Can We Determine the Top Unresolved Problems of Visualization ?

Panel Organizer & Presenter:
Theresa-Marie Rhyne, North Carolina State University

Panelists:
Bill Hibbard, University of Wisconsin at Madison
Chris Johnson, University of Utah
Chaomei Chen, Drexel University
Steve Eick, SSS-Research Inc. & University of Illinois at Chicago

INTRODUCTION:

Many of us working in visualization have our own list of our top 5 or 10 unresolved problems in visualization. We have assembled a group of panelists to debate and perhaps reach concensus on the top problems in visualization that still need to be explored.

We include panelists from both the information and scientific visualization domains. After our presentations, we encourage interaction with the audience to see if we can further formulate and perhaps finalize our list of top unresolved problems in visualization.

Keywords: visualization, top unresolved problems

POSITION STATEMENTS:

The Panel Organizer's Viewpoint

Theresa-Marie Rhyne:

One of the key unresolved challenges in visualization is collaboration in its broadest sense. How does our discipline effectively transfer its concepts and methods to specific domain scientists and experts who desire to apply visualization techniques? Does the Renaissance Team concept work as we extend visualization methods to hardware designed for computer games and mobile devices? Can there be an effective interchange between the information visualization and scientific visualization communities. Do Open Source visualization tool solutions provide for the creation of online communities? Collaboration in inter-disciplinary and intra-disciplinary ways is key to addressing these challenges.

Scientific Visualization Viewpoints

Bill Hibbard:

In the May 1999 VisFiles column in the SIGGRAPH newsletter, I set out a list of my top ten visualization problems. That list looked forward to the problems that have to be solved to create the radically different sort of information infrastructure that we expect 30 or 40 years from now. The list I present at the Visualization '04 Conference will reflect back at five problems, some high-minded and some grubby and gritty, that drove my visualization work.

A mix of high-minded ideas and grubby reality is what any new technology faces in order to become a practical reality. One of my old bosses had a rule of thumb for how long a new technology takes to mature: count the number of distinct kinds of experts who have to own a piece of it, and multiply by five years. This has turned out pretty consistent with my experience.

Chris Johnson:

Leonardo Da Vinci: ***Study the science of art and the art of science***

Scientific visualization as it is currently understood and practiced is still a relatively new discipline. As a result, we visualization researchers are not necessarily accustomed to undertaking the sorts of self-examinations that other scientists routinely undergo in relation to their work. What are the most important research issues facing us? What underlying assumptions need to be challenged and perhaps abandoned? What practices need to be reviewed?

I have been assembling my own list of the research issues I consider to be the most important ones facing researchers in scientific visualization. These were presented at IEEE Visualization 2003, Graphics Interface 2003, the AHPCRC Workshop on Graphics, Modeling, and Visualization and the 2003 Dagstuhl Workshop on Visualization. They were summarized in [1]. Here is my list of top unresolved problems in visualization. Because of space constraints, I'll elaborate on the first few in the list.

1. **Think About the Science –** Too often, creators of visualization technology do not spend enough (or any) time trying to understand the underlying science they are trying to visually represent. Visualization "scientists" need to spend more time understanding the underlying science/engineering/medical applications in order to create effective visual representations. Similarly, creators of visualizations need to understand more about the needs of the end users/observers.

2. **Quantify Effectiveness –** The majority of papers in visualization involve new techniques for characterizing scalar, vector, or tensor fields. However, the new

IEEE Visualization 2004
October 10-15, Austin, Texas, USA
0-7803-8788-0/04/$20.00 ©2004 IEEE

techniques are rarely compared with previous techniques, and their effectiveness is seldom quantified by user studies. Similarly, it is rarely the case the effectiveness of new methods is quantified within the computer graphics literature. In order to "evolve" visualization (as well as graphics) into a more scientific enquiry, visualization scientists need to understand and use the scientific method:

- Observation and description of a phenomenon or group of phenomena.

- Formulation of an hypothesis to explain the phenomena.

- Use of the hypothesis to predict the existence of other phenomena, or to predict quantitatively the results of new observations.

- Evaluation of the proposed methods and quantification of the effectiveness of their techniques.

3. **Error and Uncertainty Visual Representation** – When was the last time you saw an isosurface with ``error bars'' or streamlines with ``standard deviations'' or volume visualizations with representations of ``confidence intervals?'' With few exceptions, visualization research has ignored the visual representation of errors and uncertainty for three-dimensional visualizations. However, if you look at highly peer-reviewed science and engineering journals, you will see that the majority of two-dimensional graphs represent error and/or uncertainty within the experimental or simulated data. Why the difference? Clearly, if it is important to represent error and uncertainty in two-dimensional graphs it is equally important to represent error and uncertainty in two and three-dimensional visualizations. It is also often important to quantify error and uncertainty within new computer graphics techniques.

4. **Perceptual Issues** – The research on the human visual system is vast, yet visualization researchers rarely study or apply what is known about the visual system when designing visualization techniques. There is much to be gained by studying the biophysics and psychophysics of the visual system.

5. **Graphics Hardware Issues –** Lately there has been an explosion of papers and codes written on taking advantage of Graphics Processing Units (GPUs). In order to make GPUs effective, we need to make them easier to program so that we can integrate them into visualization and graphics algorithms. As a community, we tend to shift back and forth between largely focusing our efforts on graphics rendering hardware or focusing on software rendering. Seemingly, the largest benefits will be seen by integrating the best techniques from hardware and software rendering solutions.

6. **HCI –** Effective human computer interaction continues to be one of the top research and development goals for both visualization and computer graphics.

7. **Global/Local Visualization (Details within context)**
8. **Integrated PSEs (Pipeline complexity)**
9. **Multi-field Visualization**
10. **Sci-Info Visualization Integration**
11. **Interesting Feature Detection**
12. **Time Dependent Visualization**
13. **Distributed Visualization**
14. **Theory of Visualization**

References

[1.] C. Johnson, "Top Scientific Visualization Research Problems", in the Visualization Viewpoints Department (T-M. Rhyne, editor), IEEE Computer Graphics & Applications, Los Alamitos, California, Vol. 24, No. 3, (July/August, 2004), pp. 13 – 17.

Information Visualization Viewpoints

Chaomei Chen:

Information visualization deals with a broad range of interrelated activities involving data, computation, and human users. From a user's point of view, information visualization is a means to an end. Its primary purpose is to convey features and patterns of underlying data to the user so that one can make discoveries, identify salient connections, and gain valuable knowledge. The human-centric standing point underlines the importance of a better understanding of human perceptual, cognitive, behavioral, and social capabilities in a holistic way. We still have not reached the stage that one can analytically and systematically breakdown a user task to its perceptual components, cognitive components, and behavioral components. Until we can extract elementary perceptual and cognitive tasks, hyperbolic trees to botanic trees are apples to oranges, even if they visualize the same data in the same data structures.

The human-centric perspective also implies that we must take into account the pragmatic values and practical significance of the ultimate end to which the design and evaluation of information visualization acquire their meanings in the first place. To information visualization, problems and applications from other disciplines are lifeblood that vitalizes and energizes the field; they are essential for a healthy growth. Information visualization needs its 'teapot' and its 'storm' to show case its techniques and methodologies and make hand-shakes to the promising lands where no information visualization applications have gone before. Adapt, or die.

There are also pressing challenges concerning with data and computation, including scalability, high-speed fast-response interactive information visualization, and special-purpose underlying mechanisms that can detect and sharpen subtle patterns and track trends over time. Valuable inputs are expected to come from similarly technically oriented scientific communities such as scientific visualization and knowledge discovery and data mining.

Stephen G. Eick:

This position paper identifies three key issues for information visualization that interest me and are important to the field.

1. **Visual Scalability** is the capability of an information visualization to display large datasets, either in terms of the number of dimensions, number of data points, number of time periods, etc. The problem is that conventional visualization techniques are easily overwhelmed by datasets

that can be readily manipulated on desk-top PCs. With the widespread computerization of business and government, collecting massive datasets is easy and fast networks provide ready access to massive datasets. For Information visualizations to be useful in future environments with massive datasets, their scalability must be increased by two to three orders of magnitude.

2. **Visualization techniques for new data structures** extend information visualizations beyond the data table which comes from the relational database model. Much of the historical thinking in the information visualization research community framed the visualization problem in terms of table where the rows correspond to the observations and the columns to measurements or statistics. A more interesting challenge is to develop new information visualization techniques for non traditional data structures such as multi-dimensional data cubes, streaming data, transformed data, etc.

3. **Identifying commercial opportunities for** information visualizations. Although perhaps not of general interest, some of us are interested in building information visualization software companies. As with any new discipline there have been a few notable successes and many failures. The problem for information visualization entrepreneurs is to identify interesting niches that can support commercial businesses.

BIOGRAPHICAL SKETCHES FOR PANELISTS:

Theresa-Marie Rhyne: (tmrhyne@ncsu.edu)

Theresa-Marie Rhyne is Coordinator of Special Technology Projects in Learning Technology Service at North Carolina State University. From 1990 - 2000, she was a government contractor (initially for Unisys Corporation (1990 - 1992) and then for Lockheed Martin Technical Services (1993 - 2000)) at the United States Environmental Protection Agency's (US EPA) Scientific Visualization Center. She was the founding visualization expert at the Center. In April 2001, she joined the Distance Education and Learning Technology Applications (DELTA) unit at North Carolina State University (NCSU) as a multimedia/visualization specialist. In July 2003, her title with DELTA/LTS was changed to Coordinator of Special Technology Projects.

She was the Lead Conference Co-Chair for IEEE Visualization 1998 and the Past Conference Co-Chair for IEEE Visualization 1999. She serves on the Editorial Board of IEEE Computer Graphics & Applications (IEEE CG&A) and is editor of the Visualization Viewpoints department for IEEE CG&A. She is also a senior member of IEEE. Her specialties include streaming media, internetworked 3D computer graphics, the application of art techniques to visualization, collaborative-networked visualization, environmental sciences visualization, geographic visualization and, most recently, bioinformatics visualization.

Bill Hibbard: (billh@ssec.wisc.edu)

Bill Hibbard is an Emeritus Senior Scientist from the University of Wisconsin who led the development of Vis5D, Cave5D and VisAD. He was a member of the Program Committee of the IEEE Visualization Conferences from their inception in 1990 until 2001. He is now primarily interested in machine and natural intelligence.

Chris Johnson: (crj@sci.utah.edu)

Professor Johnson directs the Scientific Computing and Imaging Institute at the University of Utah where he is a Professor of Computer Science and holds faculty appointments in the Departments of Physics, and Bioengineering. His research interests are in the area of scientific computing. Particular interests include inverse and imaging problems, adaptive methods, problem solving environments, large scale computational problems in medicine, and scientific visualization. Professor Johnson was awarded a Young Investigator's (FIRST) Award from the NIH in 1992, the NSF National Young Investigator (NYI) Award in 1994, and the NSF Presidential Faculty Fellow (PFF) award from President Clinton in 1995. In 1996 he received a DOE Computational Science Award and in 1997 received the Par Excellence Award from the University of Utah Alumni Association and the Presidential Teaching Scholar Award. In 1999, Professor Johnson was awarded the Governor's Medal for Science and Technology.

Chaomei Chen (Chaomei.Chen@cis.drexel.edu)

Chaomei Chen is an Associate Professor in the College of Information Science and Technology at Drexel University. He received his B.Sc in Mathematics from Nankai University, China, in 1983, his M.Sc in Computation from the University of Oxford, UK, in 1991, and his Ph.D. in Computer Science from the University of Liverpool, UK, in 1995. He is a visiting professor in the Department of Information Systems and Computing at Brunel University, UK. His current research interests are information visualization and its use in analyzing the evolution of a scientific field, detecting and tracking scientific breakthroughs and emerging trends, and tracing knowledge diffusion across disciplinary boundaries. He is the Editor-in-Chief of *Information Visualization* and the author of *Information Visualization: Beyond the Horizon* (Springer 2004) and *Mapping Scientific Frontiers: The Quest for Knowledge Visualization* (Springer 2003). He was the recipient of the ISI/ASIST Citation Research Award in 2002.

Stephen G. Eick: (eick@sss-research.com)

Dr. Stephen Eick is currently an adjunct professor at University of Illinois at Chicago (Computer Science) and is the Deputy Directory of UIC's National Center for Data Mining. He is also the president and founder of SSS Research, Inc. a software startup focused on providing visualization technology to help analysts overcome complexity in massive information sets. SSS Research is a boutique visualization research company that is involved with projects that including DARPA and ARDA.

Eick is one of the founders of Information Visualization research, helped start IEEE's Information Visualization Symposium, and has published over 75 refereed research papers. Previously, he started and led the Visualization Research group at Bell Labs, where he was very successful, both from the research perspective and on having impact on AT&T and Lucent's Business Units. Eick is a fellow of the American Statistical Society, has received 26 patents, and has won many awards for his technology including the Bell Lab's President's award and the 2000 Computer-world Smithsonian award for key technologies that change the way people live and work.