The Visualization Process: The Path from Data to Insight

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Abstract

While previous Visualization panels have focused on different methods for scientific visualization, this panel focuses on the process of transforming data into insight. The overarching goal for visualization is to transform data into information or knowledge. This goal, however, can be somewhat elusive and difficult to achieve. The purpose of this panel is to discuss a variety of approaches that range from traditional to those that are new and emerging. Each of the given panelists is keenly interested in extracting relevant knowledge and information from a given set of data. However, each panelist takes a very different approach, and each has a different process by which visualization bears insight. David Ebert is inspired by the effectiveness of illustration and experimental photography techniques to convey knowledge. Kelly Gaither is keenly rooted in the physical meaning behind the data and uses this knowledge to guide the choice and style of visual representation. Pat Hanrahan is interested in self-illustrating phenomena and new approaches to visualizing streams of data such as network flows, migrations of birds and people, and flow of goods and traffic. Daniel Weiskopf is exploring the impact of color, motion, and interactivity on the visualization process. His approaches are traditional in nature but incorporate advances in graphics hardware.

Keywords: perception, self-illustrating phenomena, visualization

Position Statements

Kelly Gaither

Visualization has fueled the growth and understanding of many scientific and engineering fields. In computational fluid dynamics, for example, engineers now use numerical calculations to accurately simulate many engineering problems that once required the use of physical experiments involving wind and water tunnels. The increased capability in the simulation tools and the complexity in the range of problems has resulted in more data, thus increasing the need for better storage capabilities and most importantly, improved analysis tools. Unlike the explosive growth in computational power, visualization tools for these large simulations have evolved more modestly, failing to keep pace with the simulation capabilities and resulting data analysis requirements.

Most visualization tools today, however, fail to relieve the user from the task of sifting through a huge volume of low-level (physically irrelevant) details. Because this low-level data overwhelms the computational resources and the user's senses, these tools are impractical for very large data sets. We have been researching two options to alleviate this burden, thereby decreasing the time to insight and increasing the user's return on their investment of time and effort. Feature detection methods can be used to focus in on areas of interest, and improved visualization techniques that draw on both the physical meaning in the data and the perceptual properties of the human visual system produce stunning visualizations that transform data to insight.

David Ebert

From Data to Insight: Appropriateness and Perception are Key!

Our approach to enable insight from data is to determine the appropriate representation that is tailored to the user, the display, and the user's task. Understanding perceptual principles, the user's perceptual preferences (e.g., form dominance vs. color dominance), the user's expertise, task, and display capabilities are necessary to convey information effectively. Extracting principles from illustration, design, perception and experimental photographic techniques (e.g., Schlieren photography), we have designed systems to succinctly capture and convey information to solve the problem at hand and provide insight from the data. I'll describe the approach we have taken, our guiding principles, and some initial results of our work in this area.

Daniel Weiskopf

I believe that the observation of natural phenomena can be a good starting point for developing useful visualization methods that pave a path from data to insight. For example, nature provides compelling visual displays of the water flow in rivers or the motion of ice fields in glaciers. On more technical grounds, experimental visualization of fluid flow leads to an intuitive understanding of fluid motion. The same fundamental metaphor is successfully used in computer-generated visualization, for example, for the advection of virtual dye. On more abstract grounds, the observation of nature can be generalized to visual thought experiments that even display phenomena that would never be observable without a computer. Visual experiments are particularly useful for visual communication: Here, visual experiments are most appropriate because they just need everyday experience and common sense and do not rely on cultural conventions or educational background. For example, visual experiments have been very successful in visualizing special and general relativity for a broader public.

In addition to visual communication, computer-based visualization primarily targets data exploration. Exploration is typically performed by expert users that have a thorough understanding of their data sets. Here, visualization often rests upon pattern matching capabilities of the human observer to detect features or anomalies. Therefore, knowledge of perception mechanisms is crucial for the design of visualization methods. For example, texture-based flow visualization such as LIC makes use of receptive fields for spatial frequencies and orientations. Interactivity is another most important aspect: The user can incorporate domain knowledge by interactively specifying features of a data set—typically on top of previous automatic feature extraction. In conclusion, I believe that the chances of finding completely novel and useful visual mappings are rather low, especially for scientific visualization, which has become a mature field of research. It is more promising to use traditional visual mapping methods and advance them by perception-guided design and by incorporating them in an improved interactive visualization process.

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Pat Hanrahan

A self-illustrating phenomena is an image that exposes the science behind the phenomena (I first saw this term in H. Robin's book, "The Scientific Image"). Some famous examples are pictures of magnetic force fields shown with iron filings, stationary points of the modes of vibration of a violin where sand particles collect, stress in a mechanical part revealed through birefringence, and particle tracks in a bubble chamber. Such images brilliantly combine experimental design, analysis, and visualization. Quoting J. Tukey, "the general purposes of conducting experiments and analyzing data match, point by point." I will argue that computer tools for visual analysis often can be conceived of as computational visual experiments; and that the visualizations should be designed to help validate or invalidate the hypothesis being tested by the experiment.

Biographical Sketches

Kelly Gaither

Kelly Gaither is the Associate Director for Research and Development of the Texas Advanced Computing Center and a Research Scientist at The University of Texas at Austin. Gaither 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. Gaither 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 2005 outgoing conference cochair. Her research interests include feature detection, perceptual issues in visualization, global illumination methods for visualizing scientific data and large scale data analysis.

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.

Daniel Weiskopf

Daniel Weiskopf recently joined the Computing Sciences faculty at Simon Fraser University. Prior to his tenure at Simon Fraser, Daniel was at the University of Stuttgart where he was on the research staff at the Institute for Visualization and Interactive Systems. Weiskopf's research interests include visualization of special relativity, virtual relativity, visualization of general relativity, interactive volume rendering, perception-oriented graphics and visualization and texture-based vector field visualization. Weiskopf has numerous publications spanning these interests.

Pat Hanrahan

Pat Hanrahan is the CANON USA Professor of Computer Science and Electrical Engineering at Stanford University where he teaches computer graphics. Hanrahan's current research involves visualization, image synthesis, and graphics systems and architectures. Before joining Stanford, Hanrahan was a faculty member at Princeton. He has also worked at Pixar where he developed volume rendering software and was the chief architect of the RenderMan(TM) Interface - a protocol that allows modeling programs to describe scenes to high quality rendering programs. Previous to Pixar Hanrahan directed the 3D computer graphics group in the Computer Graphics Laboratory at New York Institute of Technology. Professor Hanrahan has received three university teaching awards, two Academy Awards for Science and Technology, the Spirit of America Creativity Award, the SIGGRAPH Computer Graphics Achievement Award, and the SIGGRAPH Stephen A. Coons Award. He was recently elected to the National Academy of Engineering.

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