Recent Advances in Light Transport Simulation: Some Theory and a lot of Practice

SIGGRAPH 2014 Course

Course Notes Sample

Course materials are available from

http://cgg.mff.cuni.cz/~jaroslav/papers/2014-ltscourse/

Organizers

Jaroslav Křivánek
Charles University in Prague

Alexander Keller
NVIDIA

Lecturers

Iliyan Georgiev
Solid Angle

Anton S. Kaplanyan
Karlsruhe Institute of Technology

Marcos Fajardo
Solid Angle

Mark Meyer
PIXAR Animation Studios

Jean-Daniel Nahmias
PIXAR Animation Studios

Ondřej Karlík
Charles University in Prague, Render Legion s.r.o.

Juan Cañada
Next Limit Technologies

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Abstract

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 industry-standard ad hoc solutions. In addition, it has been recognized that advanced 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 towards 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, the robust combination of bidirectional path tracing with photon mapping, or path space filtering 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.

The main contribution of the theoretical part of the course is 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. We also show that the path integral framework makes the extension of the surface-based algorithm to volumetric media extremely simple. The course includes an extensive empirical comparison of the various light transport algorithms. A substantial part of the course is then devoted to the application of advanced light transport simulation and path sampling methods in practical rendering tasks in architectural visualization and VFX.

Intended audience

Industry professionals and researchers interested in recent advances in robust light transport simulation for realistic rendering with global illumination.

Prerequisites

Familiarity with rendering and with basic concepts of global illumination computation is expected.

Level of difficulty

Intermediate

Syllabus

1. Introduction & Welcome (*Křivánek*)
   (5 min)

2. Path Integral Formulation of Light Transport (*Křivánek*)
   (25 min)
   - Light transport simulation as an integral over the space of light paths
   - Path sampling methods and path probability density
   - Combining different path sampling techniques
   - Bidirectional path tracing
   - Joint importance sampling in participating media

3. Combining Bidirectional Path Tracing and Photon Mapping (*Georgiev*)
   (20 min)
   - (Progressive) photon mapping
   - Photon mapping as a path sampling technique
   - Combining with bidirectional path tracing techniques
   - Discussion: advantages, limitations, and best practices

4. Path Space Filtering (*Keller*)
   (20 min)
   - Smoothing the path contributions before image reconstruction
   - Algorithmic aspects
   - Example applications in light transport simulation, multi-view rendering, shadows, ambient occlusion, translucency, real-time rendering

5. Comparison of Various Light Transport Methods (*Kaplanyan*)
   (20 min)
   - Comparison: Monte Carlo methods
   - Video: Femtosecond light propagation
   - Comparison: Metropolis light transport with different mutation strategies
   - Comparison: Energy redistribution path tracing
   - Comparison: Photon mapping with Metropolis sampling
   - Comparison: Population Monte Carlo light transport

   Break
   (15 min)

6. Efficiency = Good Importance Sampling (*Fajardo/Georgiev*)
   (20 min)
   - Importance sampling area lights
   - Importance sampling single scattering in participating media
   - BSSRDF importance sampling

7. Pixar's Fast Lighting Preview (*Meyer/Nahmias*)
   (20 min)
   - Physically based lighting in computer animation
   - Technology and integration - production pipeline, OptiX and Katana
   - Showcase the pipeline using artistic controls on full production shots and assets

8. Corona Renderer: It's all about Usability (*Karlík*)
   (20 min)
   - Users requirements in architectural visualization
   - Biased vs. unbiased rendering from the users perspective
   - Examples of solutions to specific issues: energy clamping, artistic tweaking

9. Advanced Light Transport in the VFX/Archiviz industry (*Cañada*)
   (20 min)
   - Stage of the Industry - the reasons for accurate light transport in practice
   - Current problems, solutions, and workarounds
   - What's next?

10. Conclusions / Q & A (*all*)
    (10 min)

Course presenter information

Jaroslav Křivánek *Charles University in Prague, jaroslav.krivanek@mff.cuni.cz*

Jaroslav is an associate professor of Computer Science at Charles University in Prague. Prior to this appointment, he was a Marie Curie research fellow at Cornell University, and a junior researcher and assistant professor at Czech Technical University in Prague. Jaroslav received his Ph.D. from IRISA/INRIA Rennes and the Czech Technical University (joint degree) in 2005. His primary research interest is realistic rendering, global illumination, radiative transport (including light transport), and Monte Carlo methods.

Alexander Keller *NVIDIA, keller.alexander@gmail.com*

Alexander Keller is the Director of Research at NVIDIA and leads 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). Alexander Keller holds a Ph.D. in computer science, authored 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.

Iliyan Georgiev *Light Transportation, Ltd., iliyan@solidangle.com*

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.

Anton S. Kaplanyan *Karlsruhe Institute of Technology, anton.kaplanyan@kit.edu*

Anton S. Kaplanyan is a graphics researcher at Karlsruhe Institute of Technology (KIT), Germany. Additionally he is pursuing a Ph.D. title. His primary research and recent publications are about advanced light transport methods for global illumination. Prior to joining academia Anton had been working at Crytek for three years at various positions from senior R&D graphics engineer to lead researcher. He received his M.Sc. in Applied Mathematics at National Research University of Electronic Technology, Moscow in 2007.

Marcos Fajardo *Solid Angle, marcos@solidangle.com*

Marcos is the founder of Madrid-based Solid Angle SL, 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.

Mark Meyer *PIXAR Animation Studios, mmeyer@pixar.com*

Mark Meyer is a Senior Scientist at Pixar Animation Studios. He received his BS in Computer Science and Computer Engineering from Northwestern University and his Ph.D. from Caltech. Before joining Pixar in 2003, Mark worked on virtual reality and simulation at Argonne National Laboratory and instructed Computer Graphics courses in the Computer Science department at Caltech. Mark is currently working in Pixar's Research Group on projects ranging from character articulation to lighting acceleration.

Jean-Daniel Nahmias *PIXAR Animation Studios, nahmias@pixar.com*

Jean-Daniel Nahmias received his Bsc, Msc and Phd from University College London, specializing in virtual reality, augmented reality and computer vision. Before joining Pixar he spent most of his time optimizing algorithms to run quickly on GPUs. This included limited angle tomography reconstruction for breast cancer screening and stereo vision reconstruction. He joined Pixar as a global tech TD to work on productions and is currently developing real time lighting technologies.

Ondřej Karlík *Charles University in Prague, Render Legion s.r.o., ondra@corona-renderer.com*

After graduating from the Czech Technical University, Ondřej became a PhD student at the Charles University in Prague, where he has cooperated with Jaroslav Křivánek on the research of usability in realistic rendering. In 2009 he started the development of his own photorealistic renderer, Corona, which have since then became one of the fastest growing renderers in the architectural visualization field. He is currently preparing the first commercial release of the Corona renderer.

Juan Cañada *Next Limit Technologies, juan.canada@nextlimit.com*

Juan joined Next Limit in 2001 to work in the Realflow development team and later he moved to the newborn Maxwell research team. Since then Juan held several positions in the team, leading it since 2007. He holds a bachelors degree in Mechanical Engineering and a degree in Environmental Sciences.