Recent Advances in Light Transport Simulation: Theory and Practice

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This half-day course reviews some of the recent advances in light transport simulation algorithms, which have recently been a subject of renewed interest from both academia and industry.

Introduction

We are witnessing a renewed research interest in robust and efficient light transport simulation based on statistical methods. This research effort is propelled by the desire to accurately render general environments with complex materials and light sources, which is often difficult with the currently employed solutions. In addition, it has been recognized that advanced Monte Carlo methods, which are able to render many effects in one pass without excessive tweaking, increase artists productivity and allow them to focus on their creative work. For this reason, the movie industry is shifting away from approximate rendering solutions toward physically-based rendering methods, which poses new challenges in terms of strict requirements on high image quality and algorithm robustness.

Many of the recent advances in light transport simulation, such as new Markov chain Monte Carlo methods, or the robust combination of bidirectional path tracing with photon mapping, are made possible by interpreting light transport as an integral in the space of light paths. However, there is a great deal of confusion among practitioners and researchers alike regarding these path space methods.

Course Objective

The goal of this course is twofold. First, we present a coherent review of the path integral formulation of light transport and its applications, including the most recent ones. We show that rendering algorithms that may seem complex at first sight, are in fact naturally derived from this general framework. A significant part of the course is devoted to the application of Markov chain Monte Carlo methods for light transport simulation, such as Metropolis light transport and its variants. We include an extensive empirical comparison of these MCMC methods. The second part of the course discusses practical aspects of applying advanced light transport simulation methods in practical architectural visualization and VFX tasks.

Contribution for the Audience

The course is intended for industry professionals and researchers interested in solidifying their knowledge in physically based rendering as well as learning about the latest developments in the field. Rendering software architects and developers looking for the right global illumination solution for their application will also benefit from the course. We will make annotated presentation slides and additional material publicly accessible after the conference.

Detailed Description

Our half-day course is organized into six main sections. After a short introduction, we first cover the theoretical foundations of physically based rendering, with a focus on the path integral formulation of light transport. The basics of Monte Carlo (MC) integration and path sampling techniques are be presented, while the next section discusses bidirectional path sampling techniques, their efficient combination, and how virtual point light, or many-light, methods relate to these. The third section is dedicated to the efficient combination of bidirectional path tracing and photon mapping. After the break, we review the basics of Markov Chain Monte Carlo (MCMC) and describe state-of-the-art rendering algorithms based on various MCMC methods, discussing practical considerations. In the fifth section, we present an extensive comparison of a number of ordinary MC and MCMC methods on various scenes with complex illumination. The last section of the course describes the use of advanced rendering methods in the commercial products of Next Limit Technologies, with a discussion on production requirements and necessary future developments.

Figure 1: *The advanced rendering methods, covered in this course, can handle scenes with complex specular lighting. The left image was rendered with the vertex connection and merging algorithm [Georgiev et al. 2012]. The image on the right was rendered with Metropolis light transport. Manifold exploration [Jakob and Marschner 2012] mutation strategies were used, extended with path space regularization [Kaplanyan and Dachsbacher 2013] to capture reflected caustics from the external point light source.*

This course was not taught at a previous SIGGRAPH or other conference. A number of previous courses have addressed light transport simulation. Among those, the most recent and most closely related is probably the SIGGRAPH 2012 course "Advanced (Quasi-) Monte Carlo Methods for Image Synthesis". Unlike this and other similar courses, we focus on the path-space integration and path sampling techniques as a general mathematical framework that provides a consistent formulation of many existing algorithms and allows for reasoning about their similarities, differences and efficiency. We will show the advantages of thinking in terms of "whole paths" and their sampling techniques, instead of the classic view of locally integrating the incident radiance at a point. These insights are a unique contribution of the proposed course.

This work was partially supported by the Czech Science Foundation grant P202-13-26189S.

References

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