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Improving the Efficiency of Monte Carlo Raytracing using Importance Sampling

Author: Dave Jacobsen, Lambda Research Corporation

Author Bio: Dave Jacobsen is a Senior Applications Engineer at Lambda Research Corporation with over 30 years of optical engineering experience. Dave is Lambda Research Corporation's senior sales engineer and teaches many TracePro training classes, both in the US and worldwide. Prior to coming to Lambda Research Corporation, Dave worked as a Principal Optical Engineer at PerkinElmer, formerly EG&G, working with xenon flashlamp based systems for illumination, machine vision, and process control, as well as designing spectroscopy systems for biomedical applications.

Abstract: Monte Carlo raytracing algorithms have long been used in optical design and analysis software. A limitation of the Monte Carlo method is that low probability events or ray paths may be undersampled. In this paper we will look at using Importance Sampling to improve the results in undersampled ray paths.

I. Introduction

The Monte Carlo method is a common tool in modern optical design and analysis software. The Monte Carlo method is used to simulate the scattering and diffraction of light, and to sample the distributions of rays from light sources. In Monte Carlo raytracing, scattering and diffraction are treated as random processes. Instead of propagating a distribution of light, discrete samples of the distribution, or rays, are propagated. The samples are randomly chosen, using the scattering distribution function as a probability density. This allows the well-developed techniques of raytracing to be used to model scattering[1].

In "brute force" Monte Carlo raytracing, the directions of rays are chosen randomly, and a reliable answer is obtained by tracing a very large number of rays. Variance reduction techniques can be employed to reduce the number of rays required to get an accurate result.

The fact that the Monte Carlo method uses the scattering distribution function as a probability density can lead to low probability paths being undersampled. Variance reduction techniques such as importance sampling can be used to improve the results in these undersampled paths.

II. Importance Sampling

One method of variance reduction is ray splitting. When a ray hits a surface during a raytrace, the ray can be split into one or more rays. The flux of each resulting ray is determined by the property parameters of the surface. The flux of the rays is apportioned to maintain conservation of energy.

Importance sampling is another common method of variance reduction. Importance sampling is a Monte Carlo technique in which rays are propagated in specific directions in the optical system, which are important in determining the results you need.

One way to think of importance sampling is think of it as a way to improve the likelyhood of an event of interest occuring. An example of this would be rolling a pair of dice and hoping for a 3. To get a 3 we

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