論文の内容の要旨

A Study on Acceleration of Global Illumination Calculation Based on Stochastic Light-Path Sampling

（光路の統計的サンプリングに基づく大域照明計算の高速化に関する研究）

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Global illumination is very important for photo-realistic image synthesis in 3D computer graphics. Recently, the need to compute global illumination is increasing in many applications, such as film industry, lighting design and games. During the computation of global illumination, many light paths are sampled in a stochastic manner, taking into account reflections on object surfaces and scattering within participating media, such as smokes. The contributions of these light paths are then integrated to produce the final image. Thus, the computation of global illumination is very complex and it has been one of the most important research topics in the computer graphics field to accelerate the computation of global illumination. The methods to compute global illumination can be roughly categorized into two groups: methods with and without participating media in consideration. In case without consideration of participating media, there is no need to compute the scattering and absorption of light due to participating media, thus the computation of global illumination becomes much simple. Furthermore, computing global illumination at interactive frame rates is becoming realized these years by limiting the objects in the scene to be fixed, and has discovered many applications in film industry, lighting design and games. However, it is still a challenging problem to compute the global illumination inside an architectural

scene since the occlusion due to the walls is complex, and the types of light sources that previous methods can handle are limited. On the other hand, in case with consideration of participating media, the computation becomes complex when the participating media are inhomogeneous. There has never been a method to render images in an accurate and fast manner with the presence of inhomogeneous participating media.

This dissertation first deals with the case without participating media in consideration. Algorithms are proposed for global illumination calculation inside an architectural scene at interactive frame rates by limiting the objects in the scene to be fixed. The proposed method can handle various lighting conditions, i.e., the case when the scene is lit by local light sources (e.g., area light sources), and the case when the scene is lit by an environment light source (e.g., sky light source) through the windows. Then, this dissertation deals with the case considering participating media, and an algorithm that is accurate and one to two orders of magnitude faster than previous methods is proposed.

To compute the global illumination inside an architectural scene which is lit by local light sources, such as area light sources, the proposed method is developed based on photon mapping method and two algorithms to accelerate the calculation are proposed. The first one is a novel radiance estimation algorithm using a hierarchical grid. The second one is the ray reusing algorithm under the constraint that the input scene is static. By using the proposed method, the computation time can be shortened in several orders of magnitude. An application to real-time lighting design is shown.

When computing the global illumination inside an architectural scene which is lit by an environment light source, it is difficult to compute the light paths which start from outside (e.g., sky) and reach inside the architecture since the occlusion is quite complex due to the walls. In the proposed method, light paths are split into two groups: 1) the light paths starting from outside and reaching a portal (e.g. a window or an abat-jour); 2) the light paths starting from a portal and reaching inside the architecture. An algorithm is proposed to compute these light paths in a statistically correct way. Furthermore, the light transfer between a portal and a point inside the architecture is represented as functions, and the high frequency and low frequency portions are represented using different basis functions, in order for fast lighting calculation. Using the proposed method, the viewpoint and the light sources can be manipulated in real-time.

To compute global illumination with consideration of participating media, an unbiased and fast algorithm is proposed to generate successive scattering events. During preprocessing, the proposed method partitions the analytical region (or the bounding box) of the media into sub-spaces (partitions) according to the special variation of the mean free path in the media. The partitioning is represented as a kd-tree. During rendering, the locations of the scattering events are determined adaptively using the kd-tree. A key contribution of the proposed method is an automatic partitioning scheme based on a cost model for evaluating the sampling efficiency. The proposed method is one to two orders of magnitude faster in rendering speed than the previous methods for highly inhomogeneous media.