Mathematics and Visualization

Hans-Christian Hege
Konrad Polthier
Gerik Scheuermann

Editors

Topology-Based Methods in Visualization II

With 89 Figures, 78 in Color and 10 Tables

Springer

Editors

Hans-Christian Hege
Konrad-Zuse-Zentrum für Informationstechnik Berlin
Devision Scientific Computing
Department Visualization and Data Analysis
Takustraße 7
14195 Berlin
Germany
hege@zib.de

Konrad Polthier
Freie Universität Berlin
Institut für Mathematik
Arnimallee 6
14195 Berlin
Germany
polthier@mi.fu-berlin.de

Gerik Scheuermann
Universität Leipzig
Fakultät für Mathematik und Informatik
Institut für Informatik
Postfach 100920
04009 Leipzig
Germany
scheuermann@informatik.uni-leipzig.de

ISBN 978-3-540-88605-1 e-ISBN 978-3-540-88606-8

Mathematics and Visualization ISSN 1612-3786

Library of Congress Control Number: 2008938960

Mathematics Subject Classification (2001): 37-04, 37-E35, 37E45, 68U05

Cover design: deblik, Berlin

Cover picture by Nelson Max and Tino Weinkauf

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

springer.com

Preface

Visualization research aims to provide insight into large, complicated data sets and the phenomena behind them. While there are different methods of reaching this goal, topological methods stand out for their solid mathematical foundation, which guides the algorithmic analysis and its presentation. Topology-based methods in visualization have been around since the beginning of visualization as a scientific discipline, but they initially played only a minor role. In recent years, interest in topology-based visualization has grown and significant innovation has led to new concepts and successful applications. The latest trends adapt basic topological concepts to precisely express user interests in topological properties of the data.

This book is the outcome of the second workshop on *Topological Methods in Visualization*, which was held March 4–6, 2007 in Kloster Nimbschen near Leipzig, Germany. The workshop brought together more than 40 international researchers to present and discuss the state of the art and new trends in the field of topology-based visualization. Two inspiring invited talks by George Haller, MIT, and Nelson Max, LLNL, were accompanied by 14 presentations by participants and two panel discussions on current and future trends in visualization research.

This book contains thirteen research papers that have been peer-reviewed in a two-stage review process. In the first phase, submitted papers where peer-reviewed by the international program committee. After the workshop accepted papers went through a revision and a second review process taking into account comments from the first round and discussions at the workshop.

About half the papers concern topology-based analysis and visualization of fluid flow simulations; two papers concern more general topological algorithms, while the remaining papers discuss topology-based visualization methods in application areas like biology, medical imaging and electromagnetism.

The book starts with two articles demonstrating the use of finite-time Lyapunov exponents (FTLE) in the visualization of fluid flow simulations (Garth et al., Sadlo and Peikert). The third paper focuses on the calculation of separation surfaces in realistic CFD simulations (Wiebel et al.). It is followed

by a paper on topology-based support for the visual analysis of complicated molecules in biology using isosurfaces (Bajaj et al.). The calculation of contour trees for scalar fields on arbitrary meshes is shown by Carr and Snoeyink. Pathline attributes are suggested as an extension of well-known topological concepts to unsteady fields by Shi et al. Salzbrunn and Scheuermann use flow structures based on streamline predicates to select representative streamlines in three- dimensional flows. Max and Weinkauf present a method that is guaranteed to find all critical points of a field generated by a finite set of point charges and they demonstrate its use in the study of electrical fields around molecules. Since the study of chaotic dynamical systems is a real challenge, Krauskopf et al. present a robust algorithm for the calculation of global manifolds; furthermore they demonstrate it, applying it to the well-known Lorenz system. Three applications of topological methods to fluid flow problems follow: first, a topology-guided analysis of vortex breakdown including an approximate analytical model is given (Rütten and Böhme). Second, an article by Peikert and Sadlo studies vortex rings using Poincaré sections. The third article, authored by Laramee et al., identifies several tasks for topological methods in industrial computational fluid dynamics (CFD) analysis based on specific examples. Finally, the contribution by Thomas Wischgoll shows the use of vector field topology for the calculation of center lines in medical imaging data.

Overall, the book presents an informative overview of current research in topology-based visualization and provides insight into various specific research topics.

Acknowledgments

TopoInVis 2007 was organized by the Computer Science Institute of the University of Leipzig, the Zuse Institute Berlin (ZIB) and the Institute of Mathematics of the Freie Universität Berlin. We greatly acknowledge support from the DFG Forschungszentrum Matheon. We thank all contributors of this volume for the careful preparation of their manuscripts. Special thanks go to Karin Wenzel, Monika Meiler and Alexander Wiebel for their work behind the scenes and help in the production process of this volume.

We are looking forward to the next TopoInVis workshop in February 2009 in Snowbird, Utah.

Berlin and Leipzig,
September 2008

Hans-Christian Hege
Konrad Polthier
Gerik Scheuermann

Contents