Preface

The deluge of data observed throughout research and industry has turned the analysis of the resulting information into the primary limiting factor for the rapid progress of science, engineering, and medicine. The field of visualization strives to tackle this data analysis challenge by devising visual representations that afford users an effective interface with their datasets. Driven by the explosion in data size and complexity experienced over the last decade, a prominent trend in today's visualization research applies a data abstraction approach to yield high-level depictions emphasizing various salient properties of the phenomenon considered. Topology-based methods have proved especially compelling in this regard, as the topological abstraction provides a common mathematical language to identify remarkable structures in a broad range of applications and semantic contexts. Topological concepts and metaphors are therefore permeating the visualization literature and they are the focus of a significant research effort spanning theoretical, algorithmic, and practical aspects.

This book describes the research that was presented during the third *Workshop on Topological Methods in Data Analysis and Visualization*, which took place in Snowbird, Utah, on February 23-24, 2009. Following two successful, seminal *TopoInVis* workshops held in Europe, the 2009 edition was organized in the United States in response to the growing international interest in topological methods. As in previous years, this event offered international experts the opportunity to present their ongoing research in an informal and inspiring atmosphere, as well as to discuss the emerging trends and open challenges of the field. A defining feature of the 2009 edition was the attention paid to applications, reflecting the importance of topological techniques in practical data analysis scenarios and the increased prominence of problem-driven research. The workshop featured two eminent invited speakers (Herbert Edelsbrunner, Duke University, and Jackie Chen, Sandia National Laboratory), who gave exciting lectures highlighting significant accomplishments and promising avenues for both fundamental and applied research on topological methods. All in all, *TopoInVis '09* was a resounding success thanks to the excellent contributions of over 60 participants.

Each of the 20 research papers contained in this book was accepted for presentation at the workshop after careful peer-review by the international program committee. The contents are organized in 5 main themes that correspond to major research directions.

The first part is concerned with the theoretical foundations of the topological approach. Jordan et al. apply topological concepts to the precise visualization of 1-manifolds, while Kälberer et al. employ the topology of a tubular surface to define a globally consistent stripe texture. Edelsbrunner and his co-authors prove the stability of apparent contours (i.e. silhouettes) under the erosion distance and Dillard et al. study the topologically consistent reconstruction of cell complexes from cross-section images.

The second part of the book focuses on hierarchical topological data structures, as required by the analysis of very large datasets. Vivodtzev et al. present a new technique for the topology-preserving simplification of very large tetrahedral meshes. Guylassy et al. propose several improvements to the computation of Morse-Smale complexes in the context of feature detection algorithms, while Comić and De Floriani introduce two simplification operators for Morse complexes applicable in arbitrary dimensions. Suthambhara and Natarajan consider the simplification of Jacobi sets from a level set and offset manifold perspective, and Reininghaus and Hotz describe a novel combinatorial framework for the topological analysis of 2D vector fields.

The third part deals with the algorithmic extraction of topological structures of interest in vector and tensor fields. Kasten et al. put forward a Galilean invariant notion of critical points that captures significant patterns in turbulent flows, while Obermaier and his co-authors propose an algorithm for the segmentation of three-dimensional grid-less flow simulations. Sreevalsan-Nair et al. study the impact of the interpolation scheme on the topological structure of 2D eigenvector fields. Finally, Sadlo et al. present a new method for the efficient computation of Lagrangian coherent structures in unsteady flows.

The following part is dedicated to practical applications of topological methods in data analysis and visualization. Grottel et al. consider defect detection in crystal structures; Keller and his co-authors apply a user-assisted multi-scale technique to the detection of salient features in LiDaR datasets. Wiebel et al. report on the shortcomings of existing topological approaches in the analysis of rotation-mediated cell aggregation and propose a novel solution to this problem. Szymczak applies category theory to the robust segmentation of airways from CT scans, while Bajaj and his co-authors visualize the complementary space of complex geometric models to resolve subtle structures with applications to uncertainty and dynamics visualization.

The book concludes with two papers that specifically consider the challenges posed by the topological analysis of very large datasets produced by state of the art combustion simulations. Mascarenhas et al. present a combinatorial streaming algorithm for the efficient characterization of topological features in large-scale datasets, which they apply to the comparison of terascale combustion simulations. Weber and his co-authors propose a novel technique, leveraging Reeb graphs to study the temporal evolution of burning regions in simulated flames.

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