SIGGRAPH 96 Course Notes

Wavelets in Computer Graphics

Organizers: Peter Schröder, California Institute of Technology
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Schedule

Morning Session: Introductory Material

Building Your Own Wavelets At Home
Wim Sweldens and Peter Schröder

Chapter 1: *First Generation Wavelets*
Chapter 2: *Second Generation Wavelets*

Afternoon Session: Applications

Chapter 3: *Multiresolution Curves*
Adam Finkelstein and David H. Salesin

Chapter 4: *Multiresolution Painting and Compositing*
Deborah F. Berman, Jason T. Bartell, David H. Salesin

Chapter 5: *Fast Multiresolution Image Querying*
Charles E. Jacobs, Adam Finkelstein, David H. Salesin

Chapter 6: *Multiresolution Surfaces for Compression, Display and Editing*
Tony D. DeRose

Chapter 7: *Wavelet Radiosity: Wavelet Methods for Integral Equations*
Peter Schröder

Chapter 8: *Variational Geometric Modeling with Wavelets*
Steven J. Gortler and Michael F. Cohen

Chapter 9: *Hierarchical Spacetime Control of Linked Figures*
Michael F. Cohen, Zicheng Liu and Steven J. Gortler

Contents

Introduction

Multiresolution techniques and the use of hierarchy have a long history in computer graphics. Most recently these approaches have received a significant boost and increased interest through the introduction of the mathematical framework of wavelets. With their roots in signal processing and harmonic analysis, wavelets have lead to a number of efficient and easy to implement algorithms. Wavelets have already had a major impact in several areas of computer graphics:

- *Image Compression and Processing:* some of the most powerful compression techniques for still and moving images are based on wavelet transforms;
- *Global Illumination:* wavelet radiosity and radiance algorithms are asymptotically faster than other finite element techniques;
- *Hierarchical Modeling:* using multiresolution representations for curves and surfaces accelerates and simplifies many common editing tasks;
- *Animation:* the large constrained optimization tasks which arise in physically based modeling and animation subject to goal constraints can be solved faster and more robustly with wavelets;
- *Volume Rendering and Processing:* wavelets can greatly facilitate dealing with huge data sets since they can be used for compression as well as feature detection and enhancement;
- *Multiresolution Painting:* using multiresolution analysis one can build efficient "infinite" resolution paint systems;
- *Image Query:* using a small number of the largest wavelet coefficients of an image results in a perceptually useful signature for fast search and retrieval.

Some of the very recent and most exciting generalizations and extensions of classical wavelet constructions have been developed by researchers in the context of graphics applications.

Following the success of the wavelets courses at SIGGRAPH 94 and 95 and based on the experiences of the organizers and lecturers, it was decided to hold another wavelets course at SIGGRAPH 96. Since new wavelet constructions now exist, which are easy to implement and do not require any heavy mathematical machinery to describe, the course will be accessible to those who do not have any prior knowledge of wavelets or a strong background in mathematical Fourier theory.

Lecturers' Biographies

Peter Schröder is an assistant professor of computer science at the California Institute of Technology, Pasadena. He received a BS in mathematics from the Technical University of Berlin in 1987 and his Master degree from the MIT Media Lab in 1990. After working for Thinking Machines Corporation on massively parllel graphics algorithms he studied computer graphics under Pat Hanrahan at Princeton Unviversity and received his PhD in 1994 for research on wavelet based algorithms for illumination computations. Most recently he was a postdoctoral research fellow at the University of South Carolina under the direction of Bjorn Jawerth. He has worked extensively in the area of wavelet based methods for many graphics related problems, and made fundamental contributions in this area. The Alfred P. Sloan Foundation named him as one of their Research Fellows this year. He has also received an NSF Young Investigator Award for work on wavelets in computer graphics. His work on the subject has appeared from venues such as SIGGRAPH to WIRED magazine and he has lectured widely in Europe and the US on the subject including previous SIGGRAPH courses.

Wim Sweldens is a researcher at the Mathematics Center of Lucent Technologies (formerly AT&T) Bell Laboratories. He received his PhD in May 1994 from the Katholieke Universiteit Leuven, Belgium, for his work on wavelet constructions and applications in numerical analysis. Until May 1995 he was a postdoctoral research fellow at the University of South Carolina where he worked with Peter Schröder and Bjorn Jawerth. In his PhD dissertation he introduced the notion of "Second Generation Wavelets," a generalization of classical wavelets which allows wavelet transforms for irregularly sampled data and data defined on complex geometries. Later he discovered the "Lifting Scheme," a very general and easy to implement construction of Second Generation Wavelets, which can also be used to introduce wavelets without the use of Fourier analysis. More recently, his work has been concerned with the application of wavelets to computer graphics. He has lectured widely on wavelets and their applications throughout Europe and the United States as well as in two previous SIGGRAPH courses. He is the founder and current editor of the Wavelet Digest, a newsletter on the Internet concerned with wavelets.

Michael F. Cohen is curently a member of the research staff at Microsoft. He came to Microsoft from Princeton University where he was an Assistant Professor of Computer Science. Michael received his PhD in 1992 from the University of Utah. He also holds undergraduate degrees in Art from Beloit College and in Civil Engineering from Rutgers University. He began his career in computer graphics at Cornell University where he received an MS in 1985. Dr. Cohen also served on the Architecture faculty at Cornell University and was an adjunct faculty member at the University of Utah. His recent work has focused on spacetime control for linked figure animation and variational modeling methods. He is perhaps better known for his work on the radiosity method for realistic image synthesis as discussed in his recent book "Radiosity and Image Synthesis" (co-authored by John R. Wallace). His current interests range from linked figure animation, to image capture and synthesis, to intelligent camera control, and image based rendering. Michael has published widely and presented his work internationally in these and other areas.

Tony DeRose is currently a member of the Tools Group at Pixar Animation Studios. He received a BS in Physics in 1981 from the University of California, Davis; in 1985 he received a Ph.D. in Computer Science from the University of California, Berkeley. He received a Presidential Young Investigator award from the National Science Foundation in 1989. In 1995 he was selected as a finalist in the software category of the Discover Awards. From September 1986 to December 1995 Dr. DeRose was a Professor of Computer Science and Engineering at the University of Washington. From September 1991 to August 1992 he was on sabbatical leave at the Xerox Palo Alto Research Center and at Apple Computer. He has served on various technical program committees including SIGGRAPH, and from 1988 through 1994 was an associate editor of ACM Transactions on Graphics. His research has focused on mathematical methods for surface modeling, data fitting, and more recently, in the use of multiresolution techniques. Recent projects include surface reconstruction from laser range data and multiresolution/wavelet methods for high-performance computer graphics.

David Salesin teaches Computer Science and Engineering at the University of Washington, Seattle, where he has recently been promoted to Associate Professor. He received his ScB from Brown University in 1983, his PhD from Stanford University in 1991, and joined the faculty at the University of Washington in the fall of that year. From 1983-86, he worked at Lucasfilm, where he contributed computer animation for the Academy Award-winning short film, "Tin Toy," and the feature-length film Young Sherlock Holmes. He spent the 1991-92 year on leave as a Visiting Assistant Professor in the Program of Computer Graphics at Cornell University. In 1993, he received an NSF Young Investigator award. In 1995, he received an ONR Young Investigator Award and was named an Alfred P. Sloan Research Fellow and an NSF Presidential Faculty Fellow. Professor Salesin's research interests are in computer graphics, and include photorealistic image synthesis and computer-generated illustration in particular. He has had a major impact on the use of wavelets in computer graphics and is co-author (with Eric Stollnitz and Tony DeRose) of the forthcoming book "Wavelets for Computer Graphics" (Morgan-Kaufman).