



## Computer Graphics, Visualization, Imaging, and the GII

### Technical Challenges and Public Policy Issues

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"Information is one of the Nation's most critical economic resources... We are committed to ensure the development of a National Information Infrastructure (NII) that enables all Americans to access information and communicate with each other... at anytime, anywhere." U. S. Vice President Al Gore, September 1993

"The information infrastructure will enable all Americans to access information and communicate with each other easily, reliably, securely and cost effectively in any medium-- voice, data, image or video-- anytime, anywhere. This capability will enhance the productivity of work and lead to dramatic improvements in social services, education and entertainment." Vision for a 21st Century Information Infrastructure, May 1993 report issued by the Council of Competitiveness.

### 1. Background and Overview

The quotes above represent the vision for the National Information Infrastructure (NII) in 1993. This paper addresses the current state of the Global Information Structure (GII) and its interrelationship with computer graphics, as well as visualization and public policy issues related to computer graphics transmitted over or used on the GII. An earlier discussion of some of the technical challenges of using computer graphics and the GII appeared in Gershon and Brown[1996].

The Global Information Infrastructure (GII) offers many opportunities for obtaining and sharing information, for collaborating with other people, and for new services. Representing information in a graphical form and using visual interfaces to find information is a key to making these processes more efficient and more palatable to many users. Along with these opportunities come technical challenges and questions on public policy issues. This paper is intended to provide information on the benefits of both the GII and computer graphics and some of the technical and public policy issues.

Computer graphics and visualization can enhance use of the GII by addressing some of the GII technical challenges, such as how to:

- make the GII easier to use and more effective,
- represent the same information to people with diverse backgrounds and capabilities,
- organize information effectively to reduce the complexity of information representation, and
- speed the transmission of information over the network.

There are many policy issues on the use of computer graphics on the GII, including how to manage this graphical information, how to share the information, what information should be publicly available, and how artists and image producers can be compensated for their intellectual property.



The Public Policy Committee of ACM SIGGRAPH (the ACM Special Interest Group on Computer Graphics) has been asked to investigate the relationship between computer graphics and the GII. In this paper, we discuss some of the technical and public policy issues faced by the graphics and visualization communities for computer graphics and images on the GII.

## 2. Technology Challenges

### 2.1 Background and Overview: Symbiosis Between Visual Technology and the GII

The relationship between the technical areas of computer graphics and visualization and the GII is symbiotic. While computer graphics and visualization methods can help make the GII more usable, the GII in turn enables new ways to work in computer graphics and visualization research and applications.

### 2.2 Computer Graphics and Visualization Can Resolve Some Technical Challenges of the GII

Currently, the Internet serves as a foundation for the GII. By connecting millions of information-packed computers around the world, it creates an exciting universe of information and services, such as news and weather, distance learning, remote microscopes and telescopes, and Internet videophone. As this information infrastructure fulfills the visions expressed at the beginning of this paper, we will be able to explore this universe and use its services more easily and more effectively. The Global Information Infrastructure (GII) is expected to revolutionize many aspects of our lives including education, libraries, health care, manufacturing, commerce, and entertainment. The ability to link people to resources and to other people facilitates commerce, product design, and complex decision making.

However captivating and encouraging, we are still far from being able to use this universe of information and services easily and intuitively enough for it to reach its potential effectiveness. To make the GII more useful, we must understand it as a new medium and must learn what it is good for, as well as when its use is inappropriate. The GII must also be user-centric, taking the user needs and capabilities into account rather than just the developers' views of what the user needs or wants to do. Otherwise, it will become an information graveyard, a massive burial site for assorted collections of data and information.

The following GII challenges can be met with the expertise from the computer graphics and visualization communities. They include challenges such as designing more effective interfaces, accommodating diverse users, organizing information effectively, increasing delivery speed, and reducing the information deluge from searches. Some of these challenges are not new to the computer graphics community, but they have become of utmost importance in the GII environment.

#### 2.2.1 Designing More Effective Interfaces

Current interfaces are quite limiting. It is not uncommon for users to have to go through a long series of menus and numerous mouse clicks to arrive at their destinations in information space. Sometimes, interfaces require extensive reading of text, which could be represented by visual images created with computer graphics. Alternatives to the current text-based Web metaphors are needed. These alternatives include icons, overview maps, appropriate visual interfaces, and visual metaphors based on better understanding of this new medium and the ability to communicate visually.

Icons are images that represent text, and the use of graphical images to represent information must be done sensibly. Images and text are different media and not totally equivalent. For some information and situations, text is more appropriate. On other occasions, an image or a combination of text and images is better suited to describe the information. We need to understand well both the power and frailty of images, compared to words, to effectively use new visualization and computer graphics technologies in science, education, and entertainment, especially on the World Wide Web.

Quite often, it is unclear exactly what information an image represents. In these cases, an image is not worth a thousand words. Many icons found in commercial software systems are examples of fuzzy pictorial representations. The computer graphics, visualization, and design communities should establish groups to

deal with these issues and recommend intuitive standard icons for known functions in network browsers, word processors, and other common GUI and computer-related systems. Such agreed upon “standard” icons should become as pervasive as the internationally universal road signs.

Overview maps can simplify complex information. Too many details can degrade attention and understanding. When the information space has many items, it is advantageous to use an overview, such as a table of contents or an overview map. A depiction of an overview structure of complex information space and the current or desired location in it, can help the user to get a sense of where he/she is and prevent the feeling of being lost. Representing the information visually can enable users to get the required information and to understand it more efficiently, and computer graphics and visualization can be used to build the appropriate information overview maps. The overview map of links in the World Wide Web hyperspace is a good example for the use of this concept (Figure 1).

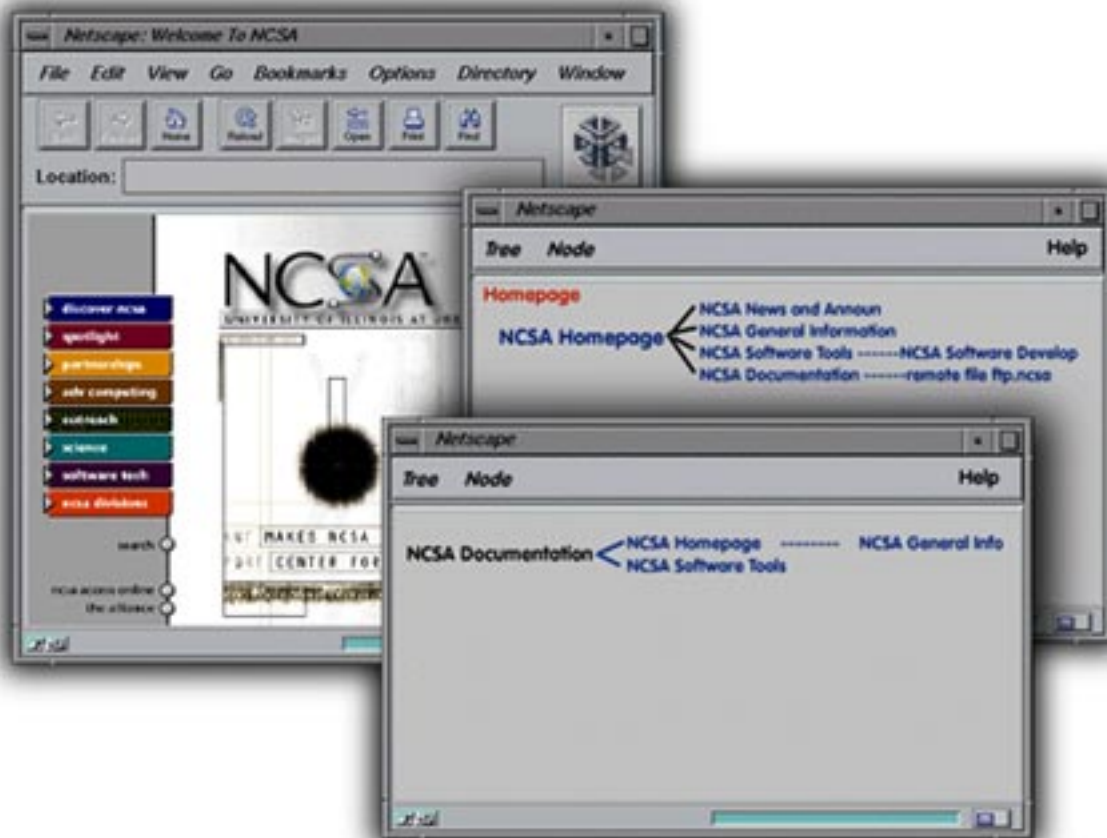


Figure 1. An overview map of a WWW hyperspace. Documents are represented by nodes and hyperlinks by lines connecting them [Gershon, et al, 1995].

An appropriate visual interface for user interaction functions can increase effectiveness. Many current information systems have cumbersome interfaces, requiring reading and typing text commands, where graphical interfaces and alternative input methods could be more useful. Some examples of visual interaction are the use of toggles and slide bars to interact with data bases, such as that in the IVEE system [Ahlgberg, 1995] (see Figure 2) and the use of eye gaze movement to drive a display [Velichkovsky, et al, 1996].

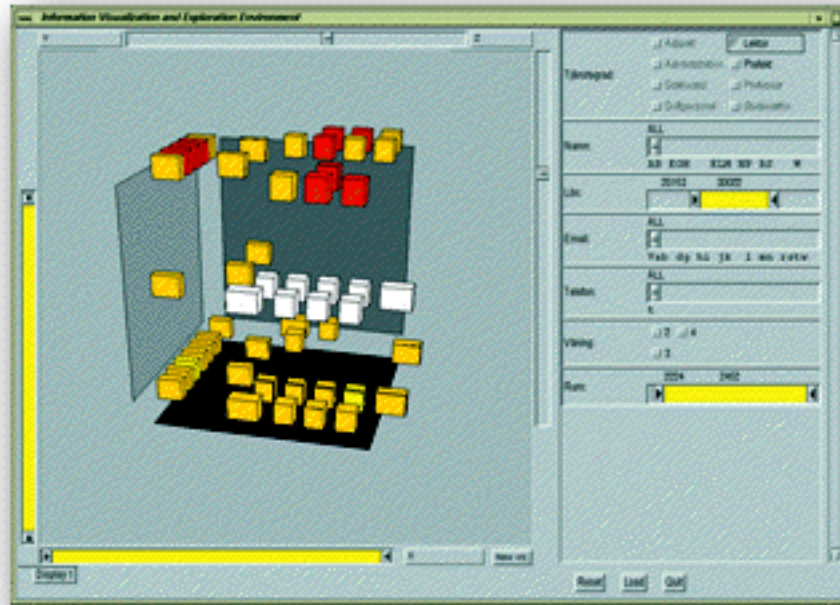


Figure 2. The IVEE system provides a visual interface via toggles and sliders [Ahlberg, 1995].

Good design of Web pages is a big challenge. The Web provides us with a new visual medium for accessing information resources and for interacting with information and other people. Since it is easy for anyone to create a Web site, these sites vary widely in style, content, and usability. Emerging standards for graphics and interaction with the Web pages will be helpful. However, some aspects are beyond the designers' control, such as the color palette variation on the systems on which their pages will appear. Also, we have much to learn about good design, especially for navigating through the pages without getting lost, for finding desired information, and for enabling collaboration.

We must gain understanding of these new media, both visual computing and display and the World Wide Web (WWW). Each medium has its characteristics, advantages, and disadvantages, and an understanding of these is crucial to the optimal and effective use of each medium. At the present time, many developers and users relate to the medium of visual computing and display as if it were a replica of paper and use it as we have used paper for the past thousand years. This new technology, however, gives us capabilities beyond that possible with paper.

Some of the characteristics of the medium of visual computing and display were summarized and discussed by Gershon and Eick [1995]. Similarly, the interaction possible through the WWW medium offers many new capabilities for learning, communicating, and collaborating. The computer graphics and visualization communities have the challenge of developing a better understanding of the characteristics, advantages, and disadvantages of these new media and of sharing their experience and knowledge with developers and the general public.

Visual metaphors could provide new ways of thinking about information. Visualization and computer graphics can be used to create visual metaphors to improve interaction with computer and information systems. For example, the rooms and the workspace metaphors developed by Robertson, et al [1993 & 1996] at Xerox PARC allow complex arrays of information spaces to be represented visually by familiar environments like rooms and office space. The workspace metaphor is used to organize information from the WWW (see Figure 3). The computer graphics and visualization communities can create additional metaphors to be used appropriately in various situations on the GII.



Figure 3. The Workspace metaphor developed at Xerox PARC is used to organize WWW information [Robertson, et al, 1996].

### 2.2.2 Accommodating Diverse Users

The user community is diverse. It includes scientists, engineers, educators, business people, politicians, people with disabilities, and a significant segment of the general public with varying levels of education and experience. Public access sites are being set up in libraries, schools and government facilities. In the future, it is possible that most commerce and public activities will, in large part, take place on the GII.

One of the problems of current interfaces is that they are usually tailored to serve one type of user. Since there is no such thing as an average user, many people from these diverse, multi-cultural backgrounds have difficulty using the standard interfaces. Designing interfaces and information presentations suited for users with diverse capabilities and diverse educational and cultural backgrounds is a challenging job for the computer graphics and visualization communities.

More work is needed to enable visual and non-visual interfaces to be adaptable to users with different capabilities, as well as to different states of attention of individual users. Further work in natural language processing, intelligent agents, and visual interface technologies will help reduce the problems of information overload by providing easy, customized access to information. The experience of the computer graphics and visualization communities in tailoring visual displays to different groups of users with different cultural and educational backgrounds can help to achieve this goal. Replacing the mouse with a more direct manipulation interface, such as touch screens, eye gaze trackers, and speech recognition technologies can be advantageous in reaching out to more diverse groups of people. Other interactive techniques will be made possible by networks capable of handling more traffic than today's networks can handle.

### 2.2.3 Organizing Information Effectively

Effective organization of information is crucial to the success of the GII. Sensible organization of information allows the user to stay focused, get the information, and understand it.

At present, the organization of most of the information residing on the WWW is far from optimal. The smallest piece of information is the individual document, which may contain many segments of information and is often too long for the user to read on-line. In some browsers, only one document is present on the screen at any given time making it difficult for users to compare two or more pieces of information. In addition, the links connecting documents on the WWW (set by the page authors) and the organization of information segments within documents are rigid and cannot be changed by the user. These various pieces of information, however, might be related to each other in different ways depending on the contents, the application, the problem being solved, each user's personal way of thinking and perception, or cultural differences.

For distributed information systems to be effective, they must allow each user to construct his or her own information space with links and associations (among pieces of information, whole documents, and images) that fit the current needs. In the system developed by Gershon et al [1995], the user can interactively and visually modify the links among documents and relate to individual segments of information, creating his or her own personal space. Another way of presenting information in more than one way is to visually present aggregates of collections of documents in overview maps (e.g., see Figure 4 [Andrews, 1996], and also [Wood et al, 1995] and Silicon Graphics MineSet [1996]). These experiences by the computer graphics, visualization, and design researchers and the techniques they have developed for presenting information to people can lead the way to improving the organization of the information on the Web.

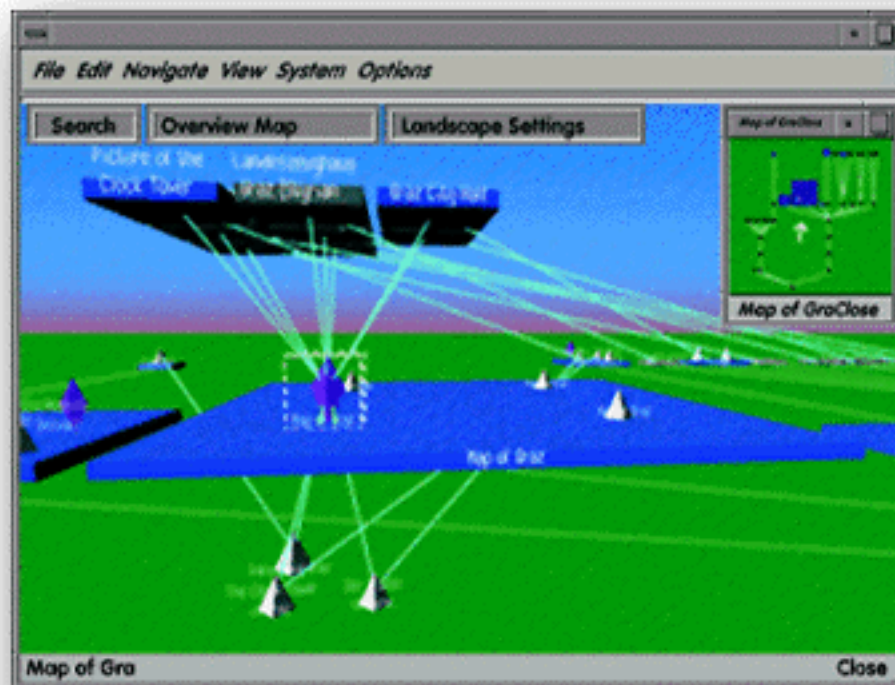


Figure 4. The Harmony Information 3D Landscape for the Hyper-G (HyperWave) Web server. The hierarchical collection structure of the server is visualized on the horizontal plane, and hyperlink relationships are selectively superimposed upon the structure map in the vertical dimension [Andrews, 1996].

## 2.2.4 Increasing Delivery Speed

The speed in which a document is downloaded can be crucial to keeping the user's interest in the document. Users do not like to wait long, and a user's concentration will lapse after a short time, affecting his or her creative thinking.

Techniques have been developed by the computer graphics community to reduce image size so that images do not significantly slow down the delivery of the document. Research continues on image compression techniques, elimination of unnecessary colors, simplification of icons, and the use of thumbnail images linked to full resolution images. Reducing image size helps reduce the Internet traffic and shortens response time.

## 2.2.5 Reducing the Information Deluge from Searches and Queries

It is difficult to find information on the WWW if you do not already know where it is. To find the desired information, users must browse or perform a search. If the documents containing the relevant information are long, the user must often browse through large amounts of text, data tables, and images. How can the user easily determine where the sources of the relevant information reside, how to get them, and, once the sources are retrieved, how to get the relevant information from them?

Advances in interactive computer graphics and visualization hardware, software, and methods offer new possibilities for improving navigation through information dispersed over the Internet, and for reducing user frustrations by enabling the user to find specific information, to access that information, and to digest it. Graphical interfaces can be used to display search results instead of long textual lists. Systems such as IVEE [Ahlberg, 1995, see Figure 2] are used to visually interact with the long lists and to represent selected regions of a list for further inspection. An alternative method is TileBar [Hearst, 1995] which allows results from a number of queries to be represented simultaneously (see Figure 5). More research and development on graphical representation of search results are needed.

The research outlined above can enable the GII to be more effective and beneficial for education. For example, scattered resources could be assembled by a teacher when a particular combination of examples is needed to make a point. Similarly, rare radiological findings, residing in small numbers in the archives of many hospitals and medical schools, could be gathered over the GII and used in the classroom to teach the fine points of diagnosis.

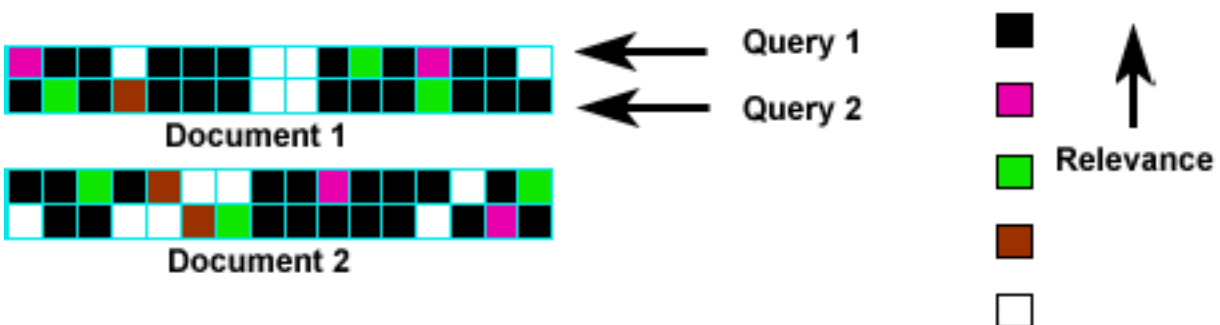


Figure 5. TileBar [after Hearst, 1995] allows viewing the results of multiple queries on the same document. Each tile represent a segment of the document. The color of the tile represents the relevancy of the contents of the segment to the search criteria.

## 2.3 The GII Can Resolve Some Technical Challenges of Computer Graphics and Visualization

Just as computer graphics can resolve some of the problems confronting the GII, so too can the GII resolve some of the challenges confronting computer graphics and visualization research and applications. In fact, the GII is already changing some of the traditional ways we work with graphics and visualization.



### 2.3.1 Enabling Up-To-Date Visual Information Transmission

The Internet allows the distribution of images of up-to-date information (e.g., weather data) in an almost continuous fashion. However, this kind of image transmittal is often quite slow, even with image size reduction, depending on the volume of the images and the network bandwidth. It is important that users get the images fast enough so that their lines of thought are not interrupted, especially for educational applications. New networks with high bandwidth should alleviate this situation. Other techniques such as routine use of high-ratio compression can increase speed, and in many cases result in images that are not appreciably diminished in quality. Delivery of the image so that the user first receives a low resolution image or that part of the image that provides the most important information piece for him or her will also reduce the load on the networks. Speedy transmission of visual information enables remote control of instrumentation such as microscopes and telescopes, remote access to educational and medical information and consultation, and real-time collaborations among scientists, researchers, and educators. It also allows policy makers to convene from different locations via video-conferencing software and discuss potential scenarios of world-wide concern, such as global air pollution.

### 2.3.2 Catering to Diverse Computer Graphics and Visualization Users

The GII has already brought the products of computer graphics and visualization onto the desktops of millions of people. Traditionally, the producer generates the images and the users get a canned product with pre-defined characteristics. Recent developments such as JAVA and Virtual Reality Modeling Language (VRML) allow final production on the user's desktop. This can reduce the amount of information needed to be transmitted over the network, and the final product can take into account the individual preferences and visual capabilities of the user at the receiving end, leading to a change in the way we do graphics and visualization in the years to come. The ability to link diverse people easily via the GII allows them to communicate visually and collaborate easily. This has had a major impact on industry by enabling world-wide collaboration on the design of products, taking cultural differences and preferences into account during the design process.

## 2.4 Research and Development Are Needed

Continued research on computer graphics generation, presentation, and delivery over networks is essential. Interaction with graphics, including networked collaboration tools and virtual environments, will accommodate the way people need to work, learn and interact with each other. Computer graphics and visualization are inseparably linked to the use of the GII and the World Wide Web. Increased understanding through research and development in these fields will yield increased benefits to the millions of GII users.

## 3. Public Policy Issues

### 3.1 Overview

The computer community is used to thinking of public policy as either non-technical or strictly a business concern. However, the widespread public availability and applicability of the GII has resulted in much greater public concern about the policy aspects of traditionally technical issues such as access, communications bandwidth, computation speed, and security. Conversely, some issues such as intellectual property, which have been thought of as primarily issues of law and policy, have come into the technical arena. Some of these public policy issues are equally relevant to graphics and non-graphics use of the GII. Others are specifically relevant to computer graphics and imaging applications. Because computer graphics and the GII are intertwined in many current applications, this paper addresses public policy issues related to the use of the GII with computer graphics, visualization, and imaging applications and research.

### 3.2 Public Policy Issues Directly Affecting Computer Graphics

There are public policy issues related to all uses of the GII, especially as it becomes more pervasive. This section addresses those issues that directly affect the use of computer graphics on the GII, such as bandwidth, user diversity, access, and convergence of TV and computers.



### 3.2.1 Bandwidth-- Communications and Computation

A picture may be worth a thousand words, as the saying goes, but it typically takes many bits of information to transmit that image and many computation cycles to process it. Although computation speed and costs have improved much more dramatically than communications technology, the exponentially growing number of GII users can overwhelm the computational capability of any server (or collection of servers) at a popular site.

When many images are being transmitted, the network speed and bandwidth determine how smoothly this process is viewed. Although there have been tremendous improvements in the field of computing, communications bandwidth and communications speed have not improved very much. For example, the typical modem speed of 2400 baud of ten years ago has improved to 28,800 baud today, only a factor of ten over a decade. Those whose access to the GII is from home over a 14.4 or 28.8 kilobaud line will not see much improvement in viewing graphics on the GII until the communications issues are resolved. Many home users don't even turn the graphics on until they "see" something that absolutely needs graphics. ISDN speed (typically 56-64 or 112-128 kilobits per second) is the minimum requirement, but the acceptability of the graphics increases as the bandwidth increases. For computer graphics, visualization, and imaging to have a true impact on the GII, appropriate communications bandwidth must be affordable and available to the millions of users, especially those who rely on the remote graphics and visualization for their work. Both individual viewing and interacting with images and collaborative interactions are becoming increasingly essential, and public policy issues are extremely important in getting the bandwidth to users at an affordable cost. There are several new technologies on the horizon such as cable modems and ADSL (Asymmetric Digital Subscriber Line, which in recent tests provided 6.14 Mbps downloading and 640 Kbps uploading). These technologies provide interesting possibilities because the primary need for bandwidth for some graphics on the GII is in the outward direction from the site where the graphics are located. However, there are technical difficulties that still need to be resolved, and in collaborative computing, bi-directional flow of graphics is essential.

The primary policy issues are tariffs and regulatory priorities. ISDN has many different tariffs around the country, depending on telephone company marketing plans and state regulatory priorities. Many state tariffs are driven by a policy to provide the lowest cost basic phone service. GII access driven by graphics may become part of the basic phone service someday, but until then, these tariff policies affect the availability of adequate bandwidth for GII graphics. Communications bandwidth on the GII involves much more than computer graphics because of the growing tendency today to work from home and on the road.

Increasingly widespread public availability and use of the GII is likely to result in a call for the regulation of providers to require that they guarantee sufficient computing and information resources to serve the public. Public outrage at not having this "basic" service could be akin to that of not getting a dial tone! Although it generated no call for regulation of on-line service providers, the December 1996 through February 1997 actions regarding the problems of getting connected experienced by America On-Line customers did involve the actions of the attorneys general of many states. As the GII access becomes critical to the public, we are likely to see more of this kind of activity.

### 3.2.2 User Diversity

As discussed in Section 2.2.2, the user community of the GII is quite diverse. Computer scientists and engineers are used to developing systems for their technological peers, and these systems are not easy to understand or use by novice users. The general public will not tolerate the usage barriers currently present in computer systems, and with broad public access to the GII, this community will be very large. Public policy for the GII will force developers to implement systems that can be used by the general public. As the GII becomes more and more the source for the most current information, especially for government information, we need official ways for diverse groups of people to be able to get information easily. One public policy need is to define the diverse group of people that governments need to address and define ways to do interfaces for these groups.

Ultimately, as the GII becomes commonplace in schools and daily life, there will not be many novice users. Developing public policy in providing GII access to schools is critical to the long term success of the GII and computer graphics, visualization, and imaging tools for obtaining and understanding information. There are increasing activities in this area, such as NetDay in California to wire schools for the Internet.

### 3.2.3 Access (including availability, affordability, usability)

There are many access parameters, including cost, availability, understanding, and accessibility by persons with disabilities. Public policy affects all of these parameters, and there are laws requiring the solution of some. How do we prioritize where to provide scarce resources? What problems should be solved first? All of these must be solved for the long term success of the GII and its uses of computer graphics, visualization and imaging. Public policy issues include universal service availability (requiring subsidies) and disability laws such as the Americans with Disabilities Act. We have a revolutionary change in our daily lives made possible by the capabilities of computer graphics and the GII, and we have a responsibility to see that no one is excluded from these benefits because of vision limitations or other disabilities. There are also economic inequities in access, further depriving the lower income people of information resources and capabilities they need to improve their standards of living.

### 3.2.4 Convergence of TV & Computers

We are seeing a convergence of TV and computers. Much computer graphics is created for TV. More computers are capable of capturing, processing and displaying TV signals. The home marketplace is seeing increased numbers of TVs that can also display computer graphics output, and some computer manufacturers are putting large, TV-like monitors on their home systems. Unfortunately TV display parameters have not been compatible with computer graphics displays in the past, and there is concern that they will not be in the future. Therefore, added cost is incurred to provide compatibility. In 1995, approximately the same number of TV sets and personal computers were sold (20 million each). If 50% of each category elected to provide TV/computer graphics compatibility (not unlikely in the future) and compatibility cost \$50 per device, purchasers of these devices will have to spend an additional \$1 billion dollars per year!

There is a monumental public policy issue in the incompatibility between TV and computer graphics display parameters. (See [O'Connor, 1996].)TV standards are driven by the broadcast industry, and both the public and the computer graphics industry are eager for an Advanced TV standard to be approved. Although it has appeared for some time that the Advanced TV standard that was headed for approval would not be compatible with computer graphics needs, recent events in response to a computer industry counter proposal hold out hope for a more computer-friendly standard.

### 3.2.5 Lifestyle Changes - Telemedicine

Telemedicine brings resources of a large hospital facility to patients, physicians, and nurses in remote areas. This is essential to basic health care in rural areas, where an injured patient might have to wait three days before a circuit-riding radiologist could read the X-rays and prescribe treatment, according to Zollo [1995]. Through telemedicine, X-rays and photos are sent over the network to specialists who can consult with the local physician, and rural health care providers can stay current on medical practice through multi-media information databases and distance learning.

Public policy issues include:

- Licensing of physicians across state (or national) boundaries.
- Malpractice suits. (Who's responsible when technology fails and colors on transferred images are incorrect?)
- How a physician gets paid for a video consultation.
- Security of patient data. (Who has access to the videos, X-rays, and photos; and how do they gain access to it?)
- Continuing high cost of telemedicine. (Most projects are started with grant money for the first few years.)

### 3.3 General Policy Issues of the GII

The GII brings many technical challenges and public policy issues, such as censorship, security and intellectual property rights. These affect, but are not limited to, the use of computer graphics, visualization, and imaging.

#### 3.3.1 International Diversity

The GII is international, with information flowing across national borders, often without the user even knowing it. There are many legal issues associated with these international border crossings. Every country has different laws and standards on what is acceptable in the privacy, security, intellectual property, language, and tariff areas. Public policy discussions will take place at an international level.

There are also cultural aspects such as colors meaning different things in different cultures. There are currently no traditional public policy issues in these cultural areas, but smart international marketing people are linking designers around the world via the GII so they can design products that sell well internationally and get these products to market more quickly.

#### 3.3.2 Legal and Security Issues

Legal issues include intellectual property rights, censorship, privacy, and security. While these issues go beyond the GII, computer graphics, visualization, and imaging make the GII more accessible and therefore help force consideration of these issues. The outcomes of discussions in these areas are vital to our success.

Individual authors, businesses, publishers and service providers all have different points of view. While many feel that all information should be freely available on the GII, this is extremely unlikely with the commercialization of the GII. How much access should be permitted for browsing? Public policy discussion will influence the future uses for browsing, downloading, and fair use, although enforcement of these policies will be difficult. There are many important issues involved with images on the GII:

- Can you use an image you find on the GII, for example in a class?
- Can you use part of an image, similarly to using a few music notes?
- How much of an image can you use?
- Can you change an image, and if you do, who owns the copyright to the new image?
- How does the original artist get compensated for the use of his/her work?
- Who owns the right to information derived from other pieces of information?

There are other financial issues concerning delivery of intellectual property on the net that are not limited to images. If you browse in a dataset and download some of it, for example, how much do you pay the owner of the dataset?

Censorship, more than any other single issue, dramatically highlights an individual's personal views, ranging from one extreme that everything is "free speech" to the other extreme that would ban internet images of art museums' nude statues. In fact, this is such a personal issue, that there is unlikely to be any resolution at a technical level.

Privacy and security are important issues for the GII in general. In the case of cryptography, the issues even involve export laws. The public policy debate is already well underway.

#### 3.3.3 Applicability of Existing Laws

There seems to be a rush to develop new legislation relative to the GII. We should ask ourselves if new laws are needed, particularly at this early stage of development. Perhaps existing laws should be given a chance to develop GII applicability first. Furthermore, not everything you find on the GII is true (or accurate, or legal)! Will there be a call for ratings and reviews of GII information and applications?



### 3.3.4 Interoperability of Hardware and Software

To provide an effective GII with computer graphics, visualization, and imaging applications, vast amounts of hardware and software must be interoperable. While we normally think of the standards process as the key to this solution, there are legal and public policy issues associated with the standards process. These include whether the standards are “official” government standards or voluntary industry standards, and the impact of trade laws on the standards developers.

Given the public importance of the GII, it is conceivable that there could be a call for enforced standards (something quite new for the computer industry). There is likely to be an active public policy debate on this.

### 3.3.5 Testbed

The GII offers the ultimate testbed. Millions of users are unknowing potential guinea pigs on the information superhighway. Collecting data on use of the GII is easy, and the capability to link this data to specific users may become available. Is this ethical? What kind of controls might be called for in the future? Does connecting to someone’s WWW site imply the loss of privacy? While related to the security and privacy issues, the computer community certainly can see this as a separate issue.

### 3.3.6 Scaling

Computer graphics, visualization and imaging systems developers are used to having to provide solutions that will scale dramatically. For example, just consider how much satellite image data from each satellite is collected and stored. Now multiply all this by thousands of sites and millions of users. How are we going to handle all this information? Will the entire world’s GNP need to be devoted to the GII and its imaging data? What level of resources should be focused on this problem? This is perhaps the ultimate public policy issue.

## 4. Conclusions & Recommendations

Computer graphics, visualization, and imaging, ranging from simple weather forecasts to detailed depictions of scientific phenomena, have become part of our everyday lives. More recently, the Global Information Infrastructure has captured the attention of diverse groups of people eager to find or disseminate information widely. There are both benefits and challenges to using computer graphics on the Internet and the World Wide Web. The use of computer graphics can enhance the use of the GII by making it easier to use, and conversely the GII opens the way to broader avenues of visual communication and collaboration on computer graphics applications and research.

There is growing public concern about the policy aspects of technical issues such as access, speed, and security because of the increasingly common use of the Internet. There are also unique public policy issues concerning the use of computer graphics on the GII. On one hand, it is very easy to use copyrighted images from the Internet without paying royalties or even giving credit to the artist who created the image. Thus, we have some challenges to overcome both technically and politically. On the positive side, sharing images across the Internet enables collaborations and enriches lives through distance learning opportunities and remote medical care. The potential of the GII is great enough to make it possible and worthwhile.

We have made great progress towards the vision expressed at the beginning of this paper. We understand better now what both the technical and public policy issues are of the world-wide information infrastructure that we have already implemented, and where it is headed in the future. As the current Internet has been deluged by millions of users, the need for better resources and more research into how to provide them is clear. Research into higher speed networks is being provided through the U. S. National Science Foundation vBNS (very high speed Broadband Network Service). Research into computer graphics and interactive techniques and into visualization, imaging, and design applications are also vital for making information sources easily accessible and useful, and for fostering scientific, industrial, and educational collaborations. Through computer graphics, as both an enabling technology and an integral part of the GII, better hardware, software, and design can yield benefits for GII content providers, users, and visual content transmission.



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