Ray Tracing is the Future and ever will be...

A. Keller (Organizer)* NVIDIA
T. Karras† NVIDIA
I. Wald‡ Intel
S. Laine§ NVIDIA
T. Aila¶ NVIDIA
J. Bikker‖ NHTV/IGAD Breda
C. Gribble** SURVICE
W.-J. Lee†† Samsung
J. A. McCombe‡‡ Imagination Technologies

SIGGRAPH 2013 Course

Abstract

The phrase "Ray tracing is the future and ever will be", as coined by David Kirk (NVIDIA fellow and former Chief Scientist), allows for two interpretations: Either, it will never be feasible, or it will be a disruptive technology.

In order to show how close the state of the art is to the latter, presenters from industry will highlight the enabling technical aspects as well as the current challenges and opportunities of ray tracing.

*e-mail:keller.alexander@gmail.com
†tkarras@nvidia.com
‡ingo.wald@intel.com
§slaine@nvidia.com
¶taila@nvidia.com
‖bikker.j@gmail.com
**christiaan.gribble@survice.com
††joe.w.lee@samsung.com
‡‡james.mccombe@imgtec.com

Figure 1: Although ray tracing primarily is associated with light transport simulation for photorealistic image synthesis (Image courtesy of Jeff Patton), new technologies for parallel ray tracing and upcoming hardware have the potential to finally democratize ray tracing as a disruptive technology even in the mobile space.

Contents

1 Course Objective

The primary objective is to present a coherent state of the art in advanced ray tracing technology. Therefore, the course will cover the most recent developments and practical aspects of the parallel construction of hierarchical acceleration data structures and their traversal using highly parallel processors including the discussion of divergent code paths and memory accesses as well as occupancy. Ray tracing in real-time games is considered one of the main opportunities, while an important part of the course is concerned with hardware for ray tracing reaching out for mobile platforms as another opportunity.

Fig. 1 shows the result of a light transport simulation based on path tracing. While such simulations require ray tracing to assemble light transport paths, the course will raise intriguing questions such as: What about ray tracing primary rays instead of rasterizing the geometry and how feasible is it to trace shadow rays in order to overcome most of the issues of shadow maps ? Can ray tracing hardware be more power efficient than rasterization?

2 Course Syllabus

The course documentation such as the presentations will be provided at http://sites.google.com/site/raytracingcourse/.

2:00 PM Ray Tracing is the Future and ever will be...

Alexander Keller will survey the basics of ray tracing, its complexity and numerical issues, as well as the algorithmic principles of accelerated ray tracing. The course presenters will be introduced and it will be pointed out how their work is connected.

2:30 PM Parallel Hierarchy Construction

Tero Karras will present the latest and novel developments in the parallel construction of acceleration hierarchies for ray tracing that are amazingly fast.

2:50 PM Combining Single and Packet Ray Tracing

Ingo Wald will review the traversal of acceleration hierarchies for single rays as well as for packets of rays, how these approaches can be combined, and how they can be efficiently implemented on processors with SIMD instructions.

3:10 PM Improving Coherence for Path Tracing

Samuli Laine and Timo Aila will elaborate on the implementation of path tracing algorithms on SIMD and SIMT architectures such that occupancy remains high and coherence can be exploited. This includes special considerations for complex shading as required in professional applications.

break

3:45 PM Ray Tracing in Real-time Games

Jacco Bikker will elaborate on ray tracing under real-time constraints. New algorithms will be presented in the light of the opportunities of ray tracing in games.

4:05 PM Integer Ray Tracing

Christiaan Gribble reviews the basics of restricting ray tracing operations to integers. Aside from obvious savings in chip area as compared to floating point ray tracing hardware, interesting precision issues are discussed.

4:25 PM MIMD Hardware Architecture for Incoherent Ray Tracing

Won-Jong Lee presents a ray tracing hardware that is developed at Samsung.

4:50 PM Low Power Consumption Ray Tracing

James A. McCombe talks about the ray tracing hardware that is developed at Imagination Technologies.

3 Course Presenter Information

3.1 Alexander Keller, NVIDIA (Organizer)

Alexander Keller is a senior research manager 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.

3.2 Tero Karras, NVIDIA

Tero Karras is a senior research scientist at NVIDIA. His expertise ranges from parallel architectures and algorithms to efficient image synthesis and light transport. In the past, he has also worked on mobile graphics hardware and software at Hybrid Graphics. His current research interests include GPU-based methods for efficient global illumination, as well as algorithms tailored for massively parallel processors in general.

3.3 Ingo Wald, Intel

Ingo Wald holds a Ph.D. in engineering from Saarland University, and is currently a research scientist at Intel Labs. After his Ph.D., Dr. Wald was a post-doctoral research associate at the Max Planck Institute for Informatics in Saarbrücken, Germany, followed by a Research Professorship at the Scientific Computing and Imaging Institute (SCI) and School of Computing at the University of Utah. His work concentrates on all aspects of real-time ray tracing and photorealistic rendering, high-performance graphics, throughput computing, parallel/high-performance hardware architectures, and, most recently, on programming paradigms and compilers for multi-core wide-SIMD compute architectures. In addition to having authored a large number of ray tracing related papers and code bases Dr. Wald is also the main author of the IVL SPMD Program Compiler for Intel Architectures as well as one of the leading contributors to the open-source Intel SPMD Program Compiler (ISPC) and upcoming Embree 2.0 ray tracing engines.

3.4 Samuli Laine, NVIDIA

Samuli Laine is a Principal Research Scientist and Distinguished Inventor at NVIDIA. He received M.Sc. and Ph.D. degrees in Information

Technology from Helsinki University of Technology, Finland, in 2006. Samuli's research interests include algorithm and architecture design for GPUs, ray tracing, stochastic rendering, and efficient reconstruction of high-quality images from sparse data. He holds graphics technology patents in US, Europe and Asia, and has co-authored numerous conference and journal papers, technical reports, and book chapters.

3.5 Timo Aila, NVIDIA

Timo Aila is a principal research scientist at NVIDIA. His expertise ranges from real-time rendering in computer games (eg. Max Payne, third-party engine development for numerous games, the first commercial occlusion culling library dPVS) to hardware architectures, and recently also to high-quality image synthesis with contributions to the PantaRay rendering system used in Avatar and Tintin. He also gained expertise in mobile graphics as the chief scientist of Hybrid Graphics. Timo has co-authored over 50 articles, patents, and patent applications in the field of graphics technologies.

3.6 Jacco Bikker, NHTV/IGAD Breda

Jacco Bikker is Associate Professor for the Academy of Digital Entertainment of the NHTV University of Applied Sciences in Breda, The Netherlands, and works as an consultant on cloud-based physically-based rendering for OTOY Inc. He received his doctorate degree from the Technical University in Delft. Jacco worked for ten years in the Dutch game industry, and is the author of the Arauna real-time ray tracer and the Brigade real-time path tracer. Arauna and Brigade have been designed specifically with games in mind.

3.7 Christiaan Gribble, SURVICE

Christiaan Gribble is a Research Scientist in the Applied Technology Operation of SURVICE Engineering Company. His work explores the synthesis of interactive visualization and high-performance computing, focusing on algorithms, architectures, and systems for predictive rendering and physics-based simulation. Prior to joining SURVICE in 2012, Gribble served as an Associate Professor of Computer Science at Grove City College. He holds a Ph.D. in computer science from the University of Utah, and has previously served as an Assistant Professor at Grove City, as a post-doctoral fellow and research assistant at the Scientific Computing and Imaging (SCI) Institute, and as a research assistant at the Pittsburgh Supercomputing Center.

3.8 Won-Jong Lee, Samsung

Won-Jong Lee is a senior researcher of SAIT (Samsung Advanced Institute of Technology) and leads a project developing a mobile GPU

based on ray tracing. In SAIT, he has been responsible for various areas involving mobile GPUs: architecture modeling/exploration, simulation framework, and scheduling algorithms for many-core systems. Before joining SAIT, he has researched graphics architecture, visualization algorithms, and parallel rendering systems in Yonsei University and AIST (National Institute of Advanced Industrial Science and Technology). He received Ph.D. degree in computer science from Yonsei University in Korea, wrote more than 20 patents, and published more than 30 papers regarding volume visualization and GPU architecture.

3.9 James A. McCombe, Imagination Technologies

James A. McCombe is an engineer and entrepreneur in the field of parallel computing, hardware architecture and computer graphics. James currently works at Imagination Technologies, a UK based company which, among other technologies, develops the PowerVR GPU which is integrated into many of the mobile phones and tablets on the market today. James is currently working to augment the PowerVR GPU architecture to support ray tracing in constrained, low-power environments with the intention of bringing ray tracing to the broadest possible range of devices. Previously, he was the Founder and Chief Technical Officer of Caustic Graphics where he developed methods for improving computational efficiency in many aspects of a ray tracing system. Imagination Technologies acquired Caustic Graphics in 2010. Prior to this, James was a lead engineer of the mobile and desktop OpenGL graphics system at Apple Computer, contributing to the evolution of programmable shading on GPUs. James A. McCombe holds more than 11 granted patents in the areas of parallel hardware scheduling, numeric representation and spatial data structures.