Preface

Since Helman and Hesselink's landmark paper on vector topology in 1989, topological analysis has formed an increasingly important part of scientific visualization. This is not only because it opens up novel forms of understanding but also because as our data has increased past terascale, machine analysis necessarily substitutes for laborious human inspection of visualizations. More and more, one can argue that data analysis precedes rather than succeeds visualization and that topological analysis is one of the key approaches given its strong mathematical underpinnings, precise answers and verifiable outcomes.

From its early starts in vector field topology, topological visualization has expanded to embrace analysis of scalar fields in the form of contour trees, Reeb graphs and Morse-Smale complexes, analysis of abstract graphs and high-dimensional data and, most recently, analysis of multivariate fields through Jacobi sets, Reeb spaces and the joint contour net, linking with the mathematical field of fibre topology in the process.

Topological visualization is, however, not concerned only with the topological computation per se. One of the strongest features of the community is its focus on the full range of theoretical understanding, algorithmic advances and application work, all of which are represented in this volume.

Starting in 2005, biennial workshops have been held on topological visualization in Budmerice (2005), Grimma (2007), Snowbird (2009), Zürich (2011), Davis (2013) and Annweiler (2015), where informal discussions supplement formal presentations and knit the community together. Notably, these workshops have consistently resulted in quality publications under the Springer imprint which form a significant part of the working knowledge in the area.

In the most recent workshop (2015), at Kurhaus Trifels in Annweiler, Germany, bivariate analysis, Reeb spaces and fibre topology increased in importance, anchored by keynotes from Professor Osamu Saeki (Kyushu), one of the leaders in fibre topology, and Professor Kathrin Padberg-Gehle (Lüneburg), who works on computational methods for nonlinear dynamical systems.

Of the 23 papers presented at TopoInVis 2015, 20 passed a second-round review process for this volume. In addition, Professor Saeki contributed a survey of the relevant fibre topology to this volume for the benefit of the community, which we expect to shape approaches to data visualization in future years, and a further paper was contributed directly to this volume.

We have grouped this paper in Part I with the two most closely related papers. Of these, one deals with multi-modal analysis in a particular application domain (atmospheric impacts of volcanic eruptions). The other deals with joint contour nets (a quantized approximation of fibre topology) and their relation to analysis based on Pareto set analysis.

We have then collected papers relating to high-dimensional data in Part II. Here, the first paper applies scalar field topology to optimization problems, based on the common description of optimization as a search landscape. In contrast, the second paper discusses algorithms for computing and visualizing merge trees (one of the principal forms of scalar analysis) in high-dimensional data. These are grouped with a paper that considers the relative quality of different measures applied to reduce the dimensionality of the data.

Part III then collects papers that use scalar topology in relatively low-dimensional spaces (i.e. three-dimensional space). Here, the first paper compares similarity between scalar fields, using histograms as summaries of geometric information to supplement the underlying topological analysis. The second paper is more applied in nature, as it addresses a practical domain problem—how to track diffusion of ions into a battery material, using Morse-Smale analysis, to identify the potential diffusion channels. Lastly, the third paper addresses the inverse problem of (re-)constructing a scalar field from a known Morse-Smale complex.

Where Part III deals with scalar fields, Part IV considers vector and tensor fields. Here, while the broad strokes of the analysis are well-understood, actual computation of topological invariants has a number of practical problems. At the heart of these is the tension between formal mathematical expression of continuous models and practical numerical computation. The papers in this part therefore primarily address issues of discontinuity and degeneracy in the analysis process.

Of these, the first paper deals with issues at the boundary of flow fields through computation of escape maps, while the second computes similarity measures between nearby integral curves to detect regions of shared behaviour. A third paper extends existing ideas for decomposition of vector fields, in order to underpin a future generation of algorithmic approaches, while a fourth paper extends existing mathematical analysis of tensor fields as a preliminary to developing new techniques.

Part V then considers a theme common to many of the newest approaches—indirect detection of topological features to avoid the numerical problems of early methods. Here, the goal is to detect coherent structures in a variety of contexts and use them as the basis of the visualization. The best known techniques for this use finite time Lyapunov exponents (FTLEs), and three of these papers extend these techniques, while the fourth considers related computations.

In the first paper on FTLEs, they are used to detect regions of topological change as a scalar field, which is then subjected to a second round of topological analysis to detect ridge features. The second paper builds on the observation that not all topological boundaries are equally important and maps secondary evaluations to these boundaries to aid in interpretation. The third paper considers an orthogonal but crucial issue—the effect of approximation on this form of analysis. Lastly, the remaining paper considers alternate measures of topological importance, replacing FTLEs with stochastic computations based on transfer operators.

The last part, Part VI, is devoted to papers that are more explicitly about algorithms or software engineering. Here, the first paper is about the selection of thresholds for topological analysis, while the second considers the software instruction necessary for practical deployment of topological techniques. A third paper looks at improving the computation of merge trees in a distributed setting, while the last paper considers knotted graphs, an area of topology not previously represented in the TopoInVis community.

We note that these areas have followed a common pattern in development—initially, there were only one or two papers published on flow topology, but over time, they expanded and triggered the development of the TopoInVis workshop. Later, new techniques were introduced, in particular the detection of coherent structures using finite-time Lyapunov exponents, and we now see this separating as a related but different topic.

Equally, the first TopoInVis workshop did not involve a significant amount of scalar topology, but this area has increased over time and is represented primarily in Parts I and II, since Reeb and Morse analyses are sufficiently well-developed to justify two distinct areas. This growth then triggered developments in analysis of high-dimensional data: hence Part V.

It is therefore encouraging to see the development of fibre topology and multivariate analysis as an emerging theme in topological visualization, as it shows that the pattern continues. Equally, we have started to see work submitted on the peculiar software engineering challenges of topology, and we expect this theme to develop further in future.

As with any workshop, however, the measure of quality is not the breadth of the papers, nor the number of people attending, but whether new ground is being broken. Here, the pattern of development is clear, and we confidently look forward to additional themes emerging in future TopoInVis workshops.

We would like to thank all of the participants in TopoInVis 2015, as well as Springer, for their continued support and look forward to further developments in all of these areas.

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