Path Tracing in Production Part 1: Modern Path Tracing

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Figure 1: Imagery from recent movie productions, featuring difficult light transport, massive geometric complexity, intricate material detail, as well as volumetric effects. Spiderman: Homecoming ©2017 CTMG, Inc. All rights reserved. Alita: Battle Angel ©2018 Twentieth Century Fox Film Corporation. All rights reserved.

ABSTRACT

In the past few years the movie industry has switched over from stochastic rasterisation approaches to using physically based light transport simulation: path tracing in production has become ubiquitous across studios. The new approach came with undisputed advantages such as consistent lighting, progressive previews, and fresh code bases. But also abandoning 30 years of experience meant some hard cuts affecting all stages such as lighting, look development, geometric modelling, scene description formats, the way we schedule for multi-threading, just to name a few. This means there is a rich set of people involved and as an expert in one of the aspects it is easy to lose track of the big picture.

This is part I of a full-day course, and it focuses on the necessary background knowledge. In this part, we would like to provide context for everybody interested in understanding the challenges behind writing renderers intended for movie production work. In particular we will give an insight into movie production requirements for new students and academic researchers. On the other side we will lay a solid mathematical foundation to develop new ideas to solve problems in this context.

To further illustrate, part II of the course will cover material system aspects and showcase practical efforts by prominent professionals in the field, pointing out unexpected challenges encountered in new shows and unsolved problems as well as room for future work wherever appropriate.

KEYWORDS

path tracing, movie production

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1 INTRODUCTION TO PATH TRACING

Johannes Hanika

This talk will introduce the course and state our motivation for our continued efforts on this topic. Johannes will give a bit of context about rendering in the movie production industry. This includes a short historical perspective on rendering algorithms and a summary of what makes movie rendering different from other fields. The particular requirements are used as a benchmark for existing rendering algorithms. In a short overview, the most important variants of path tracing are explained and it is discussed when they fail.

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2 A SHORT HISTORY OF MONTE CARLO

Luca Fascione

Luca's section is supplemented by a rigorous survey of mathematical approaches to numerical integration in our course notes. The talk itself will showcase the different methods by example, such as quadrature rules, the Monte Carlo method, quasi-Monte Carlo integration, and Hamiltonian Monte Carlo. It is our goal to enable the audience to gain an intuitive understanding of the advantages and drawbacks of certain mathematical frameworks. Formally, we approach this by analysing the error bounds of the method and the function class for which these hold. The rigorous underpinning of these intuitive examples should help researchers develop new powerful tools.

3 IMPLEMENTING PATH SAMPLING TECHNIQUES

Marc Droske

This talk carries over some of the insights of the previous two talks to production practice. We have seen that no single existing algorithm is capable of fulfilling the production needs yet, and that there is a theoretical reason for this: rendering requires us to integrate a function space with extremely heterogeneous properties in different regions of the domain. This means that we need to mix and match many specialised sampling techniques together to be able to render a shot successfully. The one tool we have at hand to perform this is multiple importance sampling. Marc will outline a software architecture that can combine an arbitrary amount of sampling techniques and transparently manage the weights.

4 FINDING GOOD PATHS

Jorge Schwarzhaupt

Jorge will showcase a few practical importance sampling techniques which are essential to movie production at Weta Digital. While the basic techniques are common to most studios employing path tracing, he will share some insights that are particular to the large scale complexity of scenes encountered in visual effects. This includes a look at how next event estimation is done in Manuka, with a sophisticated light hierarchy that has been refined over many years. Jorge will also talk about specific path sampling optimisations for motion blur and depth of field by reconnecting complete paths to different pixels. The implementation of such techniques is greatly simplified by the architecture Marc talked about in the slot before.

5 VOLUMES

Christopher Kulla

Modern production path tracing renderers must contend with volumetric effects in addition to surfaces. These are essential to represent a wide array of natural phenomena (fog, smoke, dust, snow, fire, etc...). This extra dimension in the light transport equation opens up its own unique set of challenges for efficient sampling of light paths. In this part of the course, we will review the main families of sampling techniques which are used in production, discuss how to combine them effectively and explore remaining open problems. We will also discuss production specific requirements such as how to deal with overlapping volumes, large numbers of light sources, massive data-sets and motion blur.

6 THE INS OF PRODUCTION RENDERING AT ANIMAL LOGIC

Daniel Heckenberg

Daniel will take us along on the journey Animal Logic has traveled on the last years: This talk will illustrate how to evolve material modelling from rasterisation to ray tracing-based approaches. There has always been an ever growing complexity of geometry in movie production. We will see how ray tracing scales to mega-scenes, and what particular aspects there are to instancing using this approach, as well as some additional geometry cleverness on the side. To deliver these techniques, there needs to be a tight pipeline and workflow integration. Daniel will show us which workflows they developed in terms of Maya bindings, Katana integration, and Houdini trickeries, as well as eluding us to workflows with multiple renderers.