Spatial Data Representations for Rapid Visualization and Analysis

A Dissertation Presented

by

LORI LYNNE LEMANCZYK SCARLATOS

to

The Graduate School

in Partial Fulfillment of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

in

COMPUTER SCIENCE

STATE UNIVERSITY OF NEW YORK

AT STONY BROOK

August 1993

Abstract of the Dissertation

Spatial Data Representations
for Rapid Visualization and Analysis

by

Lori Lynne Lemanczyk Scarlatos

Doctor of Philosophy

in

Computer Science

State University of New York

at Stony Brook

1993

Spatial data representations help to describe the world that we live in. Inherent characteristics of spatial data — multi-dimensionality and typically large volumes — make the representation of this information an interesting problem. As spatial data play ever greater roles in time-critical applications, demands on the data representations also increase.

The work described in this dissertation addresses three current problems with spatial data representations. First is the need for data representations that support multiple scales and precisions without losing critical information. Second is a requirement for spatial operations to exploit filtering techniques to improve performance. Third is a desire for merging techniques that will allow different data representations to exist separately yet work together so that different data representations may be used to their best advantage.

Three triangulation methods are presented. An adaptive hierarchical triangulation algorithm generates a structure with fixed levels of detail with a specified accuracy. The tree structure of this triangulation hierarchy supports pruning and filtering, and is therefore the basis of the manipulation algorithms described in the remaining chapters. Another method, curvature equalization, improves existing triangulations by ensuring that smooth areas are represented by relatively few triangles, and rough areas are represented by many more. This method is used to produce a good initial tessellation for the adaptive hierarchical triangulation. A distinguishing characteristic of all three methods is that they attempt to generalize critical lines on the surface with the triangle edges.

Algorithms for three spatial operations exploiting the adaptive hierarchical triangulation's tree structure are given.These operations — zoom, multi-resolution viewing, and line of sight calculation — represent typical time-critical visualization and analysis applications.

Techniques for merging the adaptive hierarchical triangulation with other data representations are described. These, too, exploit tree structures to improve performance of the merging algorithms. A significant contribution here is the polygonal line sweep, which can find all triangles inside an area without having to examine them all.

Table of Contents

List of Figures

List of Tables

Acknowledgements

First, I wish to thank my advisor, Theo Pavlidis, who taught me what it means to do important research. He has been a great source of knowledge and inspiration for me. I never cease to learn from his example.

I am forever indebted to Herb Tesser. Over the years he has been a great teacher, advisor, mentor, boss, and friend. Without his influence, I never would have written this dissertation.

Many thanks to Geoffrey Gardner, who encouraged me to write my first conference paper. He, too, is a great friend, source of inspiration, and role model.

I am grateful to Rob Kelly for encouraging me to pursue the PhD while working in his department; and to Jay Mendelsohn for making me welcome in his lab and getting me started on the triangulation models.

Heartfelt thanks go out to my many other friends, colleagues and teachers who have offered me encouragement, ideas, knowledge, advice, and inspiration. Among these are Anita Beadon, Steve Cento, Keith Clarke, Venkat Devarjaran, David Eames, Jay Fiacco, Arie Kaufman, John Litke, Joe Mitchell, Bill Sakoda, Hanen Samet, Mike Sieverding, Steve Skiena, Dave Southard, Paul Taub, Tom Triscari, and Bill Verts.

On a personal note, I want to thank my family for all of their encouragement. I especially commend my dad for persistently cutting out all those computer graphics articles for me. I thank Loriann and Mark Cody for moral and technical support; and Terri and Chris and Anne and Phil for their hospitality during my years at NYU. Thanks are also due to my many other wonderful friends who, with their jam sessions and other diversions, kept me sane.

My fellow students at Stony Brook will always hold a special place in my heart. Together we studied, shot pool, and helped each other over the hurdles of graduate school. Their comraderie made my years at Stony Brook all the more enjoyable.

Most of all, I want to thank my husband, Tony. Through thick and thin he’s always stood by me. I couldn't have done it without him.

To all the others who have touched my life, yet are not listed here, I thank you, too. I am no less grateful.

Finally, I thank God.