Preface

Over the past few decades, scientific research became increasingly dependent on large-scale numerical simulations to assist the analysis and comprehension of physical phenomena. This in turn has led to an increasing dependence on scientific visualization, i.e., computational methods for converting masses of numerical data to meaningful images for human interpretation.

In recent years, the size of these data sets has increased to scales which vastly exceed the ability of the human visual system to absorb information, and the phenomena being studied have become increasingly complex. As a result, scientific visualization, and scientific simulation which it assists, have given rise to systematic approaches to recognizing physical and mathematical features in the data.

Of these systematic approaches, one of the most effective has been the use of a topological analysis, in particular computational topology, i.e., the topological analysis of discretely sampled and combinatorially represented data sets. As topological analysis has become more important in scientific visualization, a need for specialized venues for reporting and discussing related research has emerged.

This book results from one such venue: the *Fourth Workshop on Topology Based Methods in Data Analysis and Visualization (TopoInVis 2011)*, which took place in Zürich, Switzerland, on April 4–6, 2011. Originating in Europe with successful workshops in Budmerice, Slovakia (2005), and Grimma, Germany (2007), this workshop became truly international with TopoInVis 2009 in Snowbird, Utah, USA (2009). With 43 participants, TopoInVis 2011 continues this run of successful workshops, and future workshops are planned in both Europe and North America under the auspices of an international steering committee of experts in topological visualization, and a dedicated website at http://www.TopoInVis.org/.

The program of *TopoInVis 2011* included 20 peer-reviewed presentations and two keynote talks given by invited speakers. Martin Rasmussen, Imperial College, London, addressed the ongoing efforts of our community to formulate a vector field topology for unsteady flow. His presentation *An introduction to the qualitative theory of nonautonomous dynamical systems* was highly appreciated as an illustrative introduction into a difficult mathematical subject. The second keynote, *Looking for intuition behind discrete topologies*, given by Thomas Lewiner, PUC-Rio,

Rio de Janeiro, picked up another topic within the focus of current research, namely combinatorial methods, for which his talk gave strong motivation. At the end of the workshop, Dominic Schneider and his coauthors were given the award for the best paper by a jury.

Nineteen of the papers presented at *TopoInVis 2011* were revised and, in a second round of reviewing, accepted for publication in this book. Based on the major topics covered, the papers have been grouped into four parts.

The first part of the book is concerned with computational discrete Morse theory, both in 2D and in 3D. In 2D, Reininghaus and Hotz applied discrete Morse theory to divergence-free vector fields. In contrast, Günther et al. present a combinatorial algorithm to construct a hierarchy of combinatorial gradient vector fields in 3D, while Gyulassy and Pascucci provide an algorithm that computes the distinct cells of the MS complex connecting two critical points. Finally, an interesting contribution is also made by Reich et al. who developed a combinatorial vector field topology in 3D.

In Part 2, hierarchical methods for extracting and visualizing topological structures such as the contour tree and Morse-Smale complex were presented. Weber et al. propose an enhanced method for contour trees that is able to visualize two additional scalar attributes. Harvey et al. introduce a new clustering-based approach to approximate the Morse–Smale complex. Finally, Wagner et al. describe how to efficiently compute persistent homology of cubical data in arbitrary dimensions.

The third part of the book deals with the visualization of dynamical systems, vector and tensor fields. Tricoche et al. visualize chaotic structures in area-preserving maps. The same problem was studied by Sanderson et al. in the context of an application, namely the structure of magnetic field lines in tokamaks, with a focus on the detection of islands of stability. Jadhav et al. present a complete analysis of the possible mappings from inflow boundaries to outflow boundaries in triangular cells. A novel algorithm for pathline placement with controlled intersections is described by Weinkauf et al., while Wiebel et al. propose glyphs for the visualization of nonlinear vector field singularities. As an interesting result in tensor field topology, Lin et al. present an extension to asymmetric 2D tensor fields.

The final part is dedicated to the topological visualization of unsteady flow. Kasten et al. analyze finite-time Lyapunov exponents (FTLE) and propose alternative realizations of Lagrangian coherent structures (LCS). Schindler et al. investigate the flux through FTLE ridges and propose an efficient, high-quality alternative to height ridges. Pobitzer et al. present a technique for detecting and removing false positives in LCS computation. Schneider et al. propose an FTLE-like method capable of handling uncertain velocity data. Sadlo et al. investigate the time parameter in the FTLE definition and provide a lower bound. Finally, Fuchs et al. explore scale-space approaches to FTLE and FTLE ridge computation.

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We are looking forward to the next *TopoInVis* workshop, which is planned to take place in 2013 in North America.

Ronald Peikert
Helwig Hauser
Hamish Carr
Raphael Fuchs

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