Guest Editors’ Introduction: Visualization

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The word “visualization” has helped distinguish what some for years have called “computer graphics.” It means using computer-generated graphics to help us understand and visually clarify the relationships inherent in data. The American Heritage Dictionary defines “to visualize” as “to form a mental image.” While our images are more than mental—they appear on our screens or, for virtual worlds, seem to surround us—it is within ourselves that we come to understand what the images represent. Perhaps we who work in visualization today will call our future work “realization,” for our true goal is realizing and understanding. The dictionary defines “to realize” as “to comprehend completely or correctly.” The goal of visualization is thus realization.

This special issue of CG&A contains five articles that significantly update and extend papers from Visualization 91, the second annual IEEE visualization conference, held October 1991 in San Diego, California. The sidebar following this introduction summarizes a conference panel presentation, and this month’s Visualization Blackboard entry is also based on a presented paper.

Continuing the successful format begun in 1990 in San Francisco, the conference saw more than 400 “visineers” attend paper sessions, panel sessions, case studies, demonstrations, workshops, and tutorials. A keynote address by Larry Smarr, director of the National Center for Supercomputing Applications at the University of Illinois, Urbana-Champaign, entranced the audience with examples of current issues and developments in visualization. Smarr predicted that the advent of high-speed networking would result in the merger of interactive desktop visualization with batch, high-performance supercomputing, creating a single “metacomputer.” The Edwin H. Land Memorial Perception Panel chaired by Nahum Gershon of the MITRE Corp. did a splendid job of delving into the mysteries of human perception of color, shape, and patterns. (See the January 1992 CG&A, pp. 15-17, for the conference report.)

Progress

Last year’s special issue on visualization discussed emerging trends in visualization, while Computer contained an excellent introduction to the topic. The articles in this issue illustrate some of these trends: new knowledge through scientific data visualization, integration of scientific techniques to develop tools for the entertainment industry, improved volume rendering algorithms, continuing synthesis of graphics and imaging, investigations into higher dimensional spaces, and new interface technology. The articles cover diverse application areas, including computational fluid dynamics, molecular bonding, 4D mathematics, medicine, and even sports. But you can extend their methods to many other domains.
The use of virtual reality to simulate scientific experiments is potentially important, and we look forward to learning over the next few years whether immersing oneself within a data space will result in improved "realization." The particular application discussed in one article in this issue uses a virtual wind tunnel to explore 3D unsteady air flow around advanced airframes. However, the issues involved are basic, and the techniques used are applicable to many scientific problems. The authors consider not only the science, but also the requirements implicit to virtual worlds: polygons must be rendered sufficiently quickly, head-position-sensitive stereo screens must serve as an effective user interface, and data gloves and 3D pointing devices must provide efficient positioning and interaction within the data space.

**Bonus CD-ROM**

We have an exciting bonus in store for readers: The authors are expanding their articles into multimedia versions that will include sound, text, and graphics. Bruce Brown is leading an effort to assemble everything on CD-ROM and distribute it with a future issue of CG&AA. The CD-ROM will be readable on PC, Macintosh, and Unix machines (with a CD-ROM reader, of course). Greg Nielson is generating in multimedia format an annotated bibliography of scientific visualization specifically for the CD-ROM (see the introduction on page 23 of this issue).

The articles on the CD-ROM will have exactly the same text as appears in this issue. Some authors have chosen to enhance their presentations by adding more images. All have added audio comments to explain or expand on what they wrote. As editors, we have added some hypertext links to allow rapid access to other areas of the documents. Word search and an index are also available. Since the articles are on line, readers may choose to have several windows open at the same time: the index in one, word search in another, and the document in a third. The convenience of on-line documents becomes apparent when you no longer have to keep a finger in the index while looking up a citation—it simply appears in another window.

The software used for displays has been adapted to different graphics user interfaces. Those who are familiar with Microsoft Windows 3.1 will have the display program act as a normal Windows application. Similarly, Apple Macintosh users will see a Mac application for the display, and Sun Sparc users will see an X Windows application. These display programs each use the same binary data files for the text, graphics and images, and sound. Mac and Sparc users will be able to hear the sound on their systems with no added hardware (it is built in). Windows 3.1 users will have to add a Windows-supported sound card to use the audio.

The multimedia CD-ROM development is being sponsored by Oracle Corporation, and both the guest editors and CG&AA gratefully acknowledge Oracle’s support. The guest editors would also like to acknowledge the help of Steve Keith of Sterling Software and the Oracle BookViewer team of Bob Nicholson, John Danner, Ruchita Parat, John Marvin, Bruce Goldman, Bruce Kasrel, and Tom Shields for making the on-line version of this issue possible.

A revolution has begun in developing new ways to present technical material. By creating layers of information, readers will be able to overview or delve with ease, with lower level information unseen unless the reader wishes to view it. An author’s ability to insert optional, detailed information into a manuscript—text, audio, graphics, and video—will provide a new capability to better explain and amplify research results. Hypertext links and multiple windows will give easy access to different parts of documents. Multimedia is a tool for achieving these goals, and we look forward to hearing readers’ reactions to this first step toward changing the nature of technical publications.
References

Lawrence J. Rosenblum is a research computer scientist in the Signal Processing Branch at the Naval Research Laboratory. His current research interest are visualization of oceanic data and vision for underwater autonomous vehicles.

Rosenblum received his BA in mathematics from Queens College (CUNY) and his MS and PhD degrees in mathematics from Ohio State University. He serves as editor of the Visualization Blackboard department of CG&A. He is a director of the IEEE Computer Society Technical Committee on Computer Graphics and a member of IEEE, the IEEE Computer Society, ACM, Siggraph, the American Geophysical Union, and Sigma Chi.

Readers can reach Rosenblum at Code 5127, Naval Research Laboratory, Washington, DC 20375, until July 15 (see box below). His new address will be published in the September issue of CG&A. His e-mail address is rosenblum@ccf.nrl.navy.mil.

Bruce E. Brown is director of the Multimedia Strategic Business Unit at Oracle Corp. He is currently working on research in multimedia data types for database applications. He is co-chair of the IEEE Visualization 92 conference and served in that position for both previous conferences.

Brown received his BS and MS in civil engineering in 1974 from Brigham Young University. He was awarded his PhD in computer science in 1977 from the University of Utah. He is a member of IEEE and serves on the Executive Committee of the Technical Committee on Computer Graphics. He is a member of ACM and Siggraph and has served as vice chair of the Executive Committee of Siggraph.

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Larry Rosenblum has accepted an 18-month assignment as Liaison Scientist at the European Office of the US Office of Naval Research (in London), beginning in September. He will provide liaison between US research activities and those in Europe and the Middle East. His focus will be on scientific visualization and virtual reality, as well as the underlying areas of computer graphics, interface technology, and computer vision. He will issue periodic e-mail reports on activities in these areas. Persons interested in receiving these reports should send a full mailing address (including their e-mail address) to rosenblum@ccf.nrl.navy.mil.

Color versus Black and White in Visualization
Haim Levkowitz, Richard A. Holub, Gary W. Meyer, and Philip K. Robertson

Color is a powerful aid to visual data representations—if used appropriately. But many of the numerous color possibilities can degrade the representation rather than improve it. Because of this risk, using color has become controversial. However, the increase in color graphics capabilities and in the demands put on visualization techniques (such as the growing size and dimensionality of data) have increased interest in using color even among traditional opponents.

This growing interest was demonstrated by attendees of Visualization 91, who voted the panel on color versus black and white in visualization the best panel of the conference. Organized and moderated by Haim Levkowitz of the Institute for Visualization and Perception Research at the University of Massachusetts Lowell, the panel addressed using color, as compared to monochromatic displays, in visualization. Panelists presented situations where color is essential for visualizations, situations where color might degrade visualizations, and situations where using color with other design features can maximize the outcome of visualization.

Color—essential for gamut visualization
Richard A. Holub of AGFA Compugraphic Division described the situation in publishing, where visualizing

![Figure 1. The gamuts of a positive reversal film and an off-press proofing system compared to the “limiting” gamut of perceivable colors. Although it appears that one gamut lies entirely within the other, it might not.](image-url)
gamuts of color reproduction devices benefits intrinsically from the use of "true" color. The gamut of a color reproduction device or medium is the subset of perceivable colors that the device can reproduce. A common requirement in printing and publishing is cross rendering, the reproduction of color images captured from one medium on another.

Different media have very different gamuts. For example, the relative lightnesses at which maximum saturation of certain colors occurs differ for VDTs and paper printers. It helps to model gamuts in a device-independent and visually uniform space. A device-independent space offers a common coordinate system in which to consider gamuts of devices whose internal coordinate systems might be as different as RGB and CMYK. Both the CIELUV and CIELAB spaces suit this purpose, especially in their cylindrical coordinate forms, which use the variables hue angle, chroma, and psychometric lightness.

As Holub traced the evolution of his group's efforts to understand gamuts and cross rendering, he illustrated the limitations of the 2D chromaticity diagram for revealing luminance-dependent differences in device gamuts (see Figure 1). The advantage of visualizing in a perceptually uniform space is that one has insight into how to map colors from one medium to another so as to preserve relational information or visual differences. We can appreciate this more directly by comparing gamuts using a computer graphics package that supports solid modeling in true color, then by building "foam core" models in black and white, for example, as illustrated in Figure 2.

Problems with color visualization

Gary W. Meyer of the University of Oregon's Department of Computer Science discussed some of the problems that can arise in using color as a visualization tool. In particular, he focused on using color to display the value of a single continuous variable on a 3D surface. Perceptually uniform color spaces are the best tool for selecting a color scale to encode a continuous variable. However, the data on which they are based was obtained under circumstances where the size and spacing of samples, the luminance and chromaticity of the background, and the ambient light are all tightly controlled. We can, therefore, create a color swatch key that is perceptually uniform, but we cannot maintain this uniformity inside an image because of color contrast effects (see Figures 3 and 4).

In rendering a 3D object, we use brightness for shading, leaving only chromaticity available to encode a parameter. We can use a uniform chromaticity diagram to select a scale of chromaticity variations with uniform perceptual spacing. The use of brightness to convey shading also means that planar surfaces will be equiluminant (for purely diffuse reflectance), making edges between color contours difficult to detect because the chromatic spatial frequency response of the visual system does not exhibit low frequency roll-off as does the achromatic spatial frequency response. Finally, because of color adaptation effects, we must be careful when using colored light sources to illuminate the objects on which the color encoded parameter is being displayed.
Lastly, approximately eight percent of the male population and one percent of the female population suffer from some form of anomalous color vision. Complete dichromatism afflicts approximately two percent of the male population and a fraction of one percent of the female population. Color scales distinguishable to a dichromat can also be seen by the corresponding type of anomalous trichromat. Therefore, we should select color scales that differ in luminance and do not lie on the same confusion line in the chromaticity diagram. The best such color scales would be more or less orthogonal to the confusion lines.

**Color by design**

Philip K. Robertson of CSIRO Division of Information Technology in Australia discussed color in relation to other aspects of visualizing information. Color can help distinguish certain factors or clarify others. Or it can help to confuse, such as when gray shades used to depict surface shape are color mapped.

The overall approach to display design (and how the variables of interest are to be represented) is more important than specific color aspects. Without such overall display design, the use of color is chancy.

Black and white (or monochrome) displays can certainly be more effective in conveying certain kinds of information; the constraint of representation effectively focuses attention on the information to be conveyed. We know little about how to exploit effectively this power of paucity in computer-synthesized displays, but we would do well to try to understand it better.

Color can also be very effective by omission, for example to distinguish among different objects in a display. This can be very effectively performed by depriving one of the objects of its color.

Color can also make nonsense of interpretation. Pseudo-coloring of black-and-white shading variations is just one of several natural occurrences of lightness variations that mean nothing if color coded. And color incorrectly modeled from device to device can introduce perceptual discontinuities where no data discontinuities exist.

Gray scales can also offer greater dynamic range than color (in particular at high saturation levels) for some purposes. This difference in available dynamic range is clearly evident in Figures 5 and 6. Those figures also show the use of color and lack of color to distinguish a difference in the resolutions of the center and surround data that is otherwise not always clear if either fully colored or fully gray scale. The gray scale allows the context to be preserved, but does not introduce distracting additional colors.

For color to be effective in improving data interpretation, we must consider three issues:

1. The context of using color should be determined by the design of the display and not by chance or experiment.
2. We should use color in a manner stimulated by our use of color for decoding real-world information.
3. Control over color production systems must allow reliable generation of colors specified in a device-independent coordinate framework.

**Panelists' recommendations**

As we have demonstrated, color can be useful in some applications, but not always. As interest in color increases, we should seek to better understand when color will be advantageous and when not, and avoid misusing it.