Recent Advances in Light Transport Simulation: Theory & Practice

SIGGRAPH 2013 Course

Course materials are available from

http://cgg.mff.cuni.cz/~jaroslav/papers/2013-ltscourse/index.htm

Organizers

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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 currently employed 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 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.

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.

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 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*)
   (30 min)
   - Rendering and measurement equations
   - Light transport simulation as an integral over the space of light paths
   - Monte Carlo integration primer
   - Path sampling methods and path probability density
   - Unidirectional path sampling: Path tracing, Light tracing. Limitations

3. Bidirectional Path Sampling Techniques (*Křivánek*)
   (20 min)
   - Bidirectional path tracing
   - Combining different path sampling techniques
   - Virtual point lights
   - Discussion: advantages & limitations

4. Vertex Connection and Merging (*Georgiev*)
   (35 min)
   - (Progressive) photon mapping
   - Vertex merging: photon mapping as a path sampling technique
   - Combining photon mapping with bidirectional path tracing
   - Consistency and convergence rate
   - Discussion: advantages & limitations

   Break
   (15 min)

5. Markov Chain and Sequential Monte Carlo Methods (*Kaplanyan*)
   (25 min)
   - Markov chains
   - Metropolis-Hastings algorithm
   - Metropolis light transport
   - Normalization, start-up bias and stratification
   - Different mutation strategies and their properties
   - Light transport with sequential Monte Carlo

6. Comparison of Advanced Light Transport Methods (*Kaplanyan*)
   (30 min)
   - Ordinary Monte Carlo methods
   - Metropolis light transport with different mutation strategies
   - Energy redistribution path tracing
   - Markov chain progressive photon mapping

- Population Monte Carlo light transport

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

8. Conclusions / Q & A (*all*)
   (5 min)

Course presenter information

Jaroslav Křivánek *Charles University, Prague*
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Jaroslav is an assistant professor at Charles University in Prague. Prior to this appointment, he was a Marie Curie post-doctoral research fellow at the Cornell University Program of Computer Graphics, 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. In 2003 and 2004 he was a research associate at the University of Central Florida. His primary research interest is realistic rendering and global illumination.

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Iliyan is a graphics researcher at Saarland University, Germany, pursuing a PhD degree. He received a B.Sc. degree in computer science from Sofia University, Bulgaria, and a M.Sc. degree in computer science from Saarland University. His primary research interests are ray tracing and Monte Carlo methods for global illumination rendering.

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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.

Juan Cañada *Next Limit Technologies*
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Juan joined Next Limit in 2004 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.