High-Quality Volume Graphics on Consumer PC Hardware

1 Abstract

Interactive volume visualization in science and engineering is no longer restricted to expensive workstations and dedicated hardware. The fast evolution of consumer graphics driven by entertainment markets has enabled interactive high-quality volume rendering on inexpensive PC platforms. The tutorial targets the growing number of developers who work on specialized implementations of volume rendering algorithms on commodity PC hardware. Participants will learn how to leverage the new features of modern graphics hardware to build high-quality volume rendering applications using OpenGL. The tutorial begins with an detailed introduction to hardware rendering and to the theoretical backgrounds of volume visualization. Several implementations for different graphics boards are explained with examples from working source code. The algorithms are improved and expanded incrementally, covering pre- and post-classification and local illumination techniques. Advanced topics such as multi-dimensional classification, transfer function design, hardware accelerated filtering and volumetric deformation are presented. In the sequel, current state-of-the-art algorithms including pre-calculated ray integration and accelerated ray casting. Practical applications of volume rendering are exemplified by means of several case studies.

2 Level

Beginner – Intermediate

3 Target Audience

The course is aimed at scientific researchers and developers of visualization tools. Course participants should have basic programming skills and should be familiar with OpenGL. Basic knowledge of graphics hardware is helpful but not required.

4 Description

We will present and demonstrate the advantages and disadvantages of the latest approaches for hardware accelerated volume rendering. Participants will

learn how to leverage the new features of modern commodity graphics hardware to build interactive high-quality volume rendering applications. The tutorial starts with an introduction to the principles of volume visualization. The concepts of modern commodity graphics hardware are explained, also covering the relevant OpenGL extensions. Beginning with the most basic 2D and 3D texture-based implementations, the algorithms are improved and expanded step by step, covering local illumination, non-polygonal shaded isosurfaces, pre- and post-classification, transfer function design, interaction, and hardware accelerated filtering. Participants are provided with working OpenGL code samples covering details usually omitted in scientific publications. Our intention is to motivate audience participation with issues such as the tradeoff between interactivity and image quality. We intend to answer questions on the fly since the content of the advanced part of the course can be quite challenging. We feel that it is important to demonstrate these ideas since the reality of implementation can be quite different from the theory presented in the scientific literature.

5 Schedule

8:30 – 9.45	**Introduction**	
	Introduction to volume rendering	[20 min]
	Introduction to graphics hardware	[25 min]
	Texture-based approaches	[30 min]
	Break	
10:15 – 11:30	**Illumination and Classification**	
	Illumination Techniques	[45 min]
	Classification	[30 min]
	Break	
11:45 – 12:15	**Usability**	
	Transfer Function Design	[30 min]
	Lunch Break	
1:45 – 2:45	**Supplements**	
	Volume Deformation	[30 min]
	Hardware-Accelerated Filtering	[30 min]
	Break	
3:00 – 4:15	**Advanced Rendering Techniques**	
	Pre-integration	[30 min]
	Accelerated Ray-Casting	[30 min]
	Break	
4.30 –	**Applications**	
	Case Studies	[30 min]
	Q & A	[30 min]

6 Speaker Biographies

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Markus Hadwiger is a researcher in the "Basic Research in Visualization" group at the VRVis Research Center in Vienna, Austria, and a PhD student at the Vienna University of Technology. The focus of his current research is exploiting consumer graphics hardware for high quality visualization at interactive rates, especially volume rendering for scientific visualization. First results on high quality filtering and reconstruction of volumetric data have been presented as technical sketch at SIGGRAPH 2001, and as a paper at Vision, Modeling, and Visualization 2001. He is regularly teaching courses and seminars on computer graphics, visualization, and game programming. Before concentrating on scientific visualization, he was working in the area of computer games and interactive entertainment. His master's thesis "Design and Architecture of a Portable and Extensible Multiplayer 3D Game Engine" describes the game engine of Parsec (http://www.parsec.org/), a still active cross-platform game project, whose early test builds have been downloaded by over 100.000 people, and were also included on several Red Hat and SuSE Linux distributions.

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Joe Kniss is a masters student at the University of Utah. He is a research assistant in the Scientific Computing and Imaging Institute. His current research has focused on interactive hardware based volume graphics. A recent paper, Interactive Volume Rendering Using Multi-dimensional Transfer Functions and Direct Manipulation Widgets, won Best Paper at Visualization 2001. He also participated on the Commodity Graphics Accelerators for Scientific Visualization Panel, which won the Best Panel award at Visualization 2001. His previous work demonstrates a system for large scale parallel volume rendering using graphics hardware. New results for this work were presented by Al McPherson at the Siggraph 2001 course on Commodity-Based Scalable Visu-

alization. He has also given numerous lectures on introductory and advanced topics in computer graphics, visualization, and volume rendering.

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Christof Rezk-Salama has received a PhD in Computer Science from the University of Erlangen in 2001. Since January 1999, he is a research assistant at the Computer Graphics Group and a scholarship holder at the graduate college "3D Image Analysis and Synthesis". The results of his research have been presented at international conferences, including IEEE Visualization, Eurographics, MICCAI and Graphics Hardware. In 2000, his paper "Interactive Volume Rendering on Interactive Volume Rendering on Standard PC Graphics Hardware" has won the best paper award at the SIGGRAPH/Eurographics Workshop on Graphics Hardware. He has regularly taught courses on graphics programming and conceived tutorials and seminars on computer graphics, geometric modeling and scientific visualization. His PhD thesis with the title "Volume Rendering Techniques for General Purpose Hardware" is currently in print. He has gained practical experience in several scientific projects in medicine, geology and archeology.

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Rüdiger Westermann is a Professor for Computer Science at the University of Technology Aachen. He is the head of the Scientific Visualization and Imaging Group. His research interests include hierarchical methods in scientific visualization, volume rendering of structured and unstructured grids, hardware accelerated image synthesis, flow visualization and parallel graphics algorithms. Westermann persued his Doctoral thesis on multiresolution techniques in volume rendering, and he received a PhD in Computer Science from the University of Dortmund in Germany.

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