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TITLE: TAKING SCIENTIFIC VISUALIZATION TO THE MASSES

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TAKING SCIENTIFIC VISUALIZATION TO THE MASSES

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Abstract

This paper offers the premise that scientific visualization capabilities are generally available only to a limited subset of scientists. Several reasons for this are presented. The paper describes a collaborative project between scientists of the Defense Nuclear Agency and computer scientists at Los Alamos National Laboratory. This project's goal is to get visualization capabilities into the hands of many more scientists.

Introduction

Today's supercomputers allow scientists and engineers to run computer simulations that generate larger amounts of data than ever before. Effective graphical representation of the data is vital to scientists as they interpret the results of these complex simulations. The 1987 report on Visualization in Scientific Computing motivated the development of numerous commercial and academic visualization products. These systems have demonstrated impressive results, but we believe the number of scientists benefiting from this wave of visualization technology is still relatively small.

At Los Alamos National Laboratory (LANL) we recognize several distinct approaches to providing visualization tools for the end user. Parallel approaches are probably found at other large scientific organizations. In this paper we discuss these approaches and describe a project where efforts are being taken to deliver visualization capabilities to a wider portion of the scientific community than is possible with the other approaches.

The Approaches

The approaches mentioned above vary in the level of interaction between scientists and graphics experts and, more importantly, in the number of scientists who benefit from the approach. Pros and cons for each are discussed below.

Approach:
Use of Graphics Subroutine Libraries

Los Alamos was an early leader in the support of system- and device-independent graphics subroutine libraries. We have built various local and commercial libraries on top of our Common Graphics System (CGS), which also supports a system-independent graphics metafile. This vector-based system continues to serve a very useful function after more than a decade of use. Scientists call graphics subroutines from within their application programs to perform basic functions such as drawing lines, curves, or even color contours. An integral part of the system is the support of high-quality devices for output of the CGS metafile.

CGS serves an extremely useful function for LANL computer users who require fast subroutine library calls. However, new trends in computer graphics are towards raster rather than vector capabilities and away from the use of programming libraries. Thus, support of graphics at LANL now involves the integration of new capabilities along with continued support of CGS.

Approach:
Consultation with a Graphics Expert

Some scientists stand out as having the best imagination or the cleverest algorithms in using graphics libraries and have come to be recognized as graphics experts. Either formally or informally, they consult with other scientists to help them effectively display their data. Consultation with such an expert is one of the distinct approaches we recognize for scientific visualization.

This approach is undoubtedly ideal for some situations and some people, providing very effective data visualization for a number of scientists. It allows scientists to concentrate exclusively on their science, leaving the display details up to the expert. However, it generally requires numerous iterations on the display, which involves repeated meetings between the expert and the scientist. Major drawbacks to this approach are its high cost in people time and the fact that few scientists have access to the expert at any given time. Since this approach requires extensive interaction with the expert, scientists at remote sites are either unaware of the expert or have limited access to his services.

Approach: Scientists Become Own Visualization Experts

Many visualization software packages and specialized hardware for computer graphics have become available in the past few years. Many scientists, recognizing the benefits of scientific visualization, have followed the introduction of these systems with great interest. A scientist with a good grasp of the technology can effectively use graphics to enhance the understanding of his scientific data.

For various reasons, however, most scientists can't stay abreast of the graphics technology and still need to rely on others to help them with their graphics needs. This leads us to the next approach, where scientists consult with people who have access to state of the art capabilities and can help the scientist use it.

Approach: Use of High Performance Visualization Systems

A recent trend has been the establishment of high-performance laboratories for interdisciplinary research in computational science. The Advanced Computing Laboratory (ACL) at Los Alamos is such a lab. Among its hardware inventory are high-end interactive graphics supercomputers. Software visualization systems such as the Application Visualization System from Stardent are also available. These hardware and software systems, along with the resident expertise, make the ACL an ideal environment for visualizing scientific data.

There are some drawbacks, however. A scientist with frequent visualization needs may not like the necessary dependence on the laboratory. Scientists with classified programs cannot work in the open environment of the ACL. Also, except for communication through slow lines, the ACL is basically inaccessible to most remote users. For these reasons, although use of the ACL is ideal for some scientists, the number who can take advantage of its resources is limited.

Helping Even More Scientists Use Visualization

All of the above approaches have been successful in helping scientists use visualization, with impressive results. However, many scientists do not have access to the capabilities of these approaches. A particular group of LANL users who fall into this category are the approximately 800 scientists of the Defense Nuclear Agency (DNA), who compute on the LANL Crays from remote locations. DNA has funded the collaborative DNA/LANL Scientific Visualization Project to increase visualization capabilities for these scientists, who have particular computing problems because of their remote locations. This project is discussed in the remainder of this paper.

User Environments and Requirements

The DNA scientists' environments have some unique characteristics. Most of them work in relatively small companies, generally with less sophisticated equipment than that of local LANL users. They depend on supercomputing at Los Alamos for their major computing power and purchase lower-cost general purpose workstations to handle their local needs, such as document preparation, and to provide interfaces with the machines at Los Alamos. Many still use graphics terminals such as the Tektronix 4105, although the use of Macintoshes and Sun workstations is increasing. Communication rates between their sites and LANL are relatively low, ranging from the most prevalent 9600 dialup to a growing number of sites with 56 Kbit or higher communication rates. In some cases the bandwidth limitation is so overwhelming that they believe new visualization techniques are not feasible in their environments.

These scientists have diverse applications, requirements, and computing environments. The single thread they have in common is the use of Crays for their computational simulations. Some general observations about these scientists follow:

- They are busy and have little discretionary time to dabble with new visualization techniques, although many have seen flashy demonstrations at conferences or vendor shows.
- They are eager to learn about the new systems and try them with their own data.
- They are looking for evolutionary steps to incorporate new capabilities using equipment they already have or can buy with tight budgets.
- Many are looking for 3-D display technologies as they move from 2-D to 3-D simulations.

These observations also apply to many local scientists at LANL.

What We've Done to Spread the Use and Knowledge of Visualization

Taking visualization capabilities to the masses involves work in many different areas. The following sections describe several aspects of the project and some of our experiences in interacting with the user community. Each individual aspect is important but it is the combination of all of them that has helped to increase the general use of visualization by the DNA community, as well as by local users.

The aspects of the project described in the following sections are: direct support of graphics and visualization capabilities, user collaborations, integration of new capabilities (two will be described), and our visualization laboratory.

Direct Support of Graphics Capabilities

Many of the DNA scientists are not experienced with basic graphics capabilities and therefore are especially intimidated by the idea of using advanced capabilities. We've found that helping them do graphics at any level gives them confidence and enthusiasm to try more advanced techniques. Although this direct support of graphics was not in our original project plans, we have found that it plays a critical role in establishing lines of communication and advancing visualization for the user community. Our efforts in this area include:

- Consulting directly on specific graphics problems or integration issues, mostly by telephone.
- Providing information on current graphics capabilities.
- Visiting user sites to understand their computing environments and concerns.
- Giving presentations on various graphics issues at regular meetings of DNA users.
- Talking directly with DNA scientists as well as computer users about scientific visualization.

These efforts have had significant payoffs in the project. The site visits, in particular, have been very useful for providing users with information on a range of topics having to do with graphics. Results of a recent user survey show that users generally feel more aware now of visualization capabilities and have confidence in our team's effectiveness in helping them advance further.

The user community has asked us to hold a visualization workshop in conjunction with one of their regular meetings. This full day workshop, to be held in November 1991, will focus on some of the visualization systems described later in the paper.

User Collaborations

We've found that the most effective way to transfer awareness of new technology is to work directly with individual users on their specific data and encourage them to transfer ideas to their peers. Working in collaboration with a scientist, we determine effective visualization techniques specific to his particular type of data. From this come solutions that can be applied to applications for other users. One of the most popular techniques to generate user interest, for example, is the use of color continuums and animations for viewing 2-D data on low-cost workstations at user sites. This system is described in more detail in a later section.

In our collaborations, we work directly with a scientist for four months or so. We visit this scientist's site to understand the computing and visualization environments and restrictions of the site. We agree on a set of data to work with in demonstrating new techniques for an application. We collaborate on different techniques and specific requirements for using them. After several months of working closely together, the scientist can select one or many techniques that show promise for his particular application.

Our experiences with these user collaborations have provided us with a clearer understanding of the issues faced by remote users and, of course, with the valuable exchange of ideas in working with the display of specific data sets. Users have been eager to visualize their data in different ways and to get help in doing so. The collaborations have benefited individual users and the project overall.

Integration of New Capabilities

An important aspect of our project is to develop new visualization capabilities or integrate existing ones into the Los Alamos computing environment. Two integrated capabilities are described below.

Integrated Capability:
Using NCSA Tools in the LANL Computing Environment

We have implemented a system for viewing and animating graphics files from a Cray on low-cost workstations such as Macintosh or Sun computers. This system includes the integration of the raster image tools from the National Center for Supercomputer Applications (NCSA) into the LANL computing environment.

Using some simple visualization techniques in a graphics program, it is easy to create graphics metafiles which take advantage of color raster capabilities. Any 2-dimensional grid with varying data values at each point on the grid lends itself to this type of display, where different values are represented by variations in color or gray level. Although especially suited to 2-D, any metafile generated in the LANL graphics system can be translated to raster and viewed with the NCSA Image software. Because the steps between creating and displaying graphics are very easy, the extended system is useful for previewing, animating a sequence of images, comparing data iterations, and analyzing data.

The integration of the Image capability represents a significant advance, particularly for remote users. In the past, they had to wait up to a week for hardcopy graphics output to be mailed from LANL. Now they can transfer graphics data from a supercomputer at LANL directly to a desktop computer, where they can view the data, manipulate its colors, show it to a colleague, or create a video from the data animation. This capability is available for all DNA and local LANL users and has been heavily used.

Integrated Capability:
Producing Computer Generated Videos

Video is a powerful and popular tool for scientists wanting to share results with colleagues. Recognizing a growing need for computer-generated video, we have developed capabilities which are useful both at Los Alamos and at remote sites.

For generating videos at remote sites, we evaluated several low-cost Macintosh video configurations. Most of the configurations produced poor results except for one. The combination of an Apple 8•24 board with a TV Box encoder from Generation Systems Inc. gives reasonable video output with little flicker We provided results of our evaluations to the user community and are now allowing users to borrow the equipment to try at their sites before purchasing their own. The convenience of on-site video production has proven very useful to several scientists.

For higher quality video output we have developed a frame by frame recording system. This system, which is on-site at Los Alamos, offers various options in the generation of video output from computer graphics applications. The video system is currently driven by a Silicon Graphics Iris Workstation. Each frame of an animation is recorded onto videodisc for playback at correct video rates. From the videodisc, we make copies onto various formats, including 3/4" U-matic and 1/2" VHS tapes.

The frame by frame video recording system provides a very popular capability. It is being used extensively by local and remote users.

A Visualization Laboratory

We have brought together various hardware platforms and software applications for use in the project. The resulting visualization laboratory allows experimental prototyping of user applications with various techniques, providing hands-on demonstrations of the suitability of particular techniques to a user's data. Also, in the laboratory, we can analyze technical aspects for various display techniques, such as computational requirements, storage requirements of floating point data versus vector graphics data versus image data, whether data is stored on the supercomputer or on a particular workstation, the use of compression on different data formats, and the transmission time for sending data to a workstation from a supercomputer.

The laboratory can help a scientist through the maze of visualization capabilities. For example, the lab has 3-D volume rendering capabilities on Crays, on specialized graphics machines like the Stardent, on general purpose scientific workstations of the SUN class (with optional graphics accelerators), and on the Macintosh. The degree of interactivity, storage requirements, ease of use, data transmission capabilities, resolution of problem size, and the frustration level of use vary widely among these platforms. Simple things like the location of the origin in a volume or whether feedback is immediate or delayed can have a significant impact on a user's preference for one system over another. Having all these levels of volume rendering capabilities in one place provides the best possible opportunity to compare them, far better than the theoretical handwaving used by vendors. Decisions made in the visualization laboratory on what hardware to buy or what software to use are based on real experience.

The visualization laboratory serves several purposes:

- It provides a good environment for evaluating and comparing the visualization techniques of various packages. This can help a scientist make purchasing decisions.
- It allows us to investigate the potential ease and benefit of integrating packages into the current LANL computing environment.
- Users and members of the computer graphics group can share experiences that lead to better informed decisions.
- It has a range of capabilities that are available at any time.

The visualization laboratory is a very useful resource for members of the computer graphics group and for local users at LANL. We originally assumed that DNA users from remote sites would also use it. Because of the difficulty of traveling to Los Alamos to work with us, this has not been the case. However, we have regularly presented information on visualization capabilities to the DNA users, generally showing videotapes displaying DNA user data.

Conclusions

Providing visualization capabilities for the masses, especially remote users, is an ambitious task. Nonetheless, we are seeing positive results from our efforts. Many scientists at remote sites are now using various techniques to enhance the display and understanding of their data. On-site scientists are also using the visualization laboratory to evaluate different systems for visualization. The interactive approach of collaboration is appreciated by the scientists and is very rewarding for us.

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