The Path Tracing Revolution in the Movie Industry

A. Keller (Organizer)* NVIDIA
L. Fascione (Organizer)† Weta digital
M. Fajardo‡ Solid Angle
I. Georgiev§ Solid Angle
P. Christensen¶ Pixar
J. Hanika‖ Weta digital
C. Eisenacher** Walt Disney Animation Studios
G. Nichols†† Walt Disney Animation Studios

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Abstract

As path tracing allows for more realistic and faster lighting, an increasing number of movies are created the physically based way. With examples from recent movies, the architectures and novel workflows of the next generation of production renderers are introduced to a wide audience including technical directors, artists, and researchers.

*e-mail: akeller@nvidia.com
†e-mail: lukes@wetafx.co.nz
‡e-mail: marcos@solidangle.com
§e-mail: me@iliyan.com
¶e-mail: per@pixar.com
‖e-mail: jhanika@wetafx.co.nz
**e-mail: christian.eisenacher@disneyanimation.com
††e-mail: gregory.nichols@disneyanimation.com

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Figure 1: Representative images from production renderers using path tracing. Courtesies: Top left: Paddington, courtesy of Heyday Films, Studio Canal and Framestore. All rights reserved. Top right: ©2014 Metro-Goldwyn-Mayer Pictures Inc. and Warner Bros. Entertainment Inc. All rights reserved. Bottom left: Marlin rendered by Andrew Pienaar and Masha Ellsworth. Image (c) 2015 Disney/Pixar Animation Studios. All rights reserved. Bottom right: ©Disney Enterprises. All rights reserved.

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1 Course Objective

The primary objective is to convey how path tracing evolved such that it now is revolutionizing the way movies are rendered. Beyond the obvious advantages of simpler and faster realistic lighting, path tracing enables novel workflows. Modeling with physically based entities is much more intuitive and allows for separating rendering algorithms from material descriptions, which results in more portable assets and requires much less tweaking in look development. Provided measured materials and light sources, even predictive rendering workflows become possible. The artistic freedom is extended by light path expressions to select any desired mode of light transport simply by a regular expression. Such regular expressions are more flexible than classic arbitrary output variables, as they may be specified without extra programming or shader modifications. As a result, modern production workflows become more efficient, reproducible, and modular.

While path tracing has been around for long, it required extensive research to develop industry proof noise and variance reduction algorithms and concepts such as push-button rendering or consistent stop-and-go refinement. As a consequence optimal results may be obtained with a much smaller set of renderer controls and less numerical issues.

The course will review the coherent state of the art in path tracing in movie production, its novel workflows, and software architectures that can face the challenges of gigantic amounts of geometry, textures, and light sources. Examples from recent movies (see Fig. 1) provide evidence of the benefits of using path tracing in movie production.

Although advanced, the course will embrace a wide audience including technical directors, artists, their producers and managers, as well as researchers. With all the spearheading companies revealing and teaching their technologies, this is a first of a kind course.

2 Course Syllabus

2:00 PM The Path Tracing Revolution in the Movie Industry

Alexander Keller will survey the principles of path tracing and modeling with physically based entities, which will serve as the foundation for all subsequent presentations. Light will be shed on the novel workflows such as simplified lighting, light path expressions, and portable material definition. The advantages of the new techniques will be contrasted to previous workflows and it will be shown that against common believe path tracing does not compromise artistic freedom. Finally, the course presenters will be introduced and it will be pointed out how their revolutionary work is connected.

2:35 PM Arnold and How Path Tracing Took Over

Monte Carlo path tracing is now the standard rendering approach in film VFX, animated films, commercials and pre-rendered video game intros. The Arnold renderer from Solid Angle played a significant role in the transition from rasterization-based technology. In this talk **Marcos Fajardo** will provide some historical context on how studios made this transition and describe the key benefits that motivated it. Marcos will also discuss some of the latest developments in the Arnold renderer as well as the challenges that still lie ahead in the never-ending quest for increased detail and visual realism.

3:10 PM Path Tracing with RenderMan RIS

Over the past 25+ years, Pixar's RenderMan renderer has evolved from being based on the Reyes algorithm to a hybrid Reyes-raytracing renderer to a physically-based global illumination path tracer. The main reason for the switch to path tracing is easier lighting set-up and progressive rendering for a more interactive workflow. The challenge for Monte Carlo path tracing has always been noise; in addition, movie production scenes require huge amounts of memory to represent the complex geometry and textures of realistic scenes. In this talk **Per Christensen** will describe path tracing in RenderMan, how to reduce noise, and handle hugely complex scenes.

3:45 PM Break

4:00 PM Manuka, Weta's Physically-Based Spectral Renderer

Johannes Hanika will share some practical insights and experiences from developing a path tracing-based production renderer, driven by artistic needs. These artistic requirements are summarized in the context of life-like digi-doubles and believable creatures. Then the implications on software architectures and light transport algorithms are discussed along with explanations which ones were implemented and why some were not adopted by production. Specialized sampling techniques that turned out to work most successfully in practice are described. Showing the examples of such techniques in shots from 'The

Hobbit: The Battle of the Five Armies' and 'Dawn of the Planet of the Apes' concludes the presentation.

4:35 PM Hyperion, Disney's new Global Illumination Renderer

Greg Nichols and Christian Eisenacher will describe Hyperion, a new global illumination path tracer, first used on Disney's 'Big Hero 6.' We will discuss the design goals behind Hyperion, including the key technical aspects that enable it to handle scenes of massive geometric scale, and to efficiently render the texture-heavy assets common at Disney Animation. We will further look at the challenges overcome while turning Hyperion from a specialized proof of concept into a full-blown production renderer, capable of handling the demanding artistic needs of 'Big Hero 6.'

5:10 PM Q&A with all presenters

3 Course Presenter Information

3.1 A. Keller, NVIDIA (Organizer)

Alexander Keller is a director of research at NVIDIA, leading advanced rendering research. Before, he had been the Chief Scientist of mental images, where he had been responsible for research and the conception of future products and strategies including the design of the Iray renderer. Prior to industry, he worked as a full professor for computer graphics and scientific computing at Ulm University, where he co-founded the UZWR (Ulmer Zentrum für wissenschaftliches Rechnen) and received an award for excellence in teaching. Alexander Keller holds a PhD in computer science, authored more than 25 granted patents, and published more than 50 papers mainly in the area of quasi-Monte Carlo methods and photorealistic image synthesis using ray tracing.

3.2 L. Fascione, Weta digital (Organizer)

Luca Fascione is Head of Rendering Research at Weta digital, where he leads the activity of research around rendering algorithms and material modeling. He joined Weta in 2004 and has also worked for Pixar Animation Studios. The rendering group's software, including PantaRay and Manuka, has been supporting the realization of large scale productions such as Avatar, The Adventures of Tintin, the Planet of the Apes films and the Hobbit trilogy.

3.3 M. Fajardo, Solid Angle

Marcos is the founder and CEO of Madrid and London-based Solid Angle, where he leads the research and development team working on the Arnold path tracing renderer. Previously he was a visiting software architect at Sony Pictures Imageworks, a visiting researcher at USC Institute for Creative Technologies under the supervision of Dr. Paul Debevec, and a software consultant at various CG studios around the world. He studied Computer Science at University of Málaga, Spain. Marcos is a frequent speaker at SIGGRAPH, FMX and EGSR. His favorite sushi is engawa.

3.4 I. Georgiev, Solid Angle

Iliyan is a rendering researcher and enthusiast. He holds a B.Sc. degree in computer science from Sofia University, Bulgaria, and a M.Sc. degree from Saarland University, Germany, with a Ph.D. degree anticipated in the near future. His primary topics of interest are high performance ray tracing and Monte Carlo methods for physically-based light transport simulation. His aspiration for practical rendering solutions has given him the opportunity to work for Disney, Weta digital and Chaos Group (V-Ray). He currently works for Solid Angle.

3.5 P. Christensen, Pixar

Per Christensen is a senior software developer in Pixar's RenderMan group in Seattle. His main research interests are efficient ray tracing and global illumination in very complex scenes. He received an M.Sc. degree in electrical engineering from the Technical University of Denmark and a Ph.D. in computer science from the University of Washington in Seattle. Before joining Pixar, he worked at mental images in Berlin and at Square USA in Honolulu. His movie credits include Finding Nemo, The Incredibles, Cars, Ratatouille, Wall-E, Up, Toy Story 3, Cars 2, Brave, and Monsters University. He has received an Academy Award for his contributions to the development of point-based global illumination and ambient occlusion.

3.6 J. Hanika, Weta digital

Johannes Hanika received his PhD in media informatics from Ulm University in 2011. After that he worked as a researcher for Weta digital in Wellington, New Zealand. There he was part of Luca Fascione's group who brought Manuka to life, Weta digital's physically-based spectral renderer. Since 2013 he is back in Germany and works as a post-doctoral fellow at the Karlsruhe Institute of Technology with emphasis on light transport simulation, continuing research for Weta digital part-time.

3.7 C. Eisenacher , Walt Disney Animation Studios

Christian Eisenacher is a Senior Software Engineer at Walt Disney Animation Studios, and earned his first screen credit for the texture synthesis system used in Tangled in 2010. After obtaining his PhD for research into real-time content creation from FAU Erlangen, he moved to Burbank in 2011, to help artists create magic as his full-time job. Besides an interactive BRDF-design tool used in Wreck-It-Ralph and Frozen, he focused his passion for "simple, fast and parallel" on the development of Hyperion, Disney's new renderer for Big Hero 6.

3.8 G. Nichols, Walt Disney Animation Studios

Greg Nichols joined Walt Disney Animation Studios as a Senior Software Engineer in 2010. He earned his PhD at the University of Iowa in 2010 working in real-time global illumination algorithms for GPUs. Besides Hyperion, he has worked on a number of projects, including a GPU-based render preview application and a real-time BRDF visualization and creation tool (BRDF Explorer, now available as open source).