The Iray Light Transport Simulation and Rendering System

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Figure 1: Images rendered with Iray, featuring subtle lighting effects from many textured geometric light sources on the dashboard and knobs as well as consistent interaction with the backplate photograph. Images courtesy of Jeff Patton.

ABSTRACT

While ray tracing has become increasingly common and path tracing is well understood by now, a major challenge consists of crafting an easy-to-use and efficient system implementing these technologies. Following a purely physically-based paradigm while still allowing for artistic workflows, the Iray light transport simulation and rendering system allows for rendering complex scenes by the push of a button and thus makes accurate light transport simulation widely available. We discuss the challenges and implementation choices that follow from our primary design decisions, demonstrating that such a rendering system can be made a practical, scalable, and efficient real-world application that is in use by many industry professionals today.

CCS CONCEPTS

•**Computing methodologies** →**Rendering;**

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KEYWORDS

Push-button light transport simulation, portable material description, rendering workflows, consistent algorithms, elastic parallelism, GPU.

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1 INTRODUCTION

The ultimate goal of light transport simulation is to create images (see Fig. 1) that cannot be distinguished from measurements of reality, which most commonly are photographs. This quest started in the early 1980s [Goral et al. 1984], where simulation results were compared to photographs of the physical Cornell Box. Later on, the RADIANCE system [Ward 1994] used more advanced algorithms to close the gap between reality and simulation, which has been successfully verified in many experiments.

In the same spirit, Fig. 1 in [Keller et al. 2017] features such a reality check experiment conducted with our system, which is a full-featured light transport simulation and rendering system that is capable of predictive rendering at the push of a button. While many contemporary rendering systems can achieve similar results, they often require extensive parameter tuning and user expertise to do so.

2 DESIGN DECISIONS

Obviously, simulation algorithms must be based on the description of physical entities. However, artistic and non-physical workflows are a requirement. The challenge lies in combining these features, which seem to be at odds.

With a primary focus on applications in the design industry, the Iray light transport simulation and rendering system has been developed over the last decade. Its primary design decisions are:

Push-button: As simple as a camera, the push of a button must deliver the desired image with as few parameters as possible. Rendering artifacts must be transient and vanish over time. Therefore, consistent numerical algorithms [Keller 2013] have been selected as the mathematical foundation of Iray, as these guarantee the approximation error to decrease as the sample size increases.

Physically-based rendering: To generate realistic and predictive imagery, the rendering core of Iray uses light transport simulation based on a subset of bidirectional path tracing [Veach 1997]. Illumination by a large number of geometric light sources with spatially varying emission, illumination by high-resolution environment maps with respect to the shading normal, photon aiming, and complex layered materials lead to the development of new importance sampling techniques.

Separating material description from implementation: In order to avoid performance pitfalls of user-written shader code but still grant all freedom for look development, appearance modeling, and programmable materials in general, the material definition language [Kettner et al. 2015] has been co-designed with the system architecture. By its strict separation of material description and implementation, efficiency improvements can be implemented within the renderer and material descriptions can be shared with other renderers.

Scalability: The architecture of the system must be such that performance scales across large clusters of heterogeneous parallel processors (CPUs and GPUs) without sacrificing any of the functionality of a sequential version. Consistency of the results must be guaranteed even across changing heterogeneous parallel computing environments including network clusters and the cloud. Load balancing must be fully automatic and elastic, providing both interactive as well as batch rendering. This is enabled by deterministic quasi-Monte Carlo methods [Keller 2013].

Rendering workflows: The system has been designed to allow for the natural and seamless combination of modern artistic and physically-based workflows, including detailed control over outputs that are useful in post-processing (via Light Path Expressions) and direct, progressive rendering of matte objects without sacrificing consistency of the light transport simulation.

Many of the design decisions have in common that they imply generalization of some sort, which contrasts with most other renderers. For example, the push-button requirement precludes the renderer from employing overly specialized methods that require manual user input in the form of parameters or choice of the algorithm used. Both physically-based rendering and explicit material description fit well to this idea.

While generalized methods are universally desirable, they often are slow to compute, which is why Iray's performance is an integral challenge of enabling this approach in practice. The key aspects of the implementation of the design decisions in the Iray light transport simulation and rendering system are detailed in our extensive report [Keller et al. 2017].

3 CONCLUSION

The unique and careful design of the Iray system architecture enables easy integration and use in new or existing products, in particular since the consistent push-button approach does not lead to complex configuration interfaces, but greatly reduces training effort and enables obtaining predictable results even for novice users. Features that follow directly from the design decisions allow for practical, flexible, and efficient workflows. As the high utilization of modern GPUs is retained when scaling across multiple devices and networks, the performance required for high quality results and interactive rendering can be provided.

Iray started to be shipped within 3ds Max in 2010, is in active use by industry professionals today, and has led to the adoption of physically-based light transport simulation in many industry solutions, among them Catia Live Rendering and Solidworks Visualize by Dassault Systèmes, Siemens NX, and Allegorithmic Substance Designer and Painter.

The insights and new technologies that have been developed over the last decade are shared in [Keller et al. 2017].

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