Visualization Case Studies: Drawing a Roadmap for Future Visualization

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Visualization has become an indispensable tool for scientific researchers to understand their data and communicate their findings. Appropriate visualization tools often lead scientists to new insights more quickly. Today, both instrument and computing technologies advance quickly, enhancing scientists' capability to study problems of increasing scale and complexity. Consequently, visualization technology must be improved and extended to take on the new challenges created by state-of-the-art application problems.

Case study sessions held at the annual IEEE Visualization Conference provide a unique arena where visualization researchers, application scientists, and visualization facilitators meet and exchange their experience. Here, they present imaginative applications of existing visualization techniques to real-world problems, visual data analysis strategies (how visualization can help to analyze a problem, which visualization tools to use, and how to use them), and comparative studies of different visualization techniques. They can exchange results and talk about their successes, failures, and the lessons learned in the process. Participants suggest new challenges for research and provide important feedback and evaluation of visualization technology—strong motivation for new visualization research and system design. Therefore, case studies are considered a vital part of the conference program.

For this special issue we selected five case studies spanning a broad range of applications, from mechanical design, nuclear physics, terascale computing, and underwater observation to weather forecasting. These completely rewritten articles include substantial extensions of the work presented at Visualization 98. One article (by Cook et al.) is not based on work presented at the conference, but was submitted directly to *CG&A*.

In computer-aided mechanical design, the ability to visualize the interaction between the parts of a system helps derive an optimal design. Sacks, Pisula, and Joskowicz suggest simplifying the typical contact analysis problems by visualizing part motions and contacts in a configuration space, as commonly used in robot motion planning. They relate the configuration space geometry to the mechanical function of the parts in terms of simple graphics. While they demonstrate their success in offering designers qualitative information about mechanical function, they also present new challenges to obtain further insights about the design problems.

Scientific visualization is particularly valuable in generating images of invisible phenomena that scientists try to perceive. Mapping numerical data into meaningful representations, scientists can more readily comprehend what the data reveals. The atomic nucleus is several orders of magnitude smaller than an atom. Cook, Hayashi, and Yoshida developed an interactive nuclear visualization software system that provides a consistent visual representation for a variety of theoretical models of nuclear structure. The software allows depicting the nuclei as particle structures in a fashion similar to molecular graphics. For research and educational purposes, it achieves a better comparison and understanding of different models of nuclear structure and dynamics.

The case study by Chapman, Wills, Stevens, and Brookes introduces visualization of sonar data for underwater surveying. They show that transforming high-resolution bathymetric sonar data into pictures for interactive viewing can provide excellent facilities for underwater inspection, planning, and design of undersea objects and structures. Their work offers a good example of replacing direct observation with exploration of virtual worlds—impossible or costly without computer visualization.

The US Department of Energy's Accelerated Strategic Computing Initiative (ASCI) program aims to ensure the safety, security, and reliability of the nation's nuclear stockpile by replacing nuclear testing with computer simulations. ASCI applications use extremely high-fidelity computer models and teraflop computing facilities to generate terabytes of raw data. These data are then analyzed by scientists who rely on the visualization capabilities being developed within the ASCI program. Heermann describes an effort at the Sandia National

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Laboratory to develop a production visualization environment capable of handling the terascale of ASCI data. He points out that optimizing one particular stage alone, or at the expense of another stage in the visualization pipeline, may not result in better overall performance. In particular, for such a demanding application, every stage in the visualization pipeline must be parallelized to eliminate any bottleneck created by a serial process.

Bringing many of the state-of-the-art visualization techniques from research curiosity to operational use proves just as challenging as developing the individual techniques. Treinish, with his knowledge of the requirements for visualizing meteorology data, identifies four classes of visualization for operational weather forecasting based on a task decomposition approach. He shows how this task-driven customization of visualization content and interface can match specific user goals. He also explains how to generalize this concept to other application domains.

The goal of this special issue is to inform you about these new applications of visualization technology. These case studies demonstrate the power of computer visualization in comprehending physical phenomena otherwise impossible to observe. In addition, they show how existing visualization techniques can be customized by following the unique requirements of the application and of different user groups. Finally, they illustrate how coupling multiple capabilities or reorganizing tasks can enhance the effectiveness of the techniques. These articles can help to draw a roadmap for future research in visualization: new visualization techniques, improved methodologies, and new visualization architectures fit to deal with data analysis at new levels of scale and complexity.

We hope you will find these articles as inspiring as we did. ■

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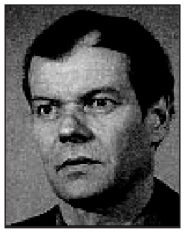

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Call for Submissions to Visualization Viewpoints

We invite submissions to *IEEE CG&A*'s Visualization Viewpoints. The department covers technical opinions on and the use of visualization techniques. It highlights the many diverse fields using graphical, imaging, and other methods of visualization to understand results from research, engineering, business, and other areas. Articles offer detailed technical opinions on trends in visualization or reports on how visualization has contributed to the comprehension of data.

The department recently expanded its charter to encompass discussions of challenges or limitations in today's methods and areas for potential new topics for research. Application writeups that focus on the physical, life, or social sciences, engineering, or commerce are welcome, as are those relating to the process of visualization in general. For application writeups, the editors strongly encourage an emphasis on lessons learned from practical experience.

Criteria cover the uniqueness of the contribution, length (two to four magazine pages), quality of figures, and format. Most articles include an introduction to the field in which the visualization techniques are applied or the context of the technical opinion, the actual visualizations, and the results—what has been learned, other techniques that could be used or should be developed, and future goals of the project.

A full author guide appears on the Web at http://computer.org/cga/edguide.htm#visualization. Contact department editors Theresa-Marie Rhyne (rhyne.theresa@epa.gov) and Lloyd Treinish (lloydt@us.ibm.com) by e-mail with questions or submissions.