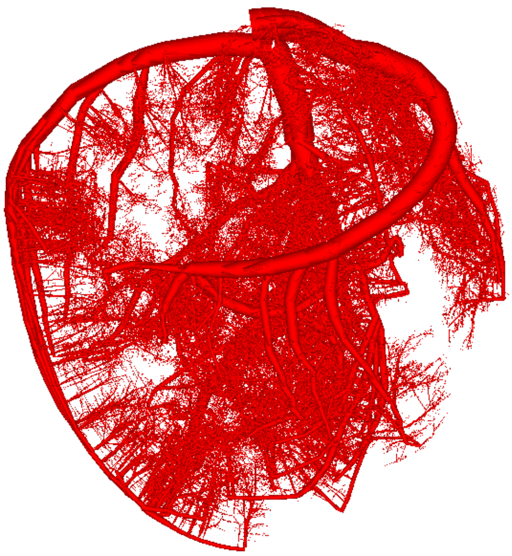
Scientific Visualization: Advanced Concepts

Edited by

Hans Hagen



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Preface

The Schloss Dagstuhl seminars on Scientific Visualization provide a dynamic setting for ongoing and future research in visualization. Numerous contributions in this active field originated at Schloss Dagstuhl, and were extended to large-scale collaborative research and high-impact works. This volume of the Dagstuhl Follow-Ups series contains the proceedings from two seminars in 2005 and 2007, as well as updated papers on topics related to talks from the 2007 seminar. Many of these works represent updated research and results on the topics that were initiated in the 2005 and 2007 seminars.[1]

Scientific Visualization (SV) is concerned with the use of computer-generated images to aid the understanding, analysis and manipulation of data. Since its beginning in the early 90's, the techniques of SV have aided scientists, engineers, medical practitioneers, and others in the study of a wide variety of data sets including, for example, high performance computing simulations, measured data from scanners (CAT, MR, confocal microscopy), internet traffic, and financial records. Somewhat as a result of these past successes, matters are changing for research in SV. The data sets are becoming massive in size, complex and multi-dimensional in nature and the goals and objectives of the visualization much less precisely defined, but yet the results are needed with higher urgency and importance. The multi-resolution and hierarchical methods of today do not scale to these new data sets. The segmentation and knowledge extraction methods of today need to be completely revamped in order to be useful. Because of the changes that are taking place in SV, it was and is important that a group of senior researchers meet with select junior researchers to map out the future research agenda for this critical area.

One of the important themes being nurtured under the aegis of Scientific Visualization is the utilization of the broad bandwidth of the human sensory system in steering and interpreting complex processes and simulations involving voluminous data sets across diverse scientific disciplines. Since vision dominates our sensory input, strong efforts have been made to bring the mathematical abstraction and modeling to our eyes through the mediation of computer graphics. This interplay between various application areas and their specific problem solving visualization techniques was emphasized in the seminars.

Reflecting the heterogenous structure of Scientific Visualization, the selected papers of this Dagstuhl Follow-Ups volume focus on the following topics:

- **Visual Analytics:** The fields of information analysis and visualization are rapidly merging to create a new approach to extracting meaning from massive, complex, evolving data sources and stream. Visual analytics is the science of analytical reasoning facilitated by interactive, visual interfaces. The goal of visual analytics is to obtain insight into massive, dynamic and often conflicting pieces and formats of information; to detect the expected and to discover the unexpected; and to yield timely assessments with evidence and confidence levels.
- **Quality Measures:** It is vital for the visualization field to establish quality metrics. An intrinsic quality metric will tremendously simplify the development and evaluation of

[1] See `http://www.dagstuhl.de/05231` and `http://www.dagstuhl.de/07291` for details on the corresponding Dagstuhl Seminars.

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various algorithms. The establishment of quality metrics will also advance the acceptance and use of visualization in industrial and medical applications.

- **Ubiquitous Visualization:** As ubiquitous computing is getting increased attention, also visual display of everywhere available data is necessary. Challenges include: heterogeneous output devices, novel interaction metaphors, network bandwidth (availability, reliability), graceful degradation of algorithms with respect to largely varying resources, in vivo visualization (real time, no pre-processing, robust).
- **Multifield and Multiscale Visualization:** The output of the majority of computational science and engineering simulations is typically a combination of fields, so called multifield data, involving a number of scalar fields, vector fields, or tensor fields. Similarly, data collected experimentally is often multifield in nature (and from multiple sources). The ability to effectively visualize multiple fields simultaneously, for both computational and experimental data, can greatly enhance scientific analysis and understanding. Multiscale problems with scale differences of several orders of magnitude in CFD, nanotechnology, biomedical engineering and proteomics pose challenging problems for data analysis. The state of the art in multiscale visualization considerably lags behind that of multiscale simulation. Novel solutions to multiscale and multifield visualization problems have the potential for a large impact on scientific endeavors.
- **Categorical Visualization:** Information and knowledge is extremely difficult to extract from multi-valued, multi-dimensional, multi-modal and multi-layered categorical data. These data sets abound today and the pay-offs for understanding them are substantial. Mathematical techniques based upon functional relationships break down requiring completely new paradigms to visualize these types of data sets.
- **Intelligent/Automatic Visualization:** Ever-increasing data sizes require semi-automatic methods that concentrate on the typically very small portion of the relevant information in the data. Techniques include model- and knowledge-based segmentation, classification in abstract feature spaces, computation of saliency information from derived data characteristics, automatic detection of important isosurfaces, automatic creation of expressive transfer functions, automatic landmark selection and automatic path and navigation guidance.
- **Point-based/Mesh-free Visualization:** A typical strategy to visualize unorganized multidimensional data sets is to transform the data into standard geometric primitives of triangles and triangular mesh surfaces prior to rendering. This intermediate step is time consuming, but necessary to map the data set to standard (hardware and software) graphics primitives. With the recent advances in point-based rendering, new efficient and creative approach for visualizing scattered and unorganized data sets are potentially possible.

Hans Hagen