Improving Visualization: Theoretical and Empirical Foundations

Stephen M. Kosslyn, Chair
Department of Psychology
Harvard University, Cambridge, MA

Nahum D. Gershon
Center for Civil Systems
The MITRE Corporation, McLean, VA

Haim Levkowitz
Institute for Visualization and Perception Research
University of Massachusetts at Lowell, Lowell, MA

Justin D. Pearlman
Harvard Medical School and
Massachusetts Institute of Technology, Cambridge, MA

Introduction

Computers have provided us with new ways of creating visual images from abstract and non-abstract data. The quality of the visualization performed by these innovative tools does not depend solely on computer hardware and software, but also on the perceptual qualities of the human being present in front of the screen. As long as there is this human interface link, understanding how humans perceive information visually could help improve the quality and the effectiveness of the visualization process. Reaching out to the fields of visual physiology, psychophysics, and cognitive psychology could not only explain why human vision is so efficient, but also how to create better images and what could be the limitations of particular representations. The panel will discuss practical issues of how the understanding of visual perception could help improve the scientific visualization process and results.

Panelists Statements

Practical Aspects of Perception and Visualization
Nahum D. Gershon

Data represented in a visual form is used for visual analysis of data and for scanning data for existence of desired features. Researchers and analysts examining data displays would like to detect regions of specified data values (e.g., high, medium, or low), their locations, and shapes. The problem of detecting the existence of patterns, locations, and shapes could be difficult especially in low resolution browse sets where one would like to be able to scan large quantities of fuzzy data as fast as possible and detect features efficiently.

Understanding human visual perception provides with ways to improve the visualization process and to create new ways to represent data visually. For example, perception of shape and symmetry of an object embedded in the data depends on the orientation of the object relative to the viewer. This means that when scanning data for familiar shapes and symmetries of features, one has to look at the data from different orientations. To allow viewing the data from different orientations, developers should create fast algorithms for orienting data on the screen.

Detection of features present in fuzzy data could be difficult not only because the data is fuzzy but also because current display devices are inefficient. However, if one could use the flexibility of display devices to feed information through pre-attentive visual processes, one would enable the user to perceive the desired information efficiently and fast. Methods discussed are based on the sensitivity of the human visual system to motion and the ease at which electronic display devices could change their display.

Graph Design For the Eye and Mind
Stephen M. Kosslyn

It is often said that a picture is worth a thousand words. But this is not always true; if one cannot

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decipher it, a picture is not worth even a dozen words. Pictures may be hard to fathom not only when they are too small or blurry, but also when the material in them is not organized in a way we can comprehend easily. The worst offenders may be graphs, pictures that are intended to convey information about numbers and relationships among numbers.

This talk develops 11 principles based on research in psychology that can be used to guide the construction of visual displays. Although the emphasis is on graphs, the principles are equally valid for all displays. The principles are introduced in the context of a discussion of specific brain systems. The talk is organized around processes that orient attention reflexively, that segregate figure from ground, that encode object properties (shape, color, texture), that encode spatial properties (location, size, orientation), that use object and spatial properties to access information in memory, and--finally--that use stored information to guide top-down search for additional information in a display.

Is Color Going to Improve Visualization?
Haim Levkowitz

Using color instead of monochrome gray levels might degrade the resulting visualization. This is because once color is introduced, the number of possibilities increases exponentially as compared with the monochrome situation. In these cases, many of the color possibilities do not produce good visualization. However, there are many color techniques that, in the appropriate situation, could increase substantially the effectiveness of the resulting visualization. The main question is how could the effective conditions be found among this ocean of possibilities and how to avoid the ones that will degrade the results. Fortunately, color vision and perception have been studied for quite some time now, and there is a large body of knowledge that can guide the user in the right direction (or in the wrong one, if one is not knowledgeable). The problem is that most implementors and problem-solvers take this part of the visualization process for granted; they assume their "gut feeling" is sufficient to guide them to the optimal direction. One example is the persistent use of color schemes that "look pretty" (e.g., highly saturated colors with their known fatigue problems) rather than those that have been tested objectively. Another one is the use of the RGB model for color specification instead of perceptual models, which are more suitable for specification by human beings. We shall discuss areas where color perception knowledge is available for us to use, and others where studies still need to be carried out.

Visualization and Information Extraction from Multi-modality Multidimensional Medical Image Data
Justin D. Pearlman

Medical imaging takes real world objects, typically regions within the body, and applies sensors to produce data which is filtered by a priori image reconstruction models and then is presented to a physician to provide information to assist referring physicians in one or more medical decisions. As we can now readily acquire multidimensional, multi-modality data sets, the presentation and extraction of information has become more challenging than ever. Furthermore, the flexibility now available in the acquisition process requires feedback which is strongly influenced by the information extraction process.

Although a generation of visualization tools has demonstrated remarkable appealing properties, there are serious flaws. Photo-realistic rendering, as a mode of visualization, has been developed largely in response to the computer-assisted design market which has different goals. Medical diagnostics has to be concerned not primarily with realism but with accuracy, reliability and the ability to track error and judge data confidence. Lighting models can convey as much or more information about the model and light source as they do about the object. Thresholding, surface rendering and other common techniques are often inadequate and potentially misleading.

Tools which allow intuitive interaction with multidimensional multi-modality data will be presented with applications in 2D, 3D and 4D Nuclear Magnetic Resonance (NMR) including applications to real-time NMR image acquisition.

Panel Participants

Nahum D. Gershon

Nahum D. Gershon is a Principal Scientist at The MITRE Corporation. His work is concerned with visualization, image processing, data organization, and analysis of environmental, medical, and other multidimensional data. He pursues research in the use of understanding of the perceptual system in improving the visualization process. He has received his Ph.D. in physical chemistry from the Weizmann Institute of Science and has held position at the Massachusetts Institute of Technology and the National Institutes of Health.

Stephen M. Kosslyn

Stephen M. Kosslyn is Professor of Psychology at Harvard University and Associate Psychologist in the Department of Neurology at the Massachusetts General Hospital. His work focuses on high-level vision, with particular emphasis on the ways in which stored visual information is used in reasoning. He has written two books on visual mental imagery (Image and Mind, 1980, and Ghosts in the Mind's Machine, 1983), a book that provides an integrated overview of cognitive neuroscience (Wet Mind, 1992, co-authored with O. Koenig), and a book on graph design (Elements of Graph Style, 1992 forthcoming). He received his Ph.D. in psychology in 1974 from Stanford University.

Haim Levkowitz

Haim Levkowitz is an Assistant Professor of Computer Science and a founding faculty member of the Institute for Visualization and Perception Research at the University of Massachusetts at Lowell. He has spent the last ten years studying the mathematical and computer science aspects of imaging in general and medical imaging in particular. His research efforts in the last seven years have concentrated on the development of methods for multiparametric representation of information. He has developed new color methods for computer graphics representation of parameter distributions. He has also developed tools for automated psychometric evaluation of these methods and has subsequently used these tools to conduct observer performance evaluations. Dr. Levkowitz has presented papers on color in graphics and visualization at the SPIE conferences in 1988, 1990, and 1992, the First Conference on Visualization in Biomedical Computing 1990, Electronic Imaging 1990, and the Radiology Society of North America (RSNA 90). Dr. Levkowitz was Video Co-chair for Visualization '91, where he also taught a tutorial on color theory, chaired the panel on color vs. black-and-white visualization, voted Best Panel, and presented a paper on color and texture visualization. He is the Registration Chair for Visualization '92 and Workshop Co-chair for the 1992 Boston Workshop on Volume Visualization.

Justin D. Pearlman

Justin D. Pearlman is the Director of Cardiovascular Imaging and Technologies at Beth Israel Hospital, Assistant Professor of Medicine at Harvard Medical School and has a joint appointment at M.I.T. where he teaches advanced methods of image processing. He is board certified in Internal Medicine and in Cardiology and is appointed in Radiology. His Ph.D. dissertation in Engineering was on multidimensional imaging of atheroma by NMR. Dr. Pearlman has developed a software platform for object-oriented generic data management, visualization and quantitative analysis of multidimensional, single and multi-modality data which has been validated in practical busy settings. He works as a researcher and consultant to industry in image applications development and deployment.