In the Eye of the Beholder: The Role of Perception in Scientific Visualization

Panel Organizer:
Kelly Gaither, The University of Texas at Austin

Panelists:
David Ebert, Purdue University
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Bill Geisler, The University of Texas at Austin (Center for Perceptual Systems)
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INTRODUCTION

The evolution of computational science over the last decade has resulted in a dramatic increase in raw problem solving capabilities. This growth has given rise to advances in scientific and engineering simulations that have put a high demand on tools for high-performance large-scale data exploration and analysis. These simulations have the potential to generate large amounts of data. Humans, however are relatively poor at gaining insight from raw numerical data, and as a result, have used visualization as a tool for understanding, interpreting and exploring data of all types and sizes. Allowing for efficient visual explorations of data, however, requires that the ratio of knowledge gained versus the cost of the visualization be maximized. This, in turn, mandates the integration of principles from human perception. Understanding perception as it relates to visualization requires that we understand not only the biology of the human visual system, but principles from vision theory, and perceptual psychology as well. This panel is the result of bringing together practioners and researchers from a broad spectrum of interests relating to the ability to maximize the amount of information that is effectively perceived from a given visualization. Position statements will be given by researchers interested in perceptual psychology and the perception of natural images, integrating art and design principles, non-photorealistic rendering techniques, and the use of global illumination methods to provide benefical perceptual cues.

Keywords: perception, visualization, human visual system

POSITION STATEMENTS

Bill Geisler

Vision is the process of deriving information about the environment from light that is either emitted, reflected or transmitted by the materials in the environment. Emitted and reflected light is an excellent source of information about the environment. For example, it provides detailed information about the shape, solidity, material composition, distance, and motion of objects. However, extracting this information from the light reaching a vision system is an extraordinarily difficult problem. Most vision systems must draw all of their inferences about the environment from just one or a couple of two-dimensional images formed by an optical system.

The human visual system is exceptionally complex. Although substantial progress has been made in understanding our vision, the science is still in its infancy. The complexity of the visual system and our incomplete understanding of its operation inhibit our ability to develop effective visualizations of complex multi-variate and multi-dimensional data.

David Laidlaw

Perceptual psychologists and visual designers both study how people understand what they see. Perceptual psychologists study with the goal of understanding the visual system. The knowledge that they have gathered tells visualization developers a lot about how to make effective tools. Visual designers study with the goal of learning how to make effective visual displays. In many ways, this is more directly applicable to visualization developers because the goals of the designers and the developers are more similar.

I'll talk about several projects where the visualization lab at Brown has been collaborating with visual designers. In some contexts we have found that visual designers can replace user studies in evaluating visualization methods – and visual designers are both faster and more informative. We have also tried to include visual design experts directly in the visualization tool development process. Unfortunately, this has been a somewhat frustrating process, primarily because tools are not available to let designers work, particularly for large-scale exploratory visualization tools. I'll talk about some of the limitations that we have found.

David Ebert

The overriding goal of visualization is the effective transmission of relevant information to the user through their visual perception system. Therefore, we are developing perceptually-motivated techniques to increase the effectiveness of volume visualization for large multivariate datasets. Since the human visual system has evolved over centuries to understand our three-dimensional world based on interaction of light with physical objects, utilizing advanced three-dimensional illumination, shading, shadowing, and scattering techniques can help improve three-dimensional perception of datasets. I'll describe the work we have been doing for more than ten years in advanced volume rendering methods based on physics-based illumination, scattering, and translucency.

Unfortunately, even with advanced volume rendering techniques, users can still be overwhelmed by the complexity and massive amount of data displayed in a visualization. Therefore, we have also been adapting techniques from technical and medical illustration into our visualization work. Effective illustrations are tremendously successful at concisely representing the essential information that the user needs to gain from the illustration, providing just enough contextual information, and focusing the user's attention on the most significant portion of the image. I'll describe our work in

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volume illustration that adapts and extends many traditional illustration and artistic techniques to make more effective visualizations of complex data. Through the use of various illustration techniques, varying amounts of rendering detail, combinations of illumination techniques, and volume highlighting, volume illustrations can be produced that are most appropriate for the task at hand.

Kelly Gaither

The role of global illumination techniques in visualizing scientific data is a topic of debate in the visualization community. Broadly speaking, the community is divided into two groups. The first group is composed of those that consider global illumination techniques unnecessary, computationally expensive, and in some cases a detractor from the underlying information present in the data. The second group is composed of those that consider global illumination a viable method for leveraging beneficial perceptual cues in the pursuit of increased insight into the data.

With the increase in capability of modern graphics hardware, it is now conceivable that global illumination techniques will run at interactive frame rates in the not too distant future. This opens the door for visualization practitioners and developers to explore new visualization methods that offer additional perceptual cues achievable only with global illumination.

We have been conducting research to examine the advantages and disadvantages of using global illumination techniques for data visualization, and to identify the beneficial perceptual cues unique to these methods. I will discuss our preliminary findings and the resulting implications with respect to using global illumination methods in visualization.

Biographical Sketches

David Ebert

David Ebert is an Associate Professor in the School of ECE at Purdue University and received his Ph.D. from the Computer and Information Science Department at The Ohio State University in 1991. His research interests are scientific, medical, and information visualization, computer graphics, animation, and procedural techniques. Dr. Ebert performs research in volume rendering, illustrative visualization, minimally immersive visualization, realistic rendering, procedural texturing, modeling, and animation, and modeling natural phenomena. Ebert has been very active in the graphics community, teaching courses, presenting papers, chairing the ACM SIGGRAPH 97 Sketches program, co-chairing the IEEE Visualization '98 and '99 Papers program, serving on the ACM SIGGRAPH Executive Committee and serving as Editor-in-Chief for IEEE Transactions on Visualization and Computer Graphics. Ebert is also editor and co-author of the seminal text on procedural techniques in computer graphics, Texturing and Modeling: A Procedural Approach, whose third edition was published in December 2003.

Kelly Gaither

Kelly Gaither is the Associate Director of the Texas Advanced Computing Center and a Research Scientist at The University of Texas at Austin. She directs the research, development and service activities for the visualization group. She received her Ph.D. in Computational Engineering from Mississippi State University in May 2000. While obtaining her Ph.D., she worked full time at the Simulation and Design Center in the National Science Foundation Engineering Research Center as the leader of the visualization group. Prior to her doctorate work, she was a Computer Science student at Texas A&M University, receiving her Bachelors degree in 1988 and her Masters degree in 1992. Dr. Gaither has a number of refereed publications in fields ranging from Computational Mechanics to Supercomputing Applications to Scientific Visualization. She has given a number of invited talks. Over the past ten years, she has actively participated in the IEEE Visualization Conference, and is currently the 2004 lead conference co-chair. Her research interests include feature detection, perceptual issues in visualization, global illumination methods for visualizing scientific data and large scale data analysis.

Bill Geisler

Bill Geisler is a professor in the Department of Psychology, the director of the Center for Perceptual Systems, and the holder of the David Wechsler Regents Chair in Psychology. He received his Ph.D. from the Indiana University before coming to The University of Texas at Austin. Dr. Geisler's research interests span a number of topics in vision and visual perception. In his lab, scientific questions are attacked with multiple techniques: psychophysics (behavior), neurophysiology (n collaboration with Albrecht), and mathematical and computational modeling. For a number of years, he has been interested in the problem of perceptual organization; that is, how the visual system finds and represents the structure that exists in visual scenes.

David Laidlaw

David Laidlaw is a Professor of Computer Science at Brown University. He conducts interdisciplinary research into robust and effective computer science and visualization tools to solve problems in biology, fluids, medical imaging, archaeology, geology, geography, and other disciplines. Collaborative work with colleagues in these areas guides the research and provides a mechanism for evaluating the usefulness and robustness of results. David received his Ph.D. in Computer Science from California Institute of Technology in 1995, where he researched biological applications of computer graphics and created new computer graphics modeling and animation techniques to collect better MRI data. He received his Masters in Computer Science from California Institute of Technology in 1992, a Masters in Computer Science from Brown University in 1985, and a Bachelors in Computer Science from Brown University in 1983. In 2003, David was awarded the Henry Merritt Wriston Teaching Fellowship.