Preface

In this book, we attempt to capture the excitement and inspiration that has been generated during a series of Dagstuhl Seminars that have looked at visualization and processing of tensor fields. This book includes contributions from attendees of the third meeting held in July 2009. As in the two earlier volumes, the authors report on recent research results as well as opining on future directions for the analysis and visualization of tensor fields. Topics range from applications of the analysis of tensor fields to purer research into their mathematical and analytical properties. One of the goals of this seminar was to bring together researchers from along the axis between pure and applied research, identifying new multidisciplinary research challenges. This book, we hope, will continue to further that goal in a broader context.

The manuscript is organized into seven parts. The parts, to some degree, increase in dimensionality and in mathematical sophistication. One change we implemented in this third in a series of Dagstuhl seminars is that it no longer restricts the underlying data models to second-order tensor fields. Research on representations that go beyond second-order tensors are clearly necessary, as became more evident during the seminars.

Part I, "Structure-Tensor Computation," focuses primarily on the generation of the so-called structure tensor to characterize image structure information. This information is often needed for feature preserving image processing techniques. The chapters present generalizations of the methodology of classic structure tensor estimation and its application beyond scalar fields.

Part II, "Tensor-Field Visualization," presents three results that extend our ability to generate, utilize, and visualize tensor fields. One looks at fabric like visualizations on surfaces. The second uses a Lagrangian metaphor to show the structure of 3D tensor fields. The third presents methods for designing tensor fields that have different applications in visualization such as realizing sampled texture fields.

Part III, "Applications of Tensor-Field Analysis and Visualization," offers contributions from researchers in disciplines where the application of analysis and visualization of second-order tensor fields is relevant. These applied domains include the simulation of combustion and the measurement of material elasticity using magnetic resonance imaging.

Part IV, “Diffusion Weighted MRI Visualization,” breaks out one scientific area where second-order tensor fields are often applied. The chapters in this part show techniques for the specific study of diffusion tensor fields produced from magnetic resonance imaging, typically of the brain. These tensor-valued images capture properties of the brain white matter and, therefore, its structural connectivity. Brain connectivity is complex and difficult to understand. These chapters take a step in making that understanding easier. The last chapter especially focuses on uncertainty visualization of features derived from the tensor field, which is a recently emerging research topic.

Part V, “Beyond Second-Order Diffusion Tensor MRI,” expands the complexity of the underlying data model used in the earlier chapters. Despite the challenges of working with second-order tensor valued images, the use of second-order tensors has limitations. In diffusion weighted imaging, it implies a model of the underlying anatomy and physics that is not sufficiently accurate in some situations. In this part, models that are more accurate or provide more information are presented. In diffusion weighted imaging, they also require more complex acquisition and processing. As the chapters in this part exemplify, some of the research in this field focuses on limiting the extra complexity.

In Part VI, “Tensor Metrics,” some of the challenges of working with sampled tensor fields are addressed. Tensor fields are intrinsically defined over a continuous Euclidean space, and yet they must be represented for computation in some finite way. Typically, this is done by sampling them spatially, keeping only one tensor for each small region of an image. Furthermore, distance measures are needed for several common image processing techniques, e.g., interpolation, segmentation, and registration. However, the distance or metric between tensors is not uniquely defined. The three chapters in this part discuss some of the consequences of various choices for these distances.

Finally, in Part VII, “Tensor Analysis,” two mathematical areas are presented that were judged to have relevance to researchers at this seminar, but which were not widely known to them in advance. These two chapters offer moderately deep introductions to the areas with the hope of stimulating cross-disciplinary collaborations.

We hope that these offerings will, overall or individually, inspire in readers some of the enthusiasm and energy that the seminar brought to its participants.

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