Siggraph 2004

Full-Day Course #26

“Real-Time Shadowing Techniques”

Course Title

Real-Time Shadowing Techniques

Category

Rendering – Real-Time or for Games

Presentation Venue

Session Room

Summary Statement

How to incorporate shadows in real-time rendering. Basic shadowing techniques, more advanced techniques that exploit new features of graphics hardware, the differences among these algorithms, and their strengths and weaknesses. The course includes implementation details.

Names of all lecturers in the format

Tomas Akenine-Moeller,
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Eric Chan,
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Wolfgang Heidrich,
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Jan Kautz,
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Mark Kilgard,
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Marc Stamminger,
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Course abstract

Shadows heighten realism and provide important visual cues about the spatial relationships between objects. But integration of robust shadow shadowing techniques in real-time rendering is not an easy task. In this course on how shadows are incorporated in real-time rendering, attendees learn basic shadowing techniques and more advanced techniques that exploit new features of graphics hardware.

The course begins with shadowing techniques using shadow maps. After an introduction to shadow maps and general improvements of this technique (filtering, depth bias, omnidirectional lights, etc.), the first section describes two methods for reducing sampling artifacts: perspective shadow maps and silhouette maps. Both techniques can significantly improve shadow quality, but they require careful implementation. The course continues with extensions of the shadow mapping method that allow soft shadows from linear and area light sources. The second part of the course discusses recent advances in efficient and robust implementation of shadow volumes on graphics hardware and then shows how shadow volumes can be extended to generate accurate soft shadows from area lights. Finally, the course summarizes real-time shadowing from full lighting environments using the technique of precomputed radiance transfer.

The course explains the differences among these algorithms and their strengths and weaknesses. Implementation details, often omitted in technical papers, are provided. And throughout the course, the tradeoffs between quality and performance are illustrated for the different techniques.

Prerequisites

Working knowledge of a low-level graphics API such as DirectX or OpenGL. Some knowledge of shadowing algorithms is useful, but not required.

Level of difficulty

Intermediate

Intended audience

Everybody who is interested in realtime and interactive graphics.

Syllabus

8:30 - 8:45 **Introduction** (Jan Kautz)
* Why Shadows?
* Definitions
* Problem Statement
* Classification of Algorithms:
  - Hacks (no shadow, projected blob, etc.)
  - Shadows using Shadow Maps (point lights and linear lights)
  - Shadows using Shadow Volumes (point lights and area lights)
  - Shadows using Radiance Transfer (full lighting environments)

Component I: Shadow Maps

8:45 - 9:15 **Shadow Maps** (Marc Stamminger)
* Introduction to hardware-accelerated Shadow Mapping
* Robustness problems
* Optimizing the shadow map
  - Tight fitting light source frustum
* Optimizing the shadow test
  - Improving the depth precission
  - 2nd depth shadow maps
  - Linear-spaced depth values

9:15 - 10:00 **Perspective Shadow Maps** (Marc Stamminger)
* Concept
* Sample density considerations
* Implementation details
* Examples, results, and limitations

10:00 - 10:15 **Silhouette Maps - Part I** (Eric Chan)
* Problems with shadow maps (and shadow volumes)
* Key idea: only shadow silhouettes need precise reconstruction

Break

10:30 - 10:55 **Silhouette Maps - Part II** (Eric Chan)
* Approximate edge data structure: the silhouette map
* Hardware implementation details
* Examples, results, and limitations

10:55 - 11:35 **Linear Light Sources** (Wolfgang Heidrich)
* Why soft shadows?
* Linear light sources
* Visibility from line segments
* Adaptation of the shadow map algorithm

11:35 - 12:15 **Smoothies** (Eric Chan)

* Fake soft shadows: a qualitative / phenomenological approach
* Observation: appearance of soft shadows depends mostly on ratio of distances between blocker and receiver
* Key idea: extra geometry (a.k.a. "smoothies") and projective texture mapping
* Hardware implementation details
* Examples, results, and limitations
* Comparison of all presented shadow mapping methods

Lunch

Component II: Shadow Volumes

13:45 - 14:45 **Shadow Volumes** (Mark Kilgard)

* Shadow volume introduction
* Implementation with the stencil buffer
* Robustness problems
* Improvements:
    - Infinite view frusta
    - Z-fail test
    - Depth clamp
* Comparison: shadow volume vs. shadow map algorithms

14:45-15:30 **Soft Shadow Volumes - Part I** (Tomas Akenine-Moeller)

* Why enhance the shadow volume algorithm?
* The penumbra wedge primitive
* Robust penumbra wedge construction
* Visibility computation inside wedge
* Implementation using programmable hardware

Break

15:45-16:00 **Soft Shadow Volumes - Part II** (Tomas Akenine-Moeller)

* Hardware optimizations
* Comparison: Soft Shadow Volumes, Smoothies, and Linear Light Sources

Component III: Radiance Transfer Shadows

16:00-17:00 **Radiance Transfer with Shadows** (Jan Kautz)

* Introduction to precomputed radiance transfer (PRT)
* Application to shadows
* Extension to animated models
    - Precomputation + compression
    - On-the-fly computation
* Comparison: PRT shadows vs. area light shadows

17:00-17:30 **Conclusions** (Jan Kautz)

* Final comparison between all algorithms
* Compare: quality, application to what kind of lighting, speed, usability, limitations, and artifacts.
* Questions & answers (all)

Course presenter information for the organizer and each lecturer

Tomas Akenine-Moeller, Lund Institute of Technology, Sweden

Tomas is an associate professor at Lund Institute of Technology, with research focus on real-time computer graphics algorithms, in particular shadow algorithms and graphics for mobile platforms. He is a co-author of the book "Real-Time Rendering" with Eric Haines, and he has published many papers at international conferences. In 2000, he was a postdoc at UC Berkely, and that year he also taught a course at SIGGRAPH. Last year he finally managed to get the first (ever) Swedish paper(s) accepted at SIGGRAPH, and so he might retire any day now.

Eric Chan, Massachusetts Institute of Technology, Cambridge, USA

Eric Chan is a 2nd-year Ph.D. student at the Massachusetts Institute of Technology, where he studies computer graphics with Frédo Durand. His current research interests includes graphics architectures, shadow algorithms, antialiasing, and digital photography. Before attending graduate school, Eric was a research staff member in the Computer Graphics Laboratory at Stanford University. He worked on the Real-Time Programmable Shading project under the supervision of Pat Hanrahan and Bill Mark. He enjoys digital photography and spends an unreasonable amount of his free time playing with cats.

Wolfgang Heidrich, University of British Columbia, Canada

Wolfgang Heidrich holds an Assistant Professor position in Computer Science at the University of British Columbia. He received a PhD in Computer Science from the University of Erlangen in 1999, and then worked as a Research Associate at the Computer Graphics Group of the Max-Planck-Institut für Informatik in Saarbrücken, Germany, where he lead the research efforts in hardware-accelerated and image-based rendering. Heidrich's research interests include computer graphics and computer vision, in particular image-based modeling, measuring, and rendering, geometry acquisition, hardware-accelerated and image-based rendering, and global illumination. Heidrich has written over 50 refereed publications on these subjects and has served on numerous program committees. He is a co-author of the recently published book "Real-Time Shading".

Jan Kautz, Massachusetts Institute of Technology, Cambridge, USA

Jan is currently a Post-Doc with the graphics group at the Massachusetts Institute of Technology. He received his PhD from the Max-Planck-Institut für Informatik, Saarbrücken, Germany. His thesis was on real-time shading and rendering. He is particularly interested in the realistic shading using graphics hardware, about which he has published several articles at various conferences including SIGGRAPH. Jan has been a tutorial speaker on real-time shading at Eurographics, Web3D, and others.

Mark J. Kilgard, NVIDIA Corporation, Santa Clara, USA

Mark J. Kilgard is a Graphics Software Engineer at NVIDIA Corporation where he contributes to the NVIDIA OpenGL driver. Mark is particularly interested in providing better interfaces to today's programmable graphics hardware. Mark authored the book "Programming OpenGL for the X Window System" and implemented the popular OpenGL Utility Toolkit (GLUT) for developing portable OpenGL examples and demos. Previously, Mark worked at Silicon Graphics on the Onyx InfiniteReality graphics supercomputer and on the SGI's X Window System implementation. Mark has taught many courses at SIGGRAPH, the Computer Game Developers Conference, and other conferences. Mark's Karaoke rendition of Dolly Parton's "9 to 5" can't be beat.

Marc Stamminger, University of Erlangen-Nürnberg, Germany

Marc Stamminger is professor at the University of Erlangen, Germany. He wrote a PhD thesis on radiosity methods, but his recent research focuses on interactive rendering techniques in the virtual reality context, in particular on point based rendering and interactive shadow generation. In this area, he published several papers at international conferences including SIGGRAPH, and has been tutorial speaker at Eurographics and other conferences.

Organizer Contact Information

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