Is Visualization REALLY Necessary? The Role of Visualization in Science, Engineering, and Medicine

Chair
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Panelists
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Hans-Peter Meinzer, German Cancer Center, Heidelberg
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This panel and the audience will discuss if the use of visualization has changed the way scientists, engineers, and physicians conduct their business. The panelists will examine, each in his own field, if it is possible to achieve the same results and effectiveness without using these dazzling visualization tools. In other words: are these just pretty pictures?

Throughout recent history, scientists and engineers used simple or complicated graphs to represent their data visually or just looked at the numbers trying to understand the phenomena they represent. With the advent of computers and modern display technology, it has become possible to represent data visually in two or higher dimensions using color, simulated shading and lighting, texture, and stereo.

"Visualization in Scientific Computing is emerging as a major computer-based field... As a tool for applying computers to science, it offers a way to see the unseen... As a technology, Visualization in Scientific Computing promises radical improvements in the human/computer interface and may make human-in-the-loop problems approachable. ...limited visualization facilities and limited access to visualization facilities are major bottlenecks to progress." This was the "prophecy" of the October 1986 National Science Foundation (NSF)-sponsored meeting [3]. Since then, many scientists, computer scientists, and engineers worked hard to develop new visualization tools and methods and to apply them to science, engineering, medicine, and education.

After 8 years of intense development in the field of visualization, comes the moment of truth. Has this visionary promise been fulfilled, or this dream has not come true? More specifically, "Is Visualization REALLY Necessary?" could mean:

- Has visualization increased productivity in science, medicine, and engineering? Or, has visualization enabled industry, science, medicine, and government to comprehend large amounts of data?
- Has visualization been successful in making complexity more comprehensible?
- Have any breakthroughs been made in science, medicine or engineering using visualization?
- Are research, research and development, and clinical practice today different from the way they were before visualization?
- Is it possible to achieve the same results and effectiveness without using these dazzling tools?
- Are these just pretty pictures? (where is the beef?)
- If they are, what should be done to fulfill the dream?

The audience and the public have been encouraged to submit samples of slides and video material illustrating effective and valuable visualizations.

Nahum Gershon: *Introduction and The Role of Visualization in the Earth Sciences*
Visualization has been used extensively by the Earth science and other communities. This use ranges from simple visualizations using 2-D representations to more complex 3-D visualizations using animation. The data sets could be both complex and massive. Some Earth scientists feel that the computer science and engineering communities do not listen to their needs. For example, there are difficulties in dealing with large data sets and with disparate data formats and types (e.g., continuous and disparate data sets). In addition, intuitive representations of data in higher dimensions than 3-D are needed. Finally, at the age of rapid telecommunications and information highways, there is a growing need to collaborate across the network. The Earth science community urgently needs new software systems that allow to perform remote visualizations bridging among disparate visualization packages and user preferences. Progress in all of these areas will make visualization much more useful and effective in the Earth science and other communities.

John Gass: *Is Visualization Really Necessary in Industry?*
Visualization is everything. In the aerospace industry, due to the huge scale and complexity of our models and mathematical representations computer aided design and manufacturing are necessities. In support of these activities, visualization of massive scientific data and of gigabytes of design data is a routine operation. Tomorrow's airliner may be explored today in fine detail from every possible angle to plan for assembly, safety, and comfort.

Robert Langridge: *The Role of Visualization in Molecular Biology*
The developments in computer graphics hardware which made it such a powerful tool for computational molecular biology were:
1) Interactive, real time, three dimensional rotation (1964).
2) Time sliced (tachistoscopic) stereo (1970).
3) Real time vector color systems (1979).

However, the developments in computer graphics which have gained the most attention in the last ten years have been in the realm of "realistic" representation of objects and scenes, developments which at present only have value in molecular biology research in the production of illustrations for publications or lectures ("realism" in molecular displays often mean realistic displays of plastic models of molecules - models which merely simulate those which can be built on the lab bench and which make minimal use of the freedom which computer graphics provides).

Most day-to-day research demands the ability to manipulate the molecules in three dimensions and in real time (that is the USER'S real-time, not the molecular time being simulated). A system that provides real time, interactive three dimensional ray traced images of arbitrary objects is not here yet. Until it is, the representation of molecules in the classical chemical way as lines for covalent bonds, with clouds of points or meshes as surfaces, meets the needs of the practicing chemist or molecular biologist, though it is often convenient to switch between the real-time (usually vector) interactive display and the shaded "realistic" display.

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I emphasize that molecular graphics systems are far from satisfactory for the average user who is more interested in the science to be done than in the computer, an individual who I have described as "aggressively apathetic" about computers. The chemist wants to do chemistry, not computer science. Satisfactory means have yet to be found for the analysis of the dynamics of macromolecular interactions, a problem that will become more acute as the speed of the associated computers increases by orders of magnitude over the next few years. Biochemical complexity is not merely three dimensional, it extends into the time domain.

Hans-Peter Meinzer: *The Role of Volume Visualization in Medicine*
For 100 years, two-dimensional Roentgen images have been used for medical diagnosis. Today, several other imaging techniques are available, e.g., Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) producing image slices of the body. There has been a considerable amount of work using series of CT and MRI slices to produce three-dimensional (3-D) views, or volume visualizations. These techniques are still mainly used at the laboratory and are not commonly utilized in clinical routine. Radiologists have been quite hesitant to accept the new 3-D volume visualization, claiming that "We don't need it." Surgeons, on the other hand, are enthusiastic about the possibility of looking into the body before operating on it. They say that these techniques improve their work significantly.

The real problem today is not the visualization but the process of identification and classification of volume elements. We do not completely understand how human beings perceive images and thus we are not able to implement an algorithm and strategies for image understanding. A large amount of research is now devoted to closing the gap between the millions of pixels in an image and the symbolic description of its contents (the signal-to-symbol gap).

Justin D. Pearlman: *The Changing Role of Visualization in Medicine*
Medicine has the mandate to save lives and alleviate suffering. This is achieved (or not) by iterations of data collection, interpretation and decision-making. Imaging has played a central role in this process, but until recently the main role of computers in clinical medicine has been data acquisition and management. Modification of the resultant images was minimal. One force for change, driven both by researchers and insurers, is quantitation on computer images. A bigger push forward in computer visualization came from magnetic resonance imaging (MRI). It typically requires data transformation, conversion and reformatting as preparation for effective visualization.

The methods in clinical practice fall into two categories: those performed either automatically or by technician input only, and those that enable interactive visualization by the clinician. An example of the former is the UMS CUBE program that constructs composite angiograms of the coronary arteries with minimal supervision from data obtained noninvasively by MRI. An example of the latter is 3D multislice reformatting by graphics prescription. These and other examples will be presented.

The role of computer-aided visualization in medicine is burgeoning. The demand is driven primarily by MRI but also by other technologies. Reformatting of 3-D and 4-D datasets, selective projection angiography of the coronary arteries and other vessels, and production of parameter maps are good examples. As data collections increase, there will also be a need for automated effective data reduction. Visualization plays an essential role in the rapid recognition of abnormalities and their relation to anatomy. The demand for computer assisted visualization is escalating.

Richard Mark Friedhoff: *Problem Solving With and Without Visualization*
Several case studies suggest that visualization can be defined as the substitution of preconscious visual competencies and machine computation for conscious thinking. This definition appears to be useful in most if not all instances in which data is rendered as imagery, including scientific, medical, and design visualization. In each case, visualization replaces ad hoc or improvised, consciously mediated processes with preconscious, hard-wired processes resident in the physiology of the visual system.

Although this distinction between conscious thinking and preconscious visual processing is easy to define qualitatively, and while qualitative distinctions are useful, much remains to be accomplished before we can define this dichotomy more formally and reconcile the perspective of the scientist interested in understanding visualization with that of the visual physiologist or psychophysicist. Vision scientists, more typically utilizing the terminology "preattentive," tend to view vision from the bottom up. Case studies in visualization suggest that this perspective is sometimes opposite that which is useful to the visualization scientist who is obliged to view visual processes from the top down and for whom the molar term "preconscious" may be more suitable.

Afterword

Throughout recent history, scientists and engineers used simple or complicated graphs to represent their data visually or just looked at the numbers trying to understand the phenomena they represent. With the advent of computers and modern display technology, it has become possible to represent data visually in two or higher dimensions using color, simulated shading and lighting, texture, and stereo. After years of intense development in the field of visualization, comes the moment of truth: has visualization changed the way scientists, engineers, and physicians conduct their business, or are these just pretty pictures?

References

[1] Friedhoff, Richard, Visualization: The Second Computer Revolution, W.H. Freeman and Company, 1991.

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