probe Sampling

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ABSTRACT We present a technique for approximating a light probe image as a constellation of light sources based on a median cut algorithm. The algorithm is efficient, simple to implement, and can realistically represent a complex lighting environment with as few as 64 point light sources.

Introduction The quality of approximating an image-based lighting (IBL) environment as a finite number of point lights is increased if the light positions are chosen to follow the distribution of the incident illumination; this has been a goal of previous stratified sampling approaches [Cohen and Debevec 2001; Kollig and Keller 2003; Agarwal et al. 2003; Ostromoukhov et al. 2004]. In this work, we show that subdividing the image into regions of equal energy achieves this property and yields a well-conditioned and easy to implement static sampling algorithm.

Figure 1: The Grace Cathedral light probe subdivided into 64 regions of equal light energy using the median cut algorithm. The small circles are the 64 light sources chosen as the energy centroids of each region; the lights are all approximately equal in energy.

Algorithm Taking inspiration from Paul Heckbert's median-cut color quantization algorithm [Heckbert 1982], we can partition a light probe image in the rectangular latitude-longitude format into 2^n regions of similar light energy as follows:

1. Add the entire light probe image to the region list as a single region.
2. For each region in the list, subdivide along the longest dimension such that its light energy is divided evenly.
3. If the number of iterations is less than n, return to step 2.
4. Place a light source at the center or centroid of each region, and set the light source color to the sum of pixel values within the region.

Implementation Calculating the total energy within regions of the image can be accelerated using a summed area table [Crow 1984]. Computing the total light energy is most naturally performed on a monochrome version of the lighting environment rather than the RGB pixel colors; such an image can be formed as a weighted average of the color channels of the light probe image, e.g. $Y = 0.2125R + 0.7154G + 0.0721B$ following ITU-R Recommendation BT.709. While the partitioning decisions are made on the monochrome image, the light source colors are computed using the corresponding regions in the original RGB image.

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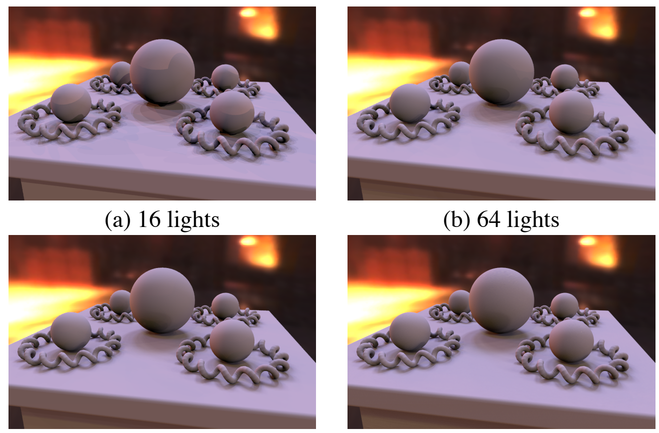
The latitude-longitude mapping over-represents regions near the poles. To compensate, the pixels of the probe image should first be scaled by $\cos\phi$ where ϕ is the pixel's angle of inclination. Determining the longest dimension of a region should also take the over-representation into account; this can be accomplished by weighting a regions width by $\cos\phi$ for an inclination ϕ at center of the region.

Results Fig. 1 shows the Grace Cathedral lighting environment partitioned into 64 light source regions, and Fig. 2 shows a small diffuse scene rendered with 16, 64, and 256 light sources chosen in this manner. Using 64 lights produces a close approximation to a computationally expensive Monte Carlo solution, and the 256-light approximation is nearly indistinguishable.



(a) 16 lights (b) 64 lights (c) 256 lights (d) 4096 ray samples

Figure 2: (a-c) Noise-free renderings in the Grace Cathedral environment approximated by 16, 64, and 256 light sources. (d) A not quite noise-free Monte Carlo rendering using 4096 randomly chosen rays per pixel.

Conclusion The median cut technique is extremely fast compared to most other sampling techniques and produces noise-free renderings at the expense of bias inversely proportional to the number of light sources used. In future work we will investigate the stability of the technique for animated lighting environments and explore adaptations for scenes with general BRDFs.

References

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