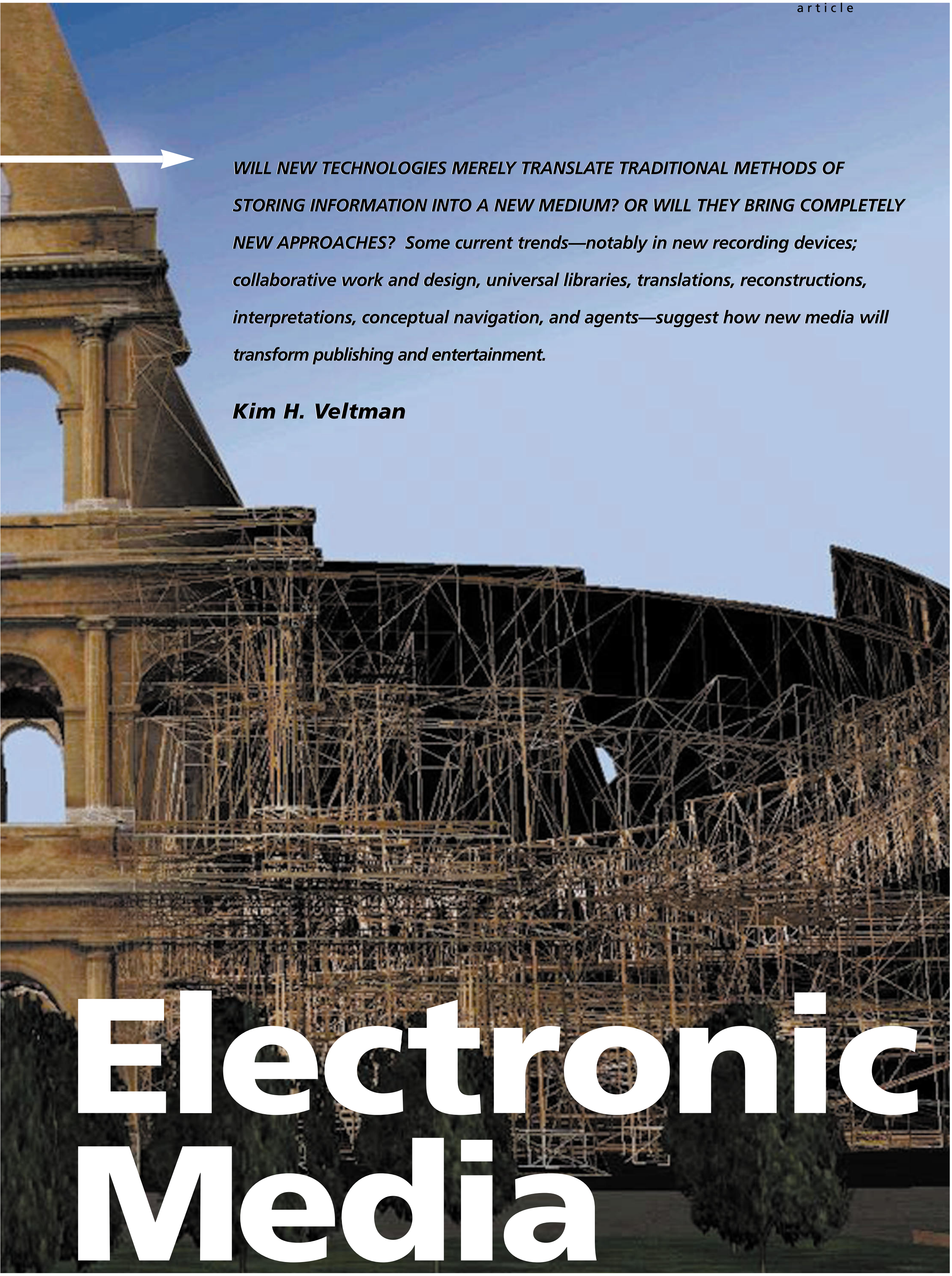
Frontiers in



Electronic Media

WILL NEW TECHNOLOGIES MERELY TRANSLATE TRADITIONAL METHODS OF STORING INFORMATION INTO A NEW MEDIUM? OR WILL THEY BRING COMPLETELY NEW APPROACHES? Some current trends—notably in new recording devices; collaborative work and design, universal libraries, translations, reconstructions, interpretations, conceptual navigation, and agents—suggest how new media will transform publishing and entertainment.

Kim H. Veltman

In the film *Disclosure* (released December 1994), the production manager of the high-tech firm Digicom provides an intriguing glimpse into the potential of new media. He stands in a space between two posts, puts on a head-mounted display, and enters into a virtual-reality environment called "The Corridor," which bears an uncanny resemblance to St. Peter's Basilica in the Vatican, recently produced in virtual reality by Infobyte of Rome, with support from ENEL, the Italian electrical company. The production manager then moves into a room with a series of virtual file cabinets built into the wall as shelves, each of which lights up in turn to indicate different centers of operations, notably Seattle and Malaysia. He touches the cabinet marked Malaysia, which opens to reveal a series of virtual documents, each of which he reads in turn. The documents include video clips of videoconferencing as well as electronic copies of letters [1].

Is this truly a model for the future?

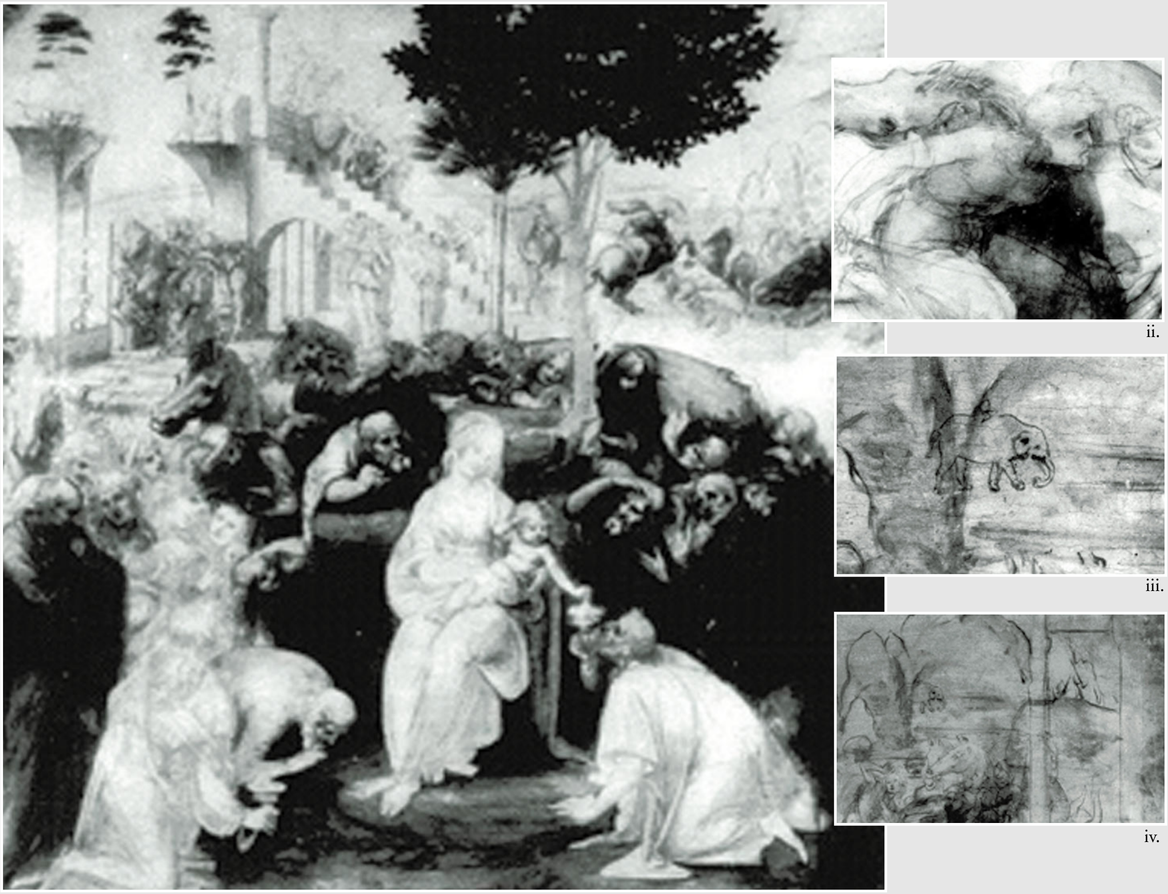
NEW DEVICES FOR WRITING, DRAWING, AND PRESENTATION

Recording and Presenting

A series of new cameras is transforming the scope of what is recorded. The IBM Brandywine camera typically scans a painting or a manuscript at 20 to 50 megabytes (MB) a page. The VASARI scanner scans images at 1.4 gigabytes per square meter (GB/m^2). Such cameras and scanners provide new levels of detail that can then be used for problems such as retrospective color conversion. The Canadian National Research Council (NRC) laser camera typically records images of 10 to 50 MB that can be rotated on screen for viewing all aspects of a three-dimensional (3-D) object, analogously to how virtual reality markup language (VRML) works with 3-D models. The NRC camera can be linked with stereolithography to produce fully 3-D reproductions, enabling sculpture on demand at any scale. The National Research Council of Italy (CNR) designed a special portable camera that fits into a suitcase and can be used for quick inventories of materials. A net result of these new technologies for capturing images is that almost any object in the natural world can be recorded digitally. Once in digital form the images of these objects can be reproduced in almost any other media.

Writing and Drawing

The first phase of the so-called "computer revolution" largely involved replacement technology. Computers replaced typewriters but continued performing essentially the same functions: typing became work with electronic word-processing packages. Some people assumed that computers would in turn replace secretaries but forgot that secretaries are much more than word processors. Their key role lies



i. ii. iii. iv.

1. New technologies, such as infrared reflectography by Editech allow us to examine the layers below the surface of a painting and thus reconstruct different stages in the creative process. These images by Infobyte show Leonardo's *Adoration of the Magi* (Florence, Uffizi) with various layers under the surface (i-iv).

in filtering persons and information for their employers. And although a great deal of rhetoric may exist about personal digital assistants (PDAs) and electronic butlers, the likelihood of such electronic devices seriously serving as this kind of filter has yet to be demonstrated.

Meanwhile, many architects have been replacing traditional drafting tools such as the rule, ruler, and compass with computer-aided drafting (CAD) tools. At the higher levels of drawing CAD became one of the four Cs, along with computer-aided engineering (CAE), computer-aided manufacturing (CAM), and computer-integrated manufacturing (CIM). More recently these developments are part of a larger trend whereby space and geography are becoming integrating metaphors (see "Space and Geography as Integrating Metaphor" section later).

There are still, however, enormous discrepancies between what is claimed possible and what actually functions in this domain. For at least three decades we have been told that electronic dictation machines were coming. We have also been assured that voice-activated computers were imminent and that translation devices into multiple languages were nearing a practical stage. Voice and translation, however, still need to be integrated with their respective devices. Recently there seems a trend to re-emphasize pen-based assistants, notwithstanding the obvious shortcomings of the Apple Corporation's early Newtons.

Editing

One of the main reasons why computers replaced typewriters was because they simplified editing. One could correct errors without the fuss and bother of erasing originals. This applied not only to words (e.g. Word, Word Perfect) but also to charts (Excel) and draw-

2. New technologies such as the laser scanner of the National Research Council of Canada transform traditional two-dimensional photographs into three-dimensional records of painting surfaces, as in the case of (i) this painting by Krieghoff, (Ottawa, National Gallery of Canada) which reveals a series of unexpected details when photographed in this way (ii-v).

ings, pictures, and photographs (Photoshop, Photostyler). In studios this extended to photofinishing. In television and videoconferencing, sequences could be edited more readily (non-linear editing). Much research currently exists on extending the concept of chroma-keying to produce blue rooms [2] and virtual sets, so that an actor at one site can be integrated with scenes at other sites [3].

The advent of desktop publishing soon revealed that not everyone who is presented with 200 fonts becomes a serious publisher. The same will prove true with desktop film production as users try to become instant producers and directors. Yet some fascinating products will undoubtedly emerge from the application of these new tools. All of these new technologies have introduced new problems: how can one know which version is an actual one, a correct one, the accepted one? The need arose for an electronic equivalent to footnotes, for new tests of veracity.

Revision Control

To answer these needs, leading vendors introduced revision control. At the simplest level this merely involved maintaining a clear record of when each version was created or modified. The introduction of object-oriented programming and dynamic link libraries (DLL) meant that whenever multiple copies of a record existed, correcting a chart once led to its correction across the board. In a networked context this meant that correcting a spreadsheet in one office automatically updated spreadsheets in other cities even if they were embedded into letters, reports, or other documents. This amounted to an automatic comparing of notes, texts, tables, and even databanks. It also introduced hierarchies of users—some authorized, some not authorized to change existing documents. As the functionalities of object-oriented programming expand, increasingly more complex materials can be included in packets that can be updated simultaneously. Companies such as Digital Equipment Corporation were among the first to introduce this approach into business office software. AutoCAD extended the notion to the offices of architects, engineers and town planners. Scholarly equivalents for revision control are still lacking.

COLLABORATIVE WORK, TRAINING, AND DESIGN

The early stages of the computer revolution effectively dealt with documents that were static, or at least aimed at being static despite changes introduced through editing and revision of letters, charts, pictures, and photographs. The trend has been toward dynamic situations where information is constantly changing, and interactivity is essential to the process. Teleconferencing is the simplest example of this kind of activity, followed by boardroom conferencing and multimedia conferencing. Here the challenge is not only to communicate over distance, but also to record the proceedings of important meetings in ways that allow individuals unable to attend a given meeting to make sense of them afterwards. IBM's We-met (still in prototype at Yorktown Heights) is an example of such new collaborative conferencing tools. One of the most impressive free tools in this context is Web4groups. [4] The basic elements of these technologies are summarized in Figure 1, which shows the cumulative nature of the process.

A next stage in complexity lies in working together on a problem at a distance. Simple video contact is the most primitive version of this activity. Audiographic packages such as Vis-a-Vis, which use smart boards, represent this next stage. Smart boards allow persons in two locations to make written comments or markings on a common image together in so-called "real time." A further stage in complexity is offered by NTT's Hiroshi Ishii, whose clearboard extends the basic principle of the window and permits people to mark things together while still maintaining eye contact [5]. Projects in development include collaborative decision support [6] and the collaboratory notebook, which fosters learning through collaborative visualization (CoVis) [7]. Such projects are transforming a well-established tradition of distance education into the concept of an interactive classroom [8], which is also being discussed in other versions as an electronic classroom, a classroom without walls, a virtual campus, and a virtual university.

One problem with these new technical possibilities is that they are often being applied in conjunction with traditional teaching models, which cancels out their potentially innovative dimensions. Videoconferencing is an excellent case in point. Videoconferences are set up by linking two or more sites and having students in these sites listen to a lecture at a distance. Such an on-line approach has the disadvantage of being very costly without bringing special advantages. It would be much more efficient to tape the lecture, send it by mail or asynchronously, and use the live videoconference experience for discussion periods in groups small enough for real interaction. Practitioners in Utah and elsewhere are "discovering" that 9 to 12 persons is pretty much the maximum for a serious exchange; that is, a class being educated at a distance ironically has the same internal characteristics as the real classroom. New technologies do not change fundamental dynamics of human communication [9].

Intimately connected with these new initiatives in distance education is a feature of computer programs that allows one to trace a user's path. This feature gives computers new roles in assessing the extent to which alternative features are employed by different users. It also proves useful for testing and goal assessment, which are of particular interest in training, where rote learning plays an important role.

Training is being extended to just-in-time, on-demand learning (JITOL), by which a person learns about a feature on the spot only as it becomes necessary. A possible scenario is the following: a repair person at a remote site encounters an unfamiliar problem. He contacts an expert at the head office who identifies the problem and guides him to a solution [10].

Similar scenarios are being discussed in the context of telemedicine. In Tokyo ambulances typically require up to 2 hours to return to a hospital from the site of an accident. Hence ambulance drivers are being equipped with head-mounted displays that permit a doctor

Figure 1. Types of distance communication

Audio	Telephone
Video	Video camera, Television
Audiovisual	Teleconferencing, Audio- and Videoconferencing
Audiographic	Smart board, [Vis-A-Vis]
Audiovisualgraphic	Virtual reality

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at a hospital to examine a patient at a distance and offer provisional advice before the patient is moved. In the LargeNet program, which links the University of Western Ontario and seven local hospitals and other institutions, there is work on Interactive Collaborative Information Services (ICIS). Telepresence, which was initially developed in a military context for operating robots at a distance, is finding new applications in medicine. A doctor at one site can now operate on an animal at another site. Some experiments have already been conducted extending this technology to humans. An ophthalmologist in London, therefore, could do surgery in Hong Kong without requiring either the doctor or the patient to travel halfway around the world.

In design and architecture, a quest is under way to make interactive the working environments for software packages such as 3-D Studio, Alias, and Softimage, so that individuals in two different cities can collaborate in the simultaneous design of a product or a building. Following the early examples of ART+COM at CEBIT, the world's largest annual computer fair (Hanover) in 1990, the Department of Information Science at the State University of Milan (1993) produced a "Virtual Space/Place Editor [11]."

Interactivity is also being extended to engineering. Companies such as Boeing are using a virtual reality wind tunnel that permits interactive study of scenarios of possible wind stress. Thus far most of these initiatives remain largely isolated efforts. For example, a training package is designed to produce a short-term result in a given discipline or section of a discipline. The participants have generally little or no awareness of activities in other fields. A medical doctor will seldom be aware of developments in biology, law, French or history, although in many cases similar or analogous technical methodologies are involved.

As with videoconferencing, the various scenarios for telepresence and collaborative work often assume traditional synchronous environments [12] when some combination of asynchronous and synchronous links would prove more fruitful. We probably need a whole new field of study to assess criteria for these alternatives and their various combinations. Otherwise, what could be a great contribution risks being just a greater technological encumbrance.

A danger also exists that this telepresence and collaborative work will lead to an ever more piecemeal approach, when the technology holds within it the capability for recontextualization of knowledge. Any test reflects material in a textbook, which is part of a course, which is part of a curriculum, which in turn is part of a corpus of knowledge. Now a person may score 100 percent on a test, which represents only 20 percent of the textbook, 10 percent of the course, 2 percent of the curriculum, and only 0.005 percent of the corpus of knowledge in that field. Using hypertext it is possible to make systematic links between these various subsets and thus make visible the connections between a given question on a test and the corpus of knowledge on which it is ultimately based. A systematic approach linking different curricula in various countries would provide an international framework for this recontextualization, so that an educator in India and an educator in the United States can fairly assess the relative preparation and achievements of students in their respective countries [13].

These trends toward increasingly greater collaboration can be seen as part of a seemingly inexorable wave toward global connectivity, whereby anyone can be reached anywhere, at anytime—if not by videoconference, telephone, or computer, then by cellular phone, satellite-linked PDA or some related device. Although these developments clearly have profound consequences, they also involve fundamental problems that require much closer attention.

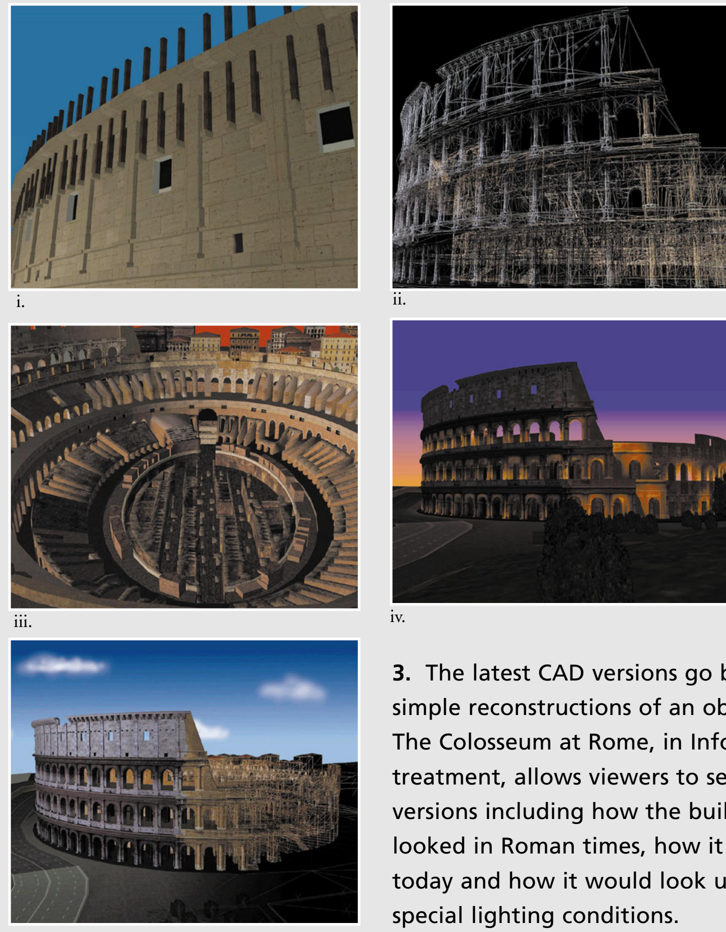
In the past, a person worked for a number of hours, or a teacher taught for a set number of hours and then went home to relax. With the advent of the telephone and e-mail, employers, colleagues, and students often expect that they can use these tools to contact others at all hours of the day and night. A person who spends the day working, teaching, answering phones, and writing letters usually does not want to spend evenings answering phones and e-mail messages. Those that do find they no longer have any private space. Work becomes a permanent mode.

The ability to extend the range of one's teaching beyond the classroom via videoconferencing and the Internet is often attractive to administrators, who see them as a source of saving by increasing the student–teacher ratio and thus decreasing the numbers of staff. This argument is all the more seductive for less popular subjects. In a networked environment, why have three professors of an obscure language such as Persian or Assyrian when one networked individual could serve everyone? What is usually overlooked is that very specialized subjects require equally specialized attention, which distance learning does not help and large numbers usually destroy. The challenge is not merely to increase quantity but rather to maintain a maximal level of quality (see "From Quantity to Quality" section later).

In research, where collaborative work is also becoming common, another issue needs attention. Some fields are more conducive to collaboration than others. Building the Hubble telescope required the collaboration of 10,000 scientists throughout the world. Compiling an encyclopedia or the *Oxford English Dictionary* requires teams of scholars working together. Conversely, many studies require the careful, painstaking analysis of a single person. Most major monographs in the humanities—precisely because they require a synthesis of facts and claims from a given viewpoint—are almost necessarily the work of one individual. We need to be careful that our enthusiasm for new collaborative methods does not suppress areas in which collaboration is neither needed nor useful.

COMPUTERS, SMART OBJECTS, AND UBIQUITY

Computers have evolved from bulky mainframes into personal computers, portables, laptops, and ever smaller versions. In addition



i. ii. iii. iv. v.

3. The latest CAD versions go beyond simple reconstructions of an object. The Colosseum at Rome, in Infobyte's treatment, allows viewers to see many versions including how the building looked in Roman times, how it looks today and how it would look under special lighting conditions.

to the now familiar personal digital assistants [14], The Italian National Research Council (CNR) has developed a telephone-like device called ECO [15], whereby dialing a three-digit number provides information about individual tourist sites. A San Francisco–based company called Visible Interactive is developing museum tours on Newton Messagepads designed not to distract other museum visitors [16]. In Bologna, PDAs are being equipped with tourist information through wireless Internet connections [17].

Some see these individual gadgets becoming completely pervasive and networked. For instance, Dr. Weiser, at Xerox PARC, has been preaching the notion of "ubiquitous computing." Instead of a single machine on one's desk, hundreds of gadgets throughout one's home and office will be connected to the system. A number of these connections would be wireless. For example, a sensor might recognize my entrance and adjust room temperature, lighting, and music accordingly. If my job took me to various points in a building, a sensor would, for instance, interact with the phone system and help it to decide which phone should ring, with a personalized dial tone. Alternative models have been offered by Baudel and Beaudouin-Lafons; Feiner, MacIntyre, and Seligmann; and Fritzmaurice [18].

In the sixteenth century an increasing proliferation of measuring devices led gradually to the proportional compass, or sector, a device that integrated all known measurement problems at the time. A similar synthesis seems called for in communications devices. Computers already send fax and e-mail messages; can act as phones, radios, CD players, and televisions; and connect with printers. We already have remote gadgets for operating our televisions and VCRs. Why should these capabilities not be consolidated into a new handheld device that combines these functions? Worldspace, working in conjunction with Alcatel and others, is already designing a satellite-linked device that will have both a radio receiver and a low-resolution monitor. The device, targeted for developing countries, will start at $100 and subsequently go down to about $20. A more advanced version could contain a few gigabytes of memory, separate programs for which would be downloaded from the Internet on arrival in each town. For example, a medical doctor arriving at his hotel in Rome on business could download relevant information about local hospitals, clinics, doctors, and medical conventions. The same doctor arriving in Rome as a tourist could download information on sites to be visited. Persons wishing to have this material in advance would pay the appropriate long-distance charges. Whereas persons now rent headsets in museums, they might in the future carry their multivalent equivalent of a cellular–computer–fax–o–phone and simply download tour information suited to their depth of interest and the time they have available; like an advanced approach to ideas introduced by Minitel. Such a device might also be equipped with global positioning system (GPS) functionality (see “Space and Geography as Integrating Metaphors”).

From Packaged Software to Online Applications

In the early days of computers a series of dumb terminals were linked to a mainframe. The advent of the personal computer brought with it the notion that each person’s computer is an island unto itself. Consequently, some companies prospered by selling a separate copy of their software for each machine, or at least aimed to do so.

In the past few years the largest computer firms have returned to or, one could argue, have extended the earlier model, which they never really abandoned. This uses the mainframe model, with its distributed terminals, now on a global scale. This has two fundamental consequences. First, in terms of hardware it means that the client machine can be considerably simpler than if it were trying to be an island unto itself — whence came the recent talk of a new wave of $500 computers. Second, in terms of software, it means that there is essentially no longer a need to produce shrink-wrapped products. A new application can simply be made available online. Although this might still seem futuristic to some, it is sobering to realize that the 12,000 employees of Silicon Graphics Inc. receive all their software in this manner. A majority of IBM’s worldwide operations use the same method. The Ford Corporation, which has 50,000 networked computers, is adopting this process. Some companies are assuming that the future lies in selling individual software, but a number of major players assure us that we will soon be able to download everything when it is required.

For average consumers this revolution has already begun. Internet software such as Netscape, VRML, Java, and other applications can be downloaded free of charge when used for educational purposes. Transferring individual applications or applets is no problem. A larger problem looms of offering integrated solutions. As noted earlier, in industry there are now so-called office packages that combine word processing, spreadsheets, fax, e-mail capabilities, and revision control. Scholarly and everyday equivalents of such tools are still lacking. Integrating solutions

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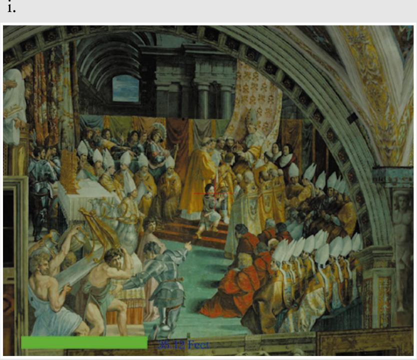

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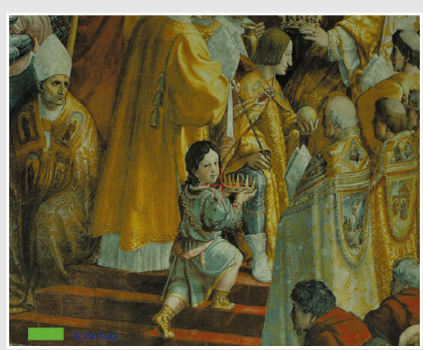

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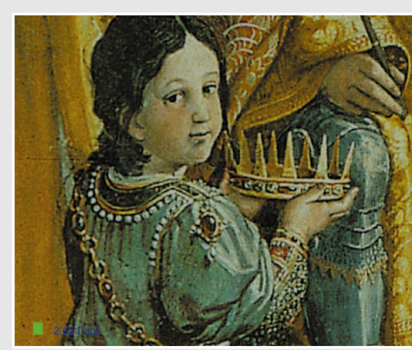

iv.

4. Infinite resolution, a technique developed by Infobyte (Rome) early in 1996, allows viewers to zoom from the whole to various levels of detail (i-iv) without any loss of clarity as shown in this version of Raphael's Rooms *(Stanze)* in the Vatican. (See figs. 25-26 for full page illustrations of the same principle).

Infobyte has also reconstructed St. Peter's Basilica and plans to extend the principle to Vatican library and museums. A separate project by IBM, sponsored by Rio Di Janeiro, is scanning in the contents of the Vatican Library. Under the auspices of G7 pilot project 5: Multimedia Access to World Cultural Heritage, it is foreseen that the Infobyte and IBM projects will eventually be integrated. A viewer will then be able to navigate through the Vatican complex in virtual reality, do virtual browsing at a distance on-line, and then consult the actual contents of a medieval manuscript or early printed book.

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with coherent interfaces are needed (see "Agents" section later).

SPACE AND GEOGRAPHY AS INTEGRATING METAPHORS

At least since the time of Aristotle, philosophers have recognized that space was one of the fundamental categories of human thought. Kant allotted space a special role in terms of conceptual as well as physical orientation. There is something almost intuitively obvious about the idea of using maps as a means of finding one's way. In the past decade a series of new technologies has been moving toward convergence to transform the traditional senses of maps as metaphors. First, satellite images, which were almost solely the domain of the military, are becoming accessible for everyday purposes (e.g., weather, geological features, and vegetation and crop patterns). Satellite images are becoming available in different scales, and there are new methods for coordinating and linking them systematically with maps at different scales. The Xerox map introduced a very simple method [19]. The Argus Map viewer linked city maps to different purposes, such as business, health, or tourism [20], and the University of Pennsylvania created a more advanced viewer [21]. Such maps, in turn, are being linked via GPSs so that starting from any point on Earth, a person can use satellites to obtain coordinates that, in turn, provide appropriate maps of a person's location. In this context one should never really be lost, especially if this becomes part of the new universal communication device outlined earlier.

In urbanized and industrial areas, attention to mapping has for some decades continued at a macro level using geographical information systems (GIS) and at a micro level using area management/facilities management (AM/FM), which scales down to the detail of individual video cameras positioned at strategic points in rooms and buildings. All these hitherto isolated efforts are moving toward integration. In 1995 a demonstration reel of *Terravision* (ART + COM), working with DT Berkom (Berlin), showed a near synthesis of satellite images, GIS, and AM/FM. It is possible to go from images in space to maps, photographs of buildings, their CAD reconstructions, and then to strategically positioned cameras within the spaces. This reel was one of the points of departure for Marc Pesce's spatial goals in producing his virtual reality modeling language [22]. A copy of the demo was also sent to the Mountainview headquarters of Silicon Graphics, which took the Berlin approach one step further in developing its demo, in March 1996, with the slogan: "From outer space to slam in your face." The innovation here lies in using two-dimensional (2-D) satellite photographs that dissolve into 3-D terrain maps as one approaches the earth, allowing fly-throughs of valleys in the Alps.

The direction of this technology is toward a new global network connecting satellite data, GIS, AM/FM, GPS, and local video cameras. A user could begin with a view of the United States from space, zoom down to street level in Los Angeles, and use a traffic camera to check congestion on the freeway firsthand. The potential uses of such integrated systems are being explored by police officers, particularly in Germany. Although the danger that such networks could also be misused is beyond the scope of this paper, it is definitely within the scope of possibility [23].

Considerable attention is being given to combining information from twin satellite images to create a 3-D stereographic image, as Pape has done for the Camargo Syncline in Bolivia [24]. These developments in satellite images are paralleled by others in regular photography, particularly in combining stereo images in the context of photogrammetry in order to translate 2-D images of buildings into their 3-D equivalents as models. Vectar, for example, produced Real View, software that permits translation of such 2-D photos into a 3-D CAD environment. Experiments at the Eidgenössische Tchnische Hochschule (ETH, Zurich), in conjunction with the Centre for Landscape Research (Toronto), are exploring how such 2-D photos can be mapped into complete 3-D environments.

One of the best examples of this approach is found in Infobyte's reconstruction, with support from ENEL, of the *Tomb of Nefertari*, using photographs of the original as it looked at the time of excavation (1905), when it was restored by the Getty Conservation Institute and as it appears now in a state of considerable degradation. This example is even more interesting because it illustrates how one can move seamlessly between the monument as it appears today and other states at different times. In the case of Infobyte's reconstruction of St. Peter's Basilica, one can move seamlessly between the existing structure and the previous basilica, which no longer exists. This same approach could be used to review key interpretations of major sites such as the Roman Forum and the Parthenon.

The frontiers of the military are working on analogous methods that will effectively make it possible to translate any 2-D stereographic photograph into a full 3-D model that can then be viewed from any viewpoint desired. This same principle is being considered for film and television. Theoretically one could take an existing scene shot from one position, reconstruct the scene in a virtual 3-D space, and be free to move to any other viewpoint in that space. This has enormous implications for those concerned with interactivity, because it means that scenes could in effect be rearranged to produce plots on demand.

In the near future there should be a synthesis between these micro experiments and the macro versions mentioned earlier above using satellite images. We are approaching a time when moving from any 2-D to its 3-D equivalent will become a matter of course.

Shared Virtual Spaces

The ongoing convergence of methods is also evidenced by recent trends to combine collaborative tools and virtual spaces. An early example of a shared virtual space occurred in the game world with the Habitat project. In 1985 Lucasgames and Quantum Computer Services set up a multiple-participant environment in the San Francisco area. This basic approach was popularized through games such as *Doom,* through which players at different stations could be connected in a single virtual space, each individual represented by a symbolic image known as an avatar. One of the latest fashions has been to combine this concept of avatars with virtual malls so that I can "see" and communicate with the image of a person who is physically in a remote location but is sharing my virtual space. Although this is conceptually intriguing, why one would want to interact in this way on a long-term basis is not clear.

Another example of shared virtual spaces is provided by the German National Institute for Supercomputing (GMD), which foresees a "communication wall [25]." If one wishes to meet with others, one enters a special room, onto the wall of which is projected a mirror version of the room in which one is situated. This mirror version has life-sized video images of the persons with whom one wishes to speak, both facing one. If these two individuals wished to speak to one another they would in real life turn to face one another. In the case of a video image such a 90-degree rotation would normally reduce the images to lines (because one is merely looking at the side of the video clip). Therefore, the GMD researchers project this image onto a 3-D CAD model of a head that thus maintains the proportions of the speakers even as they turn.

A third scenario was explored by Philippe Queau, at the Institut National de l'Audiovisuel, one of the leading pioneers in this field. At the IMAGINA exhibition in 1993 he

> *organized the first "tele-virtuality" liaison in Europe, allowing a virtual meeting of two persons, physically present in Paris and Monte-Carlo, but linked by an ISDN 64kbits/sec liaison, in a real time 3D simulation of the Abbey of Cluny. These two people wearing virtual immersion helmets and represented as "clones" could walk together in the virtual abbey, speak to each other and point at architectural details [26].*

Tele-virtuality has tremendous implications for teaching. Instead of showing a slide of the Abbey of Cluny or St. Peter's Basilica, the teacher takes his students on a personal tour through a virtual reality model, pointing out architectural features as they go. A student wishing to learn more about clerestories would return after the lecture to examine this feature more carefully and study earlier and later examples in other churches.

In a recent article Philippe Queau outlined a dramatic vision of things to come [27], whereby televirtuality offers an economical alternative to teleconferencing. He predicts that interactive games will soon exist wherein participants can don the costume of any character as they set out to fight or play with or against friends and adversaries wearing electronic costumes of their own and appear as clones of other beings on my screen. These figures may or may not bear any resemblance to the way one actually looks, and they can play out their games in models of real places or imaginary spaces.

Various alternatives for achieving the effects of full immersion are being developed. The most elementary alternative is simply to display this virtual world on a monitor ranging from a simple desktop size to a large television monitor. A second involves using stereoscopic glasses. A third alternative combines a head-mounted display with gloves that permits the user to navigate freely within the space. A fourth alternative uses a binocular omni-oriented monitor (BOOM), which is a head-mounted display on a balance so that the weight is not all on the user's head. A fifth alternative places a person into a special theater and projects images on large curved screens or all around to create the illusion of being surrounded. These alternatives were developed by the Canadian company IMAX Corporation, which in turn created a series of variants. The simplest version is a large curved screen. A second version increases the field of the screen. A third version places the audience on transparent seats and adds a further screen below to give the illusion of a flying carpet. A fourth version includes stereoscopic glasses to produce 3-D images. Plans to link these 3-D images with 3-D audio effects are being developed, and are now being tested at Caesar's Palace (Las Vegas).

The Goto Optical Company [28] has developed a new technology called "Virtuarium," which involves projecting images onto the walls of a planetarium to create an even more vivid sense of immersion. This technology will allow audiences to share the experience of a trip through the body, as in *Fantastic Voyage*, or walk through Infobyte and ENEL's reconstructions of St. Peter's Basilica or the Roman Colosseum.

As fascinating as they are, all these developments raise more questions than they answer. Some enthusiasts argue that virtual communities have enormous potential for expanding human experience [29]. When should persons focus on real communities and when should they turn to virtual communities? Does the appropriate balance differ from person to person? What are the consequences? Spatial intelligence is but one of seven basic intelligences identified by Sternberg [30]. Should individuals with spatial intelligence focus specifically on this mode of cognition or should precisely those with other kinds of intelligence be encouraged to use spatial approaches?

Landscapes as Metaphors

Early notions of conceptual navigation simply translated the experience of physical walkthroughs into metaphorical walks through a virtual environment. For instance, a video by Northern Telecom on a virtual mall for a shopping network showed someone walking down an aisle with various consumer goods (coffee, cereals, etc.), being reminded of what the person had chosen last time and given an option to see alternative brands, before ordering electronically what that person wanted. Variants of this concept were developed in Time-Warner's Orlando Trial and in IBM's latest versions of the virtual mall. The same idea is being applied to the idea of navigating through information [31].

Companies such as Silicon Graphics are exploring other potential uses of landscape metaphors as in its 3-D Fusion Information Landscape Prototype. Essentially the prototype transforms multiple 2-D windows to objects in a 3-D landscape. The effect is impressive but does not solve the basic problem. Having too many windows overloads the mind with an abundance of choices. Moving from two to three dimensions increases rather than decreases the problem of visual overload. Purely technological solutions do not solve more basic needs of human communication. In most cases we need interfaces that present us only with the information we need at a given moment. Hence the assumption that everything should be translated into virtual landscapes is almost certainly misleading.

FROM QUANTITY TO QUALITY

Until recently most machines had hard disks of a few hundred megabytes (MB) or a gigabyte (GB), whereas many applications require terabytes (TB). Most machines have 8 to 64 MB of random-access memory (RAM), whereas powerful applications such as the Virtual Human or Infobyte's reconstruction of Raphael's *Stanze* require a gigabyte of RAM [32]. Machines with several gigabytes of RAM exist. Storage devices now exist in which a thousand 50-GB cartridges are combined in a juke box to produce a 50-TB container. The technology is beginning to exist; it is not yet available at reasonable costs.

A glimpse at some of the leading projects today gives some hint of the magnitude of the challenges involved. As mentioned earlier, the VASARI scanner currently being used at the Uffizi Gallery (Florence) is scanning paintings at a rate of 1.4 GB/m^2. The Uffizi has only some 1,300 paintings. Even if each painting were only one square meter, on average the total would be 1,820 GB, or 1.8 TB. Major photographic collections such as the Marburg Archive contain 1.5 million images. To digitize all of these paintings and objects with the VASARI scanner would require 2,100,000 GB, or 2,100 TB. IBM's Vatican Library Project involves scanning manuscripts at an average of 20 MB per page. An average manuscript might contain 100 pages. Scanning all 150,000 manuscripts would take up some 300 million GB, or 300,000 TB. The Vatican is one major library. There are 75,000 "major" libraries in Europe alone.

Polygons provide a further sense of discrepancies between what is needed and what is available. Every visible object requires polygons, which at the simplest level are defined by the number of sides of an object. Hence, a cube has six sides or polygons, and an icosahedron has 20 sides or polygons. Complex objects such as hills and mountains are made up of thousands and thousands of polygons that are used to approximate the complexities of their true contours. In 1995 the most advanced machine of Silicon Graphics (Reality Engine 2) dealt with 2 million polygons. The latest machine (the Infinity Engine), introduced in February 1996, deals with 10 million polygons. The range of human vision encompasses an estimated 80 million polygons. Engineers at SGI believe that they can reach this capacity within the next 3 to 5 years.

The same holds for bandwidth problems. Most private homes are currently limited to 28,800 modems. The Canadian Asynchronous Transfer Mode (ATM) network has been working at 35 megabits/sec and will move up to about 622 megabits (OC12) in the next few years. Laboratory demonstrations of OC 192 have already been demonstrated. Gigabit and terabit transmissions are technically possible. Currently the bottleneck is in the switches rather than the lines.

The point here is to note that quantitative hurdles are quite rapidly being overcome. Only a decade ago most of today's achievements were completely impossible, and pioneers in the field were still skeptical whether it would ever be possible to achieve these technological challenges.

The real challenge is not quantity but quality. The need for computer equivalents to captions and footnotes has already been mentioned. When a person is being hired, the employer typically requires letters of reference. When a hotel or a restaurant is being considered, the potential client checks the number of stars it has. This is not to say that materials on the Internet should be dominated by rating systems and reduced to a popu-

i. ii. iii. iv. v.

5. Recent trends point to a new synthesis between a series of hitherto disparate technologies: satellite imagery, Global Positioning Systems (GPS), Geographical Information Systems (GIS), Computer Aided Design (CAD), Area Management (AM), and Facilities Management (FM). Viewers can begin with (i) a view of the world, zoom from space to (ii) the continent of North America, to (iii) a country such as Canada, the province of Ontario, (iv) the city of Ottawa, and (v) to a section of town.

i. ii. iii. iv.

6. These same principles allow one further to zoom from (i) an individual building such as the (Canadian) National Gallery of Art in Ottawa, to (ii) a particular room devoted to Canadian art, (iii) acquire the equivalent of a card-entry file for a painting by Arthur Lismer, *A September Gale*, Georgian Bay (1921), and then (iv) zoom in to have a full scale view of the painting.

larity contest, but rather that we need methods for judging the reliability of what is made available online. Does this represent merely a personal view? Is it a position shared by a local club, a professional organization, and then is it shared locally, nationally or internationally? Is the position accepted or rejected by the experts in the field?

History has taught us that all such indicators are limited at best. When Copernicus published his theories in 1543, a majority of experts rejected his position even though he was correct. This was also the case with Leonardo, Harvey, Leibnitz, Einstein, and others. There is no easy solution to these difficulties of discerning which claims are worthwhile and which are not. We need to look at both the product and the author. We need methods to trace the intellectual lineage of the individuals involved. Authors such as Copernicus and Leonardo were painstaking in studying great minds, even if they reached very different conclusions than their contemporaries. Hence, having conquered the challenges of RAM, disk size, and numbers of polygons, the next generation will need to focus on recontextualizing the parameters of quality.

UNIVERSAL "LIBRARIES"

The rise of networks [33] has introduced new possibilities of sharing knowledge, particularly in practical realms. Teams are working on a product-family–based framework for computer-integrated manufacturing (CIM) [34]. Leading institutes such as the Centre for Landscape Research, the ETH, and the Graduate School of Design at Harvard University are beginning to share symbol libraries.

The rapid development of object-oriented programming has meant that various elements of an object can be integrated in new ways. In the past three years there has been a movement, initiated by AutoDesk in conjunction with other industry leaders, to develop object or industry foundation classes. Here the quest is to go far beyond a simple inventory of building parts such as doors and windows to include the characteristics of a door or a window in all situations. Hence, if an architect is planning a 50-story office building, the knowledge repository will "know" that a building of that height will require doors and windows that have certain characteristics in terms of thickness, usual size, or strength. If, by contrast, an architect were building a simple 1-story cottage, the system would again know the parameters of a door or window in such a case. If this concept is extended to include cultural and historical dimensions, a "door object" will eventually integrate all our past and present knowledge of doors when planning for future applications. The emerging Global Engineering Network (GEN) sponsored by the European Community is aiming at a similar approach to all the principles of engineering [35].

The concept of object-oriented programming can be extended to the whole body of knowledge. At the outset databases served mainly as lists of names or objects. The introduction of multiple fields made it possible to include an increasing number of attributes concerning objects. An object-oriented approach suggests that databases concerning any object will eventually contain all the parameters of that object: i.e. in the case of the term "tree," a future database would know that there are conifers and deciduous trees, that they range in size from *a* to *b*, that their average age extends from x years to y years, that a particular species is found only in Africa, that the leaves of a certain tree have the following medical properties, that a given species is known to have first appeared several million years ago and since became extinct at a given period, and so on.

In simple terms, databases will no longer just be about lists of persons (who) or things (what), or places (where), which the Taligent initiative sought to address, but rather any list of persons (who) will have associated with it all the persons they knew (family, teachers, friends, colleagues—that is, related who), all the objects with which that person is associated (what), all the places they visited or with which they were in contact (where), the time they lived and all chronological details concerning that person (birth, school, marriage, major events—that is, when); all the techniques associated with that person (their inventions, their methods of teaching, their approaches—that is, how), and all the motivations known for what they did (money, fame, honor—that is, why).

Although this goal is theoretically so sensible as to seem inevitable, in practice it is fraught with many difficulties. To begin with there are serious problems of making data in various locations compatible: creating authority lists to include translations from multiple languages, and variants of names, objects and places. Next is the more difficult challenge of reflecting different claims about what ought to be facts. For instance, the painter Titian produced a number of documented paintings; therefore, he must have a date of birth and death. Scholars have several claims about these dates. Nebulous facts will have to have their own sub-objects that provide the parameters of dates within which an event was possible (*ante quem* and *post quem* in technical terms).

Interested parties will not infrequently find it to their advantage to pass off as incontrovertible that which is actually a matter of contention, so policies will have to be made to address that issue. There will also have to be a campaign to make available electronically all the conflicting points of view and to record duly the level of reliability of each claim. This is much more demanding than most people suspect and will probably require a movement that provides a modern equivalent of the medieval monks to make it happen. This movement would demand a massive campaign of translation, reconstruction, and interpretation.

TRANSLATIONS, RECONSTRUCTIONS, AND INTERPRETATIONS AS NEW INDUSTRIES

Computers and electronic media are typically described in terms of their being time- saving devices. We can edit faster, we can do charts more quickly, we can make indexes almost automatically. Some see this as a euphemistic way of saying that computers invariably eliminate jobs, which is not entirely true. To have computers requires personnel not just to operate them but also to service them, the network connecting them, and the various databases on which they draw. Existing materials need to be digitized but also translated, reconstructed, and interpreted. These are the new industries of the so-called "knowledge economy."

7. Traditional education typically focused on one outstanding example as if it were the only one. The Colosseum in Rome (i) is an excellent case in point. There were at least 76 such structures scattered throughout the Roman world in many cities including (ii) Arles, (iii) Nimes, (iv) El-Djem, (v) Pula, Bordeaux, and Italica.

Frontiers in **Electronic Media**

Because they are linear in nature, books almost inevitably present a single storyline. A history text that set out to deal with each episode from all recorded viewpoints would be too long to be practical. So, we have French histories that give one account of the Napoleonic wars, German histories that give another, and English histories that have their own view of what happened at Waterloo. These histories are usually printed only in their original language, so unless an individual takes the trouble to learn French, German, and English; acquires the history books in question; and studies them in detail, they have no way of discovering these differences.

Computers can present material both linearly and nonlinearly. They are theoretically not restricted in terms of storage size. This gives them two fundamental advantages over books and makes them particularly suited for presenting multiple interpretations of the same person, object, text, place, or period. However, this process is not automatic. It requires translation exercises of hitherto unparalleled proportions. Only then can all the facts and insights be correlated.

In terms of reconstructions, one of the paradoxes of the new technologies is that software initially designed to solve a given problem usually has so many "bells and whistles" (special lighting effects and textures) that every solution is effectively a personal interpretation. Fifty students producing a CAD version of the Roman Forum or the Parthenon would produce 50 different versions. Paradoxically, 50 experts producing a CAD version of the same monuments would produce at least as many versions. The rhetoric of salesmen may well pretend that the revolution associated with computers and multimedia is merely about scanning in existing knowledge to gain content, as if a great digitizing process were all that is really involved. Yet this is but a small part of the actual revolution, which the paradox just mentioned brings into focus.

When Ivan Sutherland first wrote about virtual reality, he envisaged it as a tool for visualizing processes otherwise invisible to the eye, models of the possible rather than snapshots of the ontologically established [36]. Virtual reality is only one aspect of multimedia, but both are about new tools to visualize not just things as they exist, but also things as they are thought or believed to have been, as they might have been, as they could be, or as they could possibly become.

Scanning in a photograph of the Roman Forum is easy. Scanning in all existing images of the Roman Forum is still somewhat easy. The challenge lies in organizing images in terms of schools of interpretation. Italian archaeologists had one set of views concerning the site, French archaeologists had another, and Germans yet another, as did the British, the Americans, the Swedes, and so on. Recreating these different visualizations, tracing how they were modified in view of excavations of the actual site—herein lie future industries.

A preview of things to come is provided by Infobyte's virtual-reality reconstruction of the Roman Colosseum, which allows people to walk through all its passageways. Such reconstructions have obvious implications for tourism. A tour guide who is on site can use it to draw various aspects of the construction to the visitors' attention. People in other countries could view such monuments in trying to decide whether they wish to travel to that spot. There are also obvious implications for entertainment. Films such as *Ben Hur* and *Spartacus* remind us that Hollywood has a long tradition of interest in ancient themes. Steven Spielberg has already expressed an interest in Infobyte's Colosseum to create a theme park using Goto Optical's Virtuarium, not unlike Universal Studios' *Back to the Future*, with a classical twist. A next step would be to create virtual Roman circuses. Presented in the context of planetariums and other specialized viewing spaces, these reconstructions would be like the ultimate video game. They could in turn be extended to include a series of networked contestants as well as regular spectators. If this sounds like science fiction, IMAX Corporation is already working with Playdium Entertainment Corporation to provide an IMAX® Ridefilm attraction at the Sega City Playdium, an interactive entertainment center in

8. Computers will integrate traditional tools from the history of art such as catalogues with images from galleries and museums such that one could start from (i) a list of Renaissance Painters; choose (ii) a painter such as Leonardo da Vinci; choose (iii) a list of his paintings; choose (iv) a given painting such as the *Last Supper* with an electronic version of a file card; (v) choose a list of drawings related to the *Last Supper* and (vi) choose an example from this list such as *Study for the head of Saint Bartholomew.* These examples illustrate the prototype of SUMS (System for Universal Media Searching) which was chosen for the navigation section of G7 pilot project 5 (Midrand, June 1995).

Mississauga, Ontario. Forty such centers are planned [37].

As blue rooms and virtual sets enable a larger integration of content from different sites, the enormous cultural heritage of Europe could well serve as the background content for new films and other visual odysseys of the imagination. It could, for instance, see a reinstatement of a serious European role in the film industry. The panorama in the late eighteenth century and the movie house in the early twentieth century were two enormously popular and profitable industries. The new technologies could well result in unexpected combinations of these effects, with equally great economic advantages.

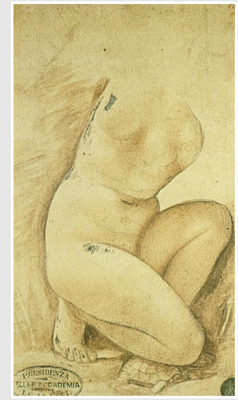
Perhaps the greatest potential for new technologies lies in the realm of education. Elementary and high-school students could use such models in learning about the basics of history, geography, and other subjects. University students and researchers could use models of the Colosseum to examine various theories about its construction and reconstruction. They could also compare these models with other examples elsewhere as has already been done by a team at Bordeaux [38]. The reconstructions could also help everyone to recognize the cultural dimensions involved in all interpretations. A French model of Rome may be very different from a German one. A Jewish history of the Holy Land may be quite different from an Arabic history of the same territory. Russian maps of the Mongolian borders may differ considerably from Chinese maps of the same area.

As always, there is a flip side to this wonderful coin that offers new industries in translation and in visualizing reconstructions and interpretations: some countries and certain individuals will continue to see it in their interest to present their particular interpretation of the past and present as if it were the only one. They will seek to use these tools for censorship that closes rather than opens interpretation. Concrete evidence of these dangers is visible in China and Russia [39] today.

It is easy to attack such blatant forms of totalitarian censorship in faraway countries and brand them as the enemy. The greater danger probably lurks in more subtle forms in our midst that are less easily recognized for what they are. Intimately connected with interpretation, the theme of this section, is the question of how images and words in electronic form on computers are judged. A simple example will suggest that the problem is more profound than it first appears. If Mr X is walking down the street and a total stranger shouts an obscenity at him or calls him a name, Mr. X will not be pleased but he will

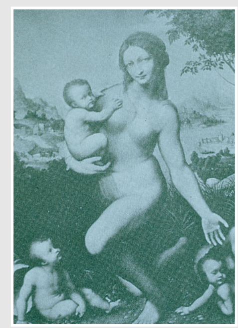
9. The SUMS system will allow one to trace the development of a painting such that one will be able to see how (i) a Roman sculpture inspires a drawing by one of Leonardo's students which leads via (ii-v) various preliminary drawings for his painting of *Leda.*

i.



ii.

iii.



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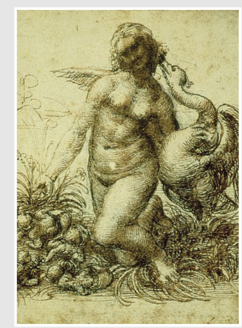
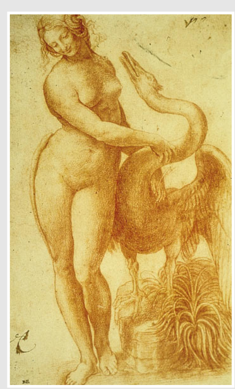
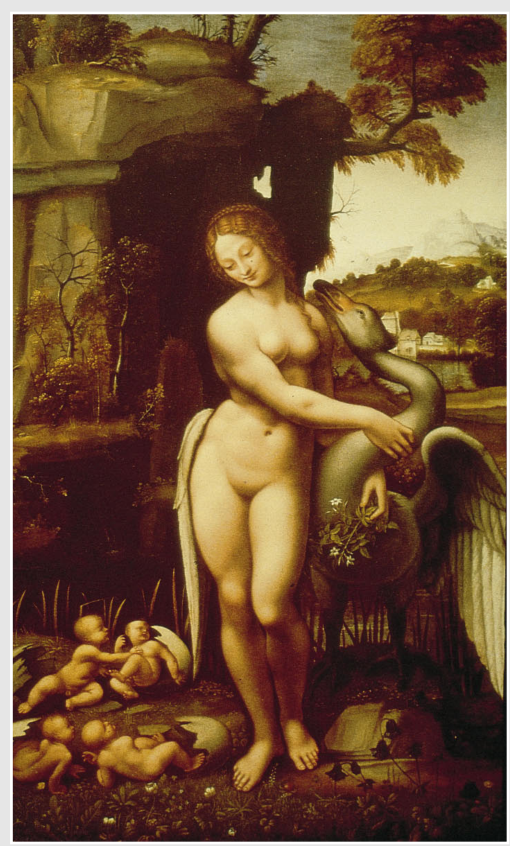


v.

10. One will then be able to trace how further drafts lead him and his students to arrive at the well known versions of *Leda.*





very likely just brush the matter off as something insignificant. If Mr. X receives a letter from a stranger calling him names it is again unlikely that he will jump to legal action. Even if these names are printed in a publication such as the *National Enquirer* he is unlikely to take action. The same words published in a major newspaper might prompt him to sue for libel. Yet the same words uttered via a computer screen are currently considered a crime, although this tendency is being challenged [40].

One reason for these problems, which we might all too easily be tempted to dismiss as silly and trivial, is that the computer screen removes aspects of context that we take for granted in other media. Notwithstanding sayings about not being able to tell a book by its cover, the covers and jackets of books, their size, their typeface, all provide us with copious clues whether the book is a scholarly tome or a cheap novel for bedtime reading. These clues disappear on a typical computer screen. We therefore need to devise new tools for recontextualization to distinguish the fictional and flippant from the scholarly. Until we do so we are in danger of judging Shakespeare's murders in the same court as the murder by the latest criminal and in so doing close the very doors of interpretation that computers promise to open to new degrees.

INTERFACES AND CONCEPTUAL NAVIGATION

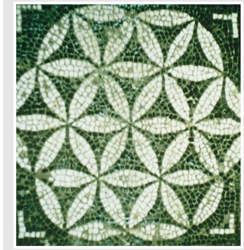
Interfaces are a key element in developing tools for recontextualization. Interfaces, according to some, are merely reflections of evolving technology. First there were only character-based commands (DOS), then icons and images (Windows). Now primitive 3-D spaces are evolving (VRML, Active VRML, Moving Worlds, Java). When the technology catches up there will be fully immersive realistic environments (full virtual reality). The evidence suggests, however, that each new advance does not simply replace the earlier technologies [41]. Evolution is usually embracing, not replacing, so the advent of 2-D images and 3-D virtual reality worlds will probably not replace the value of lists, which have been useful for the past three thousand years. Perhaps the real challenge lies in creating methods for deciding when to use a particular display strategy. At present these decisions are governed largely by budgets, since very few persons have access to the million-dollar machines required for high-level virtual reality. But this will change.

A whole series of questions needs attention. Some experts, such as Shneiderman, in his Starburst method, prefer to give all the data in a given field before focusing on single items [42]. Alternatively one could begin with classes giving general surveys before focusing on particular details. Ideally one could choose whether one wished to go from the universal to the particular, or from a universe of particulars to a single item. One significant example of a strategy is offered by the brain interface [43].

Thus far most interfaces have been limited to visual commands in the forms of buttons and others signs. At the University of North Carolina at Chapel Hill, and at the ARTS-LAB of the Scuola Superiore Sant'Anna in Pisa (the Esprit project SCATIS), there has been considerable work on the use of tactile stimuli in the form of force feedback as a cue to navigation. Using voice tracking as a navigational aid, Intel at CEBIT 1992 (Hanover) presented an extension of vrTrader produced by Avatar Partner. The extension showed financial data in a virtual-reality environment through which one navigated using voice commands and an electronic butler in the form of a stellated dodecahedron. One of the visionaries in this field is Warren Robinett [44].

The Massachusetts Institute of Technology (MIT) has been among the most articulate on questions of interface, which it treats in three categories: spatial data, symbolic data, and typography. First, spatial data includes metaphors of the landscape and geography, such as Silicon Graphic's 3-D Fusion Information Landscape Prototype, which was discussed earlier in this article (see "Landscapes as Metaphors" subsection).

Second, symbolic data transform lists of terms into a variety of shapes. The Dutch Medi-



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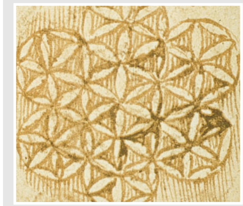

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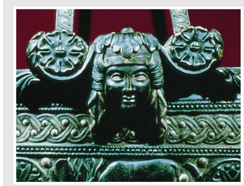
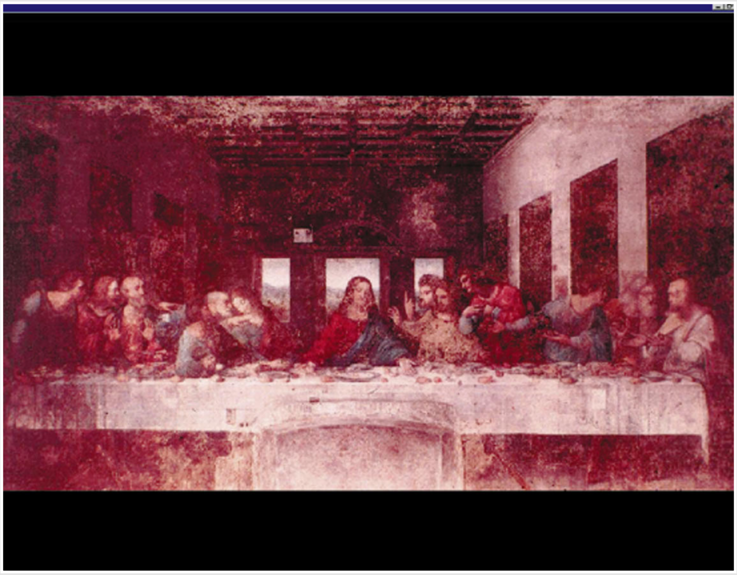


iii.

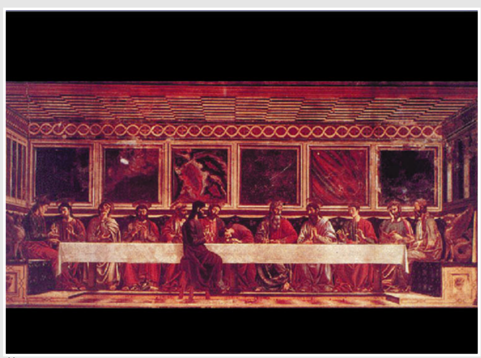
iv.

v.

11. One will also be able to trace the continuity of a given theme such as the six-sided geometrical flower motif, found in such disparate sources as (i) a Roman Mosiac in Sousse (Tunisia), (ii) in the Codice Atlantico (Milan, Ambrosiana), one of the notebooks of Leonardo da Vinci, (iii) as a decoration on the base of a cauldron in the Royal Ontario Museum (Toronto), (iv) a decoration on a house in Goslar (Germany), and (v) in nature on the surface of a puffer fish.



i.



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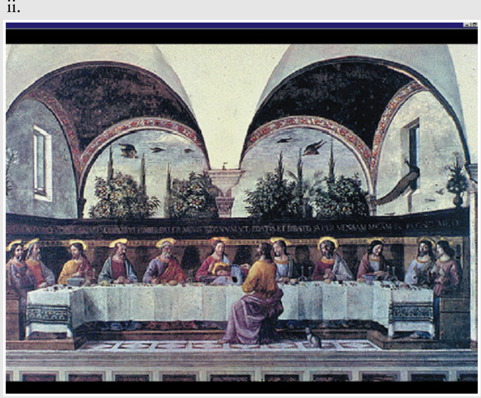

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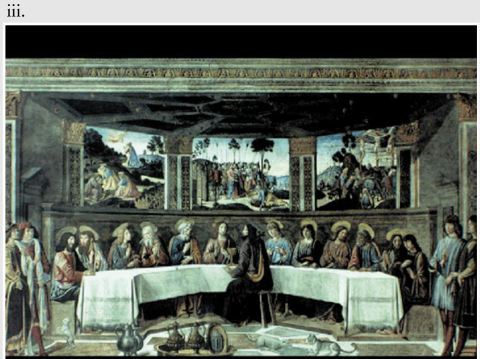

iv.

12. SUMS will also allow one to examine different versions of a painting such as the *Last Supper* ranging from Taddeo Gaddi's fresco in the Refectory of Santa Croce in Florence, through versions by (i) Leonardo da Vinci (Milan, Santa Maria delle Grazie); (ii) Andrea Del Castagno (Florence, Sant'Apollonia); (iii) Domenico Ghirlandaio (Florence, Museo di San Marco); and (iv) Cosimo Roselli (Vatican, Sistine Chapel, Refectory).

aLab (Schellinkhout), notably Thijs Chanovski, has focused on the role of visual symbols. He has been exploring, for instance, how a cube viewed from different sides can make users intuitively aware of different aspects of a problem. Related to this are the n-views and n-Power projects linked with the Rogers Communications Centre, which use different intersections of a cube to address different aspects of a problem. Also related to this approach are concepts (environment, culture, seeing, drawing, diagramming, imagining) found in a new product called Vizability, which was designed by Kristina Hooper Woolsey and is based on Scott Kim's principles of visualization. These could be seen as points of departure for a method.

Xerox PARC developed both a perspective wall visualization and a cone tree visualization, the latter of which bears an uncanny resemblance to the cone tree (*Kegelbaum*) of LyberWorld [45] developed by the GMD, who have also worked on a relevance circle (*Relevanzkugel*), Information Overviews VISualization (IOVIS), and other techniques for presenting learning materials [46]. Closer examination of these techniques will probably confirm that their usefulness varies with the level of knowledge to which they are applied. For instance, cone tree and perspective wall visualizations lend themselves to lists of individual terms as in classification systems, but have less value in the presentation of abstracts or full contents.

Third, typography can be used as a tool to highlight important texts in different fonts and colors. The Visual Language Laboratory at MIT has been exploring a combination of all three approaches (spatial data, symbolic data, and typography). The laboratory envisages perspectival grids of terms, distinguished in terms of different fonts and colors. Although this tool produces dramatic and sometimes spectacular effects, a danger exists that the bravura of the effects distracts the user from the actual purpose of the exercise, namely to find new materials systematically. An interface is needed that maintains a coherent look and feel while adjusting constantly to different levels of expertise and many different applications. The System for Universal Media Searching (SUMS) offers a prototype.

Agents

In the United States, Brenda Laurel has emphasized the notion of agents, or knowbots [47]. Nicholas Negroponte calls them electronic butlers: the idea being that this technology will replace the need for direct human searching; that a person can give simple instructions using a voice-activated computer that will then find everything. In this view agents are merely slaves to human commands. It is assumed that persons with very different levels of expertise will be able to pose questions using natural language query systems such as CHAT [48], developed at the Centre for Information Technologies Innovation (CITI). In Europe a more active role for agents is foreseen by the research into televirtuality of the Institut National pour l'Audiovisuel (INA) [49]. Cameras linked to computers will produce electronic clones of individual users who will then go out to represent us and find what we need. While rhetorically fascinating to the extreme, there are reasons for being skeptical about this approach. Basic search engines such as Yahoo, Lycos, Alta Vista, and Opentext are still painfully inadequate.


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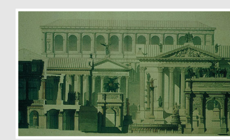
iii.


iv.


v.

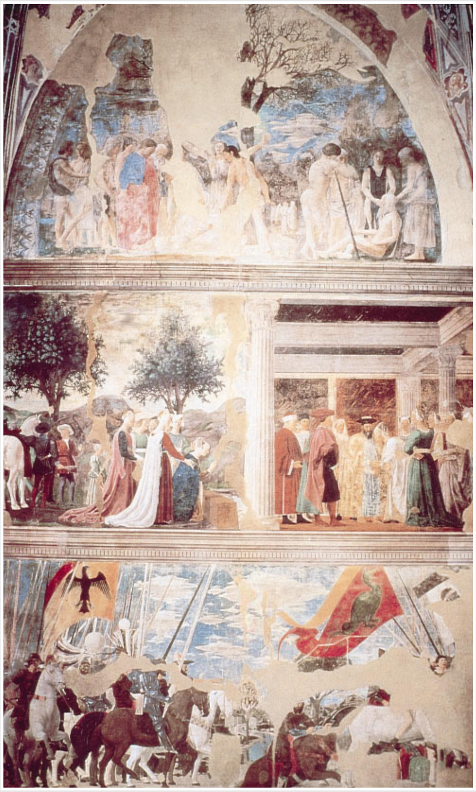
13. One will also be able to trace different cultural interpretations of a site such as the Roman Forum (i) modern day, noting version by (ii) Martin van Heemskerk (Escorial, Sketchbook, 16th century), and compare these with a (iii) French, (iv) German, and (v) Italian reconstruction of what it looked like in the days of its glory.

Those at the frontiers of data mining, such as Bigus, foresee a series of roles for agents in this emerging field, namely, data preparation, model and architecture selection, training and testing, output analysis, and agent-directed data mining [50]. Perhaps the best survey of agents is found in an insightful thesis by Hermans [51], who distinguishes between a weak and a strong notion of agents. The weak notion involves at least six types of agents (Figure 2).

According to Hermans, a strong notion of agents incorporates a series of five other characteristics, namely, mobility, benevolence, rationality, adaptivity, and collaboration. Hermans suggest a three-layer model for the Internet in which there would be users, intermediaries and suppliers. The intermediary layer would have agents that negotiate between users and suppliers. Hermans distinguishes between short-term (1996–1997), midterm (1998–2000), and future (after 2000) applications. Short-term applications include mail filtering, calendar scheduling, and making queries and requests using unambiguous sentences and wizards to guide users through a procedure, launch or set-up agents, and give advice or hints. They can be used for information management, personal newspapers, personal assistants, and personal research assistants. Mid-term applications extend to multi-agent systems integrating non-mobile and mobile agents, user agents that "see a need" or "propose a solution," or agents that act as a research librarian. After 2000, agents will understand even ambiguous sentences, dealing with ambiguity through user preferences and user models, and there will be anthropomorphic user interfaces. Such agents pose many questions about hardware, standards [52], user interfaces, security, reliability

14 i.

14 ii.



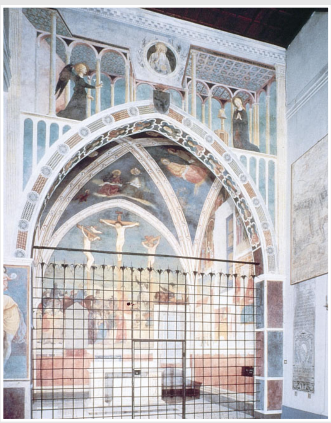
14 iii.

14-18. The life of Christ represents only a very small fraction of the Christian religious heritage. In the latter Middle Ages and throughout the Renaissance fresco cycles of the Lives of the Saints inspired an enormous corpus of artistic material. This corpus spanned the entire period from the creation of man, as recorded in the Old Testament and told in (14) the Story of the True Cross (Arezzo, San Francesco), and (15) the Life of Saint Peter in the New Testament (Florence, Chiesa del Carmine, Brancacci Chapel), the earliest martyrs Saints Lawrence and Stephen in the third century (Vatican, Chapel of Nicholas V), to various saints throughout the Middle Ages including the lives of (16) Saint Catherine of Alexandria (Rome, San Clemente), (17) Saint Augustine (San Gimignano, Sant'Agostino), and (18) Saint Francis of Assisi (Montefalco, San Francesco). The net effect of this enormous corpus of religious images was an awareness of a continuity between the time of Christ and the saints throughout the centuries. It is often said that the Renaissance marked a rejection of the so-called dark Middle Ages and the rediscovery of Antiquity. In fact, the Renaissance marked a discovery of the continuity between Antiquity, the Middle Ages and their own period. Computers will make visible these continuities as the cultural heritage dispersed through galleries and museums is virtually re-united electronically with the churches, monasteries and other places where it was originally conceived. The series in (i) shows global views of these five cycles, (ii) shows the left walls and (iii) shows the right walls, respectively.


15 i.


15 ii.


15 iii.


16 i.


16 ii.

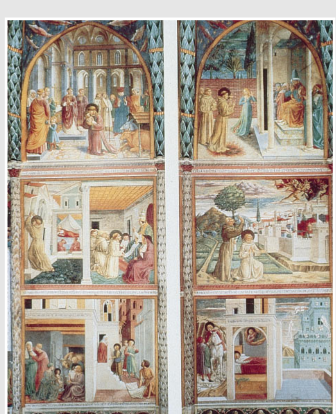

16 iii.


17 i.


17 ii.


17 iii.


18 i.


18 ii.


18 iii.

1. **Autonomy agents**
   Act without direct intervention of humans
2. **Social ability**
   Act with other agents or humans via some kind of agent communication language
3. **Reactivity**
   React to environment
4. **Proactivity**
   Are goal directed
5. **Temporal continuity**
   Are time based
6. **Goal orientedness**
   Handle complex, high-level tasks

Figure 2. Six types of agents according to the weak notion of agents as reported by Hermans (1996)

and not least ethics: to what extent do users wish to or should users wish to relegate their autonomy to electronic representatives?

It is an old adage that researchers who know what they will conclude at the outset are usually the least interesting. An essential dimension of research is about the materials I find in the periphery of my study, the book beside the one that I set out to find on the shelf, the tidbit that does not concern my main topic but that I file away and 20 years later produces a valuable insight. Hence if we can create agents that can find precisely what we think we want, the next challenge will be to produce agents to search the peripheries of what we think we want. Learning is largely about discovering that the real questions and answers are often not the ones with which we began.

All too little work has been done in systematically organizing materials even in major fields. A refreshing exception is offered by the eleven Group of 7 countries (G-7) pilot projects, namely, global inventory, global interoperability, education, libraries, world cultural heritage, environment, global emergency, health, government, small and medium enterprises, and maritime information systems. A common interface and more support are required for such initiatives [53].

TRANSFORMATIONS IN PUBLISHING, ENTERTAINMENT, AND KNOWLEDGE

Many of the initial electronic solutions assumed that the computer revolution lay merely in translating earlier media into a digital form that could readily be reproduced on a computer screen. We have already shown that more is involved, namely, linguistic translation, reconstruction, and interpretation. In fact, much more is involved. Computers involve polymedial transformations; that is, it is not just a question of translating various media into digital form but equally one of translating back from digital into other forms, meaning that an electronic version will in turn generate new versions of printed, voice, and other media. A digital version can be reprinted as a book or played back as if it were an audio tape. Moreover, digitization may require much more than a simple translation: (1) it invites retrospective image updating, by which old articles that have poor photographs or rough drawings can also draw on proper color photography, which could become a new service industry in itself; (2) each article or book in the secondary literature can be seen as offering a series of horizontal links between ideas, objects, or pictures and these connections can be linked retroactively with the respective databases; and (3) electronic versions require much more uniform and detailed descriptions than was required in manuscript or book form, which may become one of the new duties of librarians, or could amount to a further service industry.

All this points to a transformation of publishing. Thus far electronic publishing has tended to mean that one sends in a diskette with a file along with one's typescript. But the end product has remained with the same limitations as before. A major lecture with 150 color slides and 5 minutes of video is typically printed as text with a half dozen black-and-white images. A completely new approach to texts is possible, whereby there is a distributed repository of all basic paintings, objects, places, and so on. When an author writes a paper on the *Mona Lisa* or Notre Dame,

i. ii. iii. iv. v.

19. The SUMS system will also allow one to trace different variants of a painting by a given painter and his school, as in the case of Leonardo da Vinci's *Virgin of the Rocks* beginning with (i-ii) his own versions (Paris, Louvre; London, National Gallery) and including those (iii-v) of his students (Milan, Castello Sforzesco and Chiesa di Affori; Foglianise, Collection Pedicini).

hyperlinks are automatically made to all the source materials, drawings, photographs, and video clips about that painting or church. In time, such materials can be organized in terms of levels of interest so that authors and readers can choose between a brief image that serves as an *aide-mémoire* or a detailed survey of available materials. This process can be applied retroactively to articles and books of the past. Thus, the function of authors, the nature of new publications, and the value of past publications can be transformed. The fundamental implications of this transformation on copyright are beyond the scope of this article.

Computers point to an analogous transformation in entertainment. Video on demand is only an initial step. Instead of paying Blockbuster Video or the local video store for rental of a physical tape, the user will be debited for having downloaded a digital version of the film. Once new technologies allow users to alter the sequences of films, there will a whole range of "new" content. Will these be exchanged freely in online amateur clubs or sold individually, or will a new kind of dis-

ii.

iii.

iv.

v.

i.

20. Similarly in the case of his famous *Burlington Cartoon* (now London, National Gallery), which leads (i) to his *Virgin and Saint Anne* (Paris, Louvre), the figures of which (ii) his student Cesare da Sesto copies without the landscape (Venice, Accademia), and for which other students subsequently supply either (iii) a North Italian (Milan, Poldi Pezzoldi) or (iv), in the case of Quentin Massys, a Flemish background (Budapest, Museum) or (v) Milan, Brera.

tributor make this its niche market? In the case of famous themes such as *Tarzan* we already have dozens of versions by major companies. Will the new technologies mean that there are thousands of versions of *Tarzan* and, if so, who will want to see them all? Will there be more home entertainment or will new combinations of movie theater and theme park bring a revival of public media centers? What implications will all this have for our sense of community?

Ultimately computers are transforming knowledge itself by radically altering the tasks and goals of learning. In the thirteenth century, for instance, it took nearly 100 monks 10 years to create an index of the writings of one great man, Saint Thomas Aquinas. Today that same task would take a large and powerful computer a few minutes. In the past the ultimate goal of an individual scholar was to identify everything connected with the artist (*catalogue raisonnée*) or person he was studying. This often constituted a lifetime's work. Within the next generations such lists can also be reduced to a few minutes. Therefore, the kinds of questions scholars have traditionally tackled will become obsolete, or rather they will become so easily solved that scholars can concentrate on other things [54].

A whole range of new questions will pose themselves. In the past, a classicist often spent a lifetime reading through the major texts of classical literature in order to understand the evolution of concepts such as nature or love. Today, the entire corpus of Greek and Latin literature exists electronically. Initiatives such as the Perseus project [55] are making this available online. Tracing the etymology and all the uses of a word takes only a matter of minutes even if the question of their interpretation still requires some time. A Shakespearean scholar, instead of simply studying a single text, may choose to study the history of different editions and translations, exploring how German treatments of *Hamlet* were very different from French and Danish treatments during the nineteenth century. Instead of looking only at a given concept, scholars may examine the impact of different mentalities to explore how this affected changing definitions, locally and historically.

In the future there will be other kinds of questions for those who devote their lives to scholarship [56]. It used to be the case, for instance, that historians limited themselves to studying what the evidence showed happened, as it actually was (*wie es eigentlich geschehen*, in Ranke's terms). The latest developments are prompting Italian archaeologists to consider using virtual reality to create various scenarios and test hypotheses about urban organization, social structure, and economic factors [57]. Visualizations are becoming so realistic that these tools can no longer be dismissed as idle conjectures. This is not to say that everything that is convincing will necessarily be true. Here again we need new criteria for veracity [58].

So often in the past a scholar spent a lifetime working on some difficult or obscure problem, unaware that someone else was interested in the same thing. In the future, those who by nature are loners will use the emerging tools in seeing new patterns and trends, and not just the facts but the contexts in which they arise, and share the results online. Meanwhile, collaborative tools will allow people inclined to cooperate to compare notes more regularly. Thus, the very tools that may seem to preclude the need for study for some can provide incentives for a new revival of learning.

CONCLUSIONS

Those introducing new technologies have frequently applied them to solve traditional or outdated methods of teaching and research. This article has surveyed some major trends in computing, consciously omitting some realms such as the military [59]. I have focused on computers as recording devices; how they are replacing traditional writing and drawing devices; bringing new liberties in editing; revision control; collaborative work and design; space and geography as integrating metaphors; a move from packaged software to online applications; from quantity to quality;

toward universal libraries; translation, reconstruction, and interpretations as new industries; increasing emphasis on interfaces and conceptual navigation; attention to agents; and how computers are transforming publishing, entertainment, and knowledge itself.

In the past the great advances of learning came when people took the trouble to translate the great achievements of others. Alexandria became great because its inhabitants collected and translated the wisdom of the Egyptians, the Greeks, and others. Arabic civilization became great when it took the trouble to translate the Greek and Roman classics. The Renaissance achieved its greatness by bringing this translation campaign to a higher plane through visionaries such as Erasmus, who worked with Aldus Manutius to invent portable versions of the classics. Hand in hand with translation has been the growth of methods of reconstruction and interpretation. Each of the historical milestones just mentioned—the Greeks, Arabic civilization, and the Renaissance—made serious contributions to these fields.

This article has claimed that the computer revolution marks a new stage in this translation process, and at the same time has major implications for reconstruction and interpretation. Indeed, these contexts are probably where computers will have their most enduring impact: in helping reconstruct past achievements and possibilities from multiple cultural viewpoints, so that interpretation is seen not just in terms of cultural differences, but rather as a tool for cross-cultural tolerance and understanding, literally helping us to see different cultural views.

At the same time, reconstruction is not only a process for dealing with things past. In the case of existing objects, reconstructions create models and simulations of reality. In terms of future objects, this same process helps in designing new things, imagining that which could be. Thus, although some continue to see computers mainly as multimedia gadgets, computers are changing our approaches to the past, present, and future. They are transforming what we know, how we know, and the very nature of knowledge itself.

Acknowledgments

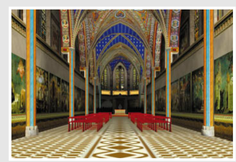
I am thankful to John Rheinfrank III, who visited the McLuhan Program in late 1995 and casually challenged me to write about the impact of computers on culture. I thank warmly Eric Livermore and Arnold Campbell (Advanced Networks and HCI respectively at Nortel's Bell Northern Research Laboratory) for a research contract and Stuart McLeod (VP Technology, Bell MediaLinx) for a consultancy which gave me the "leisure" to produce this paper, as well as Dr. Larry Moore (Executive Director, Ontario Library Association) for providing me with an office to continue my work. This paper owes insights to generous comments by John Orme Mills O.P. (London), Dr. Ingetraut Dahlberg (Frankfurt), Dr. Hiroshi Ishi (Hitachi and MIT), Ing. Udo Jauernig (Leonberg), Eric Dobbs (Las Vegas), Warren Robinett (Chapel Hill), Dr. Fabrizio Funto (Infobyte, Rome), Professor Alfredo Ronchi (Politecnico, Milan), Professor John Danahy (Centre for Landscape Research, Toronto), Dr. Manfred Kaul and Dr. Monika Fleischmann (GMD, Sankt-Augustin), Professor Giuseppina Battisti (Sapienza, Rome), Professor Anna dell'Agata (Rome), Dr. Fred Minzer (IBM, Watson Labs), Father Leonard Boyle (Prefect, Vatican Library), Dr. Eric McLuhan (Toronto), Dr. Heiner Benking (Ulm), Principal John Volpe, (Toronto), John MacDonald (Toronto), as well as student members of our team Rakesh Jethwa, Hasan Murtaza, David Pritchard, Andrew McCutcheon, Greg Stuart, Jeremy Meaghan Cargill and Hugh Finnigan (Toronto). I am grateful to all of them for expanding my horizons. Finally, I thank Jennifer Bruer, Steven Cherry and Naomi Berger for their great patience in seeing this article through the press.

ADDITIONAL ART IN THIS ISSUE

21-22. [Page 19 and Page 25] A closer look at scenes from only one of these cycles, namely, The Life of Saint Francis of Assisi (Montefalco, San Francesco) helps us to see how the story was translated into a coherent set of scenes:

i. Saint Francis Celebrates Christmas at Greccio
ii. Dream of Pope Innocent III, Pope Honorius Confirms the Franciscan Rule
iii. Birth of Saint Francis, Christ as Pilgrim, Spreading the Cloak
iv. Trial by Fire Before Sultan
v. Expulsion by the Demons from Arezzo
vi. Saint Francis gives a Soldier his Cloak, Saint Francis Dreams of a Heavenly Fortress
vii. Stigmatization of Saint Francis
viii. Saint Francis Preaching to the Birds, Blessing the Bishop and Dignitaries of Montefalco
ix. Saint Francis Denies his Father in Assisi, The Bishop of Assisi Clothes Saint Francis
x. Saint Francis Ascends into Heaven, Death of Saint Francis
xi. Death of the Nobleman of Celano
xii. Vision of Saint Dominic, Meeting of Saint Dominic and Saint Francis

We note also that each scene has beneath it a specific text in Latin. A full appreciation of this heritage will require translations of the texts, which will then be linked with the various textual sources scattered in libraries and archives throughout the world. Since the Renaissance we have used different media to separate different aspects of cultural heritage: paintings go to museums, engravings to engraving cabinets (Kupferstich Kabinett), drawings to drawing collections (cabinet de desseins), etc. Computers offer new possibilities of virtual integration of these dispersed treasures.

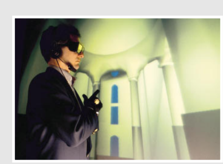


23. [Page 7] Reconstructions of the Church of San Francesco at Assisi (Infobyte, Rome). Initially, this project, funded by ENEL (the Italian hydro-electric company) as part of their Light for Art (Luce per Arte) series, set out to show the potentials of illuminating the actual church. It was such as success that they decided to make a virtual reality reconstruction of the church. This was awarded a prize as the best virtual reality model in the world in 1993. It is of particular interest for our purposes because it shows in context the theme of Lives of the Saints as shown in figures 14-22.

24. [Page 88] Reconstruction of space within a fresco, San Francesco, Assisi (Infobyte, Rome). Here the depicted space of one of the paintings by Giotto has been reconstructed. This potential of entering into the space of a painting has recently been explored in the Virtual Lowry project at the University of Salford. These techniques give a whole new meaning to the idea of entering into the world of an artist.

25. [Page 75] Reconstruction of Raphael's Rooms *(Stanze),* Vatican (Infobyte). The concept of infinite resolution has already been explained above. This full image gives some sense of the richness of these images when seen on a high resolution Silicon Graphics Infinite Reality Engine.

26. [Page 79] Detail of same. In famous museums viewers are typically forced to remain at least two or three feet away from the walls with paintings and/or frescoes. As a result, especially in the case of images high up on a wall, the viewer is unable to see all the details. One of the great advantages of this new reconstruction technique is that a viewer is able to see these details which they could not see while at the actual sight.



27. [Page 13] Reconstruction of Frauenkirche, Dresden (IBM). The Frauenkirche is a particularly fascinating case because this church was bombed to a rubble heap in World War II. Engineering students at the Technical University of Dresden used photogrammetric methods to record each stone, whole or partial. These measurements became the starting points for CAD equivalents of each "building block", which were then combined to create a virtual model of the church which became a featured display at the 1994 CEBIT show (Hanover). This virtual reality of the reconstructed church is now serving as a basis for a physical reconstruction of the original building.

We thank the following churches, museums, galleries, companies and individuals for permission to reproduce their paintings, drawings, frescoes and reconstructions:

Churches

Chiesa di Afforni, Milan (fig.19.iv)
Chiesa di Ognissanti, Florence (fig.12.ii)
Chiesa di Sant'Apollonia, Refectory, Florence (fig. 12.iii)
Sistine Chapel, Vatican (fig. 12.iv)
Santa Maria delle Grazie, Milan (fig. 8.v; 12.i)

Collections, Museums and Galleries

Accademia, Venice (fig. 9.ii; 20.ii)
Archeological Museum, Sousse (fig. 11.i)
Biblioteca Ambrosiana, Milan (fig. 11.ii)
Brera Museum, Milan (fig. 19.iii)
Duke of Devonshire, Chatsworth (fig. 9.v)
Galleria Borghese, Rome (fig. 10.iii)
MacNamara, Dawlish (fig. 10.iv)
National Gallery of Canada, Ottawa (fig. 2.i-v)
National Gallery of England, London (fig. 19.ii)
National Museum, Poznan (fig. 20.iii)
Louvre, Paris (fig. 11.iii; 19.i; 20.i)
Palazzo Vecchio, Florence (fig. 10.v)
Pedicini, Foglianise (near Benevento) (fig. 19.v)
Poldi Pezzoldi, Milan (fig. 19.iii; 26.iii)
Prado, Madrid (fig. 9.i)
Royal Ontario Museum, Toronto (fig. 11.iii)
Staatliche Kunstsammlungen, Schloss Wilhelnshöhe, Kassel (fig. 9.iv)
Windsor, Collection of Her Majesty the Queen (fig. 9.iii; 10.i)
Uffizi, Florence (fig. 5.i-v)

Companies

Editech, Florence (fig. 1)
IBM, Germany, Manuela Rost-Hein (fig. 27)
Infobyte, Dr. Fabrizio Funto and Pier Luigi Zerbini (figs. 3, 23-26)
National Research Council of Canada, Dr. George Forrester (fig. 2)
SUMS Corporation (figs. 4, 5, 8)
Worldsat maps (fig. 5)

Individuals

Barry Selwyn (11.iv)
Dr. Rolf Gerling (fig. 11.i)
The scenes of cycles of saints are from the excellent book by Steffi Roettgen, Italian Frescoes, The early Renaissance, New York: Abbeville Press 1996, pp. 139; 45; 124; 64; 226; 174 (fig 14.i, 15.i, 16.i, 17.i, 18.i); pp. 138; 44; 122; 63; 225; 173 (fig 14.ii, 15.ii, 16.ii, 17.ii, 18.ii); p. 173 (fig 21) and p. 174 (fig.22).

References

[1] Some endnotes contain references to projects being developed on the Internet. They are introduced by the letters "http" (hyper-text transfer protocol).
[2] For a recent example in the realm of games see *Police Quest Swa*t. I am grateful to Jeremy Meaghan-Cargill for this reference.
[3] A major project, led by the Gesellschaft für Mathematik und Datenverarbeitung (GMD), concerns distributed video production (DVP). See http://viswiz.gmd.de/DVP.
[4] http://www.soe.oeaw.ac.at/w4g.
[5] Ishii, Hiroshi, and Miyake, Naomi. "Toward an Open Shared Workspace: Computer and Video Fusion Approach of Team Workstation." *Communications of the ACM 34*, 12 (December 1991), pp. 37-50. Ishii, Hiroshi, Kobayashi, Minoru, and Grudin, Jonathan. "Integration of Interpersonal Space and Shared Workspace: Clearboard Design and Experiments." *ACM Transactions on Information Systems 11*, 4 (October 1993), pp. 349–375.
[6] http://gopher://zserve.nist.gov:79/0:docs/atp/94010169.
[7] http://www.nwu.edu/CoVis_Wellcome.html.
[8] http://nu-gna.mit.edu.8001/uu-gna/text/cc/moo/what.html.
[9] For a more detailed examination of the relative values of synchronous and asynchronous communication, see Veltman, Kim. "Space, Time, Information and Knowledge." *Proceedings of the Simposio Europeo Eco-Crea 1996. Spazio tempo informazione nella scienza, cultura, economia* (Venice, May 24–25, 1996), (in press), pp. 1–5.
[10] The Neurope Lab, the Centre de Recherches d'Informatique de Montréal (CRIM), and the Telecommunications Research Institute of Ontario (TRIO), through their Knowledge Connection project, have been protagonists in this field.
[11] See Ronchi, Alfredo. "Virtualità reale." *Bolletino d'Informazioni. Centro di Ricerche Informatiche per I Beni Culturali IV*, 1 (1994), Pisa, pp. 7–31, especially pp. 26–27.
[12] For a significant description see Harasim, Linda. *Global Networks: Computers and International Communication.* MIT Press, Cambridge MA, 1993. For a critical review of same see Mansell, Robin. *Intermedia, 22,* 1 (February 1994), London, pp. 44–45.
[13] For a more detailed discussion of this topic see Veltman, Kim. "Content Ordering or Ordered Content? Active versus Passive Knowledge."(Unpublished paper available on request from the author).
[14] The latest PDA is Pilot from U. S. Robotics. See Heilbron, Maarten."U.S. Robotics' Pilot Soars Above the Rest of the PDA Pack." *The Globe and Mail* (June 22, 1996), Toronto, p. B20.
[15] ECO is an interactive, computerized voice system (sistema informatico vocale interattivo).
[16] Sullivan, James. "Invisibly Interactive." *Wired* (July 1996), San Francisco, p. 64.
[17] http://www.omega.it/million/synopsis.html.
[18] For a description of these models and a good survey of developments in virtual reality, see Ronchi, Alfredo. "Virtualità reale," cited in Note 11, pp. 7–31, especially p. 21.
[19] http://pubweb.parc.xerox.com/hypertext/services.html.
[20] http://www.argusmap.com.
[21] http://tracy.esrin.esa.it:5555/query.html.
[22] http://www.hyperreal.com/~mpesce.
[23] Most of us have become inured to the fact that we are being observed by video cameras every time we enter a bank, subway, or other public building, largely because we assume that all these snapshots of our lives are restricted to the context in which they are being recorded. But

what if all these snapshots can be coordinated? What are the consequences for privacy, especially for people who work in downtown areas where almost all the space is public. Theoretically it would be possible to "follow" persons as they moved from building to building, subjecting them to an unconscious version of *Candid Camera.*

[24] http://www.eccs.uic.edu/~ddpape/gallery/RemSens.html.

[25] http://viswiz.gmd.de/DML/cwall/cwall.html.

[26] http://www.ifi.uio.no/~sigar/vroslo/queau.html

[27] Queau, Philippe. "Televirtuality, Virtual Communities, Real Time Image Processing, Facial Synthesis" (1996) at http://www.ifi.uio.no/~sigar/vroslo/queau.abstract.html. See also Queau, Philippe. *Le Virtuel: vertus et vertiges.* Editeur INA, Champ Vallon, 1993; *Metaxu: théorie de l'Art Intermédiaire,* INA, Champ Vallon, 1989; *Eloge de la Simulation—de la Vie des Langages a la Synthèse des Images,* INA, Champ Vallon, 1986.

[28] http://www.bekkoame.or.jp/~goto-co/GOTO_home.html.

[29] Rheingold, Howard. *The Virtual Community*, Addison-Wesley, Reading, MA, 1993.

[30] Sternberg, Robert J., *Successful Intelligence*, Simon & Schuster, New York, NY, 1996. cf. Howard Gardner, *Multiple Intelligences: The Theory in Practice,* Basic Books, New York, NY, 1992.

[31] http://nemo.ncsl.nist.gov/~sressler/projects/nav/nav.html.

[32] Valerio, Giovanni. "RV e arte. L'affresco che parla," *Virtual 31* (May 1996), Milan, pp. 35–37.

[33] The concept of networks needs to be developed considerably. The International Standards Organization (ISO) identifies seven layers of network architecture: 1. Physical (network layer) , 2. Data-Link (network layer), 3. Network (network layer), 4. Transport (transport layer), 5. Session (user service layer), 6. Presentation (user service layer), 7. Application (user service layer). All this is excellent, but it addresses only objects being pipelined and how they come out the other end. It does not address the whole input side. What are the standards for identifying objects, recording them, scanning them in, verifying that the images we have correspond to the objects that they claim to represent—that is, the whole question of forgeries and imitations, which need also to be distinguished from deliberate copies, reproductions, and the like.

[34] http://gopher://zserve.nist.gov:79/0/doc/atp/94030012.

[35] email: hans-guenter.thonemann@mch.sni.de.

[36] Sutherland, Ivan E. "The Ultimate Display." *Proceedings of the IFIP Congress,* 1965, pp. 506–508. Compare. Sutherland, Ivan E. "A Head-Mounted Three-Dimensional Display." Fall Joint Computer Conference, 1968, pp. 757–764.

[37] "Report on Business." *The Globe and Mail* (June 18, 1996), Toronto, p. B27.

[38] http://silicon.montaigne.u-bordeaux.fr:8001/HTML/TUNISIE/sites.html.

[39] The site at http://www.nww.co/ruscrypto.html reproduces an edict of Boris Yeltsin's that provides a rather frightening insight into how cryptography is being used to achieve these ends. Only slightly less obvious techniques are evident in the United States, which is trying to make the spread of encryption technology a serious crime. Compare. Meeks, Brock. "Major Loss for U.S. in Internet Privacy War." *Now* (June 13–19, 1996), Toronto, p. 23. Related to this problem of encryption is the proposed use of clipper chips which potentially censor free speech.

[40] See, for instance, "U.S. Court Blocked as Unconstitutional a New Federal Law Prohibiting Indecency on Computer Networks." *Toronto Star* (June 13, 1996), reproduced in http://www.aclu.org.

[41] Why, for instance, do some people prefer text-based discussion groups (MOOs) when they could have conference calls or videoconference calls? One reason, of course, is that the more primitive text-based mode provides a greater sense of anonymity.

[42] See Shneiderman, Ben. *Sparks of innovation in human and computer interaction,* Ablex Publishing Co., Norwood, NJ, 1993.

[43] http://www.bbb.caltech.edu/hbp/design/html.

[44] Robinett, Warren. "Electronic Expansion of Human Perception." *Whole Earth Review* (May 2, 1991), San Francisco, pp. 2–8, Figures 1–7.

[45] Hemmje, M. "Lyberworld—Eine 3D basierte Benutzerschnittstelle für die computerunterstützte Informationssuche in Dokumentmengen." *Der GMD-Spiegel* (1993), Bonn-Sankt Augustin.

[46] Kling, Ulrich. "Neue Werkzeuge zur Erstellung und Präsentation von Lern- und Unterrrichtsmaterialien." In *Learntec 93, Europäischer Kongress für Bildungstechnologie und betriebliche Bildung, Tagungsband.* Uwe Beck and Winfried Sommer, eds. Springer Verlag, Berlin, pp. 335–360, 1994.

[47] Laurel, Brenda. *Computers as Theatre.* Addison-Wesley, Reading, MA, pp. 35–92, 1991.

[48] http://debra.dgbt.drc.ca/chat/chat.html.

[49] http://www.ina.fr.

[50] Bigus, Joseph P. *Data Mining with Neural Networks* McGraw-Hill, New York, 1996, pp. 125–127.

[51] Hermans, Björn. Intelligent Software Agents on the Internet, An Inventory of Currently Offered Functionality in the Information Society and a Prediction of (Near-) Future Developments. *Doctoral dissertation.* Tilburg University, July 1996. For an on-line copy see http://www.hermans.org/agents/h22.htm). For an excellent bibliography on agents, see also the site of the University of Maryland, Baltimore County (http://www.umbc.edu/agents/web).

[52] Standards pose an enormous challenge. The G7 pilot project 2 on global interoperability is intended to address some of these problems. Another series of initiatives is intended to address the problem of metadata, including the following:

INSTITUTION	COMMITTEE/SOFTWARE	
AEGIS for G7		
American National Standards Institute	ANSI	X3L8
American Society for Information Science	ASIS	
ARPA Knowledge Sharing Effort	ARPA	
Deutsche Institut für Normung		
Document Management Alliance		
European Open Systems Workshop	EWOS	
Expert Centre for Taxonomic Identification	ETI	
Infoterm Österreichisches NormungsInstitut	ON	ISO 639:1988 (EF)
International Institute for Terminology Research	IITF	
International Society for Knowledge Organization	ISKO	
International Standards Organization	ISO	JTCI/SC14, TC 37
Global Information Infrastructure	GII	
L. Livermore National Labs Intelligent Archive	LLNL	
Library of Congress	LC	USMARC
National Information Infrastructure	NII	
National Information Standards Organization	NISO	
National Metacenter for Computational Science and Engineering	NMCSE	Khoros
Online Computer Library Company	OCLC	Dublin Core
Open Information Interchange	OII	
Open Systems Implementors Workshop		

Scientific Data Management	SDM
Society for Terminology and Knowledge	
Standard Graphical Markup Language	SGML
Termnet	
Text Encoding Initiative	TEI

In the context of European efforts toward data standardization, some of the major steps are provided by the Guide to Open Systems Specifications (GOSS) and the Open Information Interchange (OII), which include the following:

Audio interchange	OII
Character sets	GOSS, OII
Color information exchange	OII
Conformance and testing	GOSS
Document handling and management	GOSS,OII
Electronic data interchange	GOSS, OII
Electronic payment support	OII
Geographical information	OII
Information structure and representation	GOSS
Internet communication protocols	OII
Library applications	GOSS, OII
Management	GOSS
Messaging and e-mail	GOSS
Miscellaneous	OII
Multimedia/hypermedia interchange	OII
OSI data transfer	OII
Product description	OII
Raster graphic interchange	OII
Scientific data exchange	OII
Security	GOSS
Transport coexistence and convergence	GOSS
Vector graphic interchange	OII
Video exchange	OII

North American initiatives in data standardization include the following:

- Agents
  - KQML
  - Telescript
- Character Sets
  - IETF working group
  - MIME_SGML working group
  - HTML working group
  - HTTP working group
- Geospatial Standards
  - ASTM American Society for Testing and Materials
  - FGDC Federal Geographic Data Committee
  - OGIS Open Geographic Data Committee
  - SAIF Open Geodata Interoperability Specification
  - SDTS Spatial Data Transfer standard
  - Z39.50 + spatial data elements
- Other Data Standards
  - Draft International Standard (DIS) 10303-STEP
  - MIL-STD-1388
  - DoD Enterprise Data Model
  - ANSI X12
  - UN/Edifact.

Significant Web sites include the following:

http://llnl.gov/liv_comp/metadata/proceedings/author_index.html.
http://llnl.gov/liv_comp/metadata/other-efforts/other-metadata-efforts.html.
http://www.ewos.be/aegis/home.htm.
http://cpmcnet.columbia.edu/www/asis. (This has a special interest group for Classification Research. Another branch of the same site is http://cpmcnet.columbia.edu/www/asis/interest.html.)
http://www.ewos.be/ewos
http://sil/sgml/iso639.html
http://www.fh-hannover.de/ik/Infoscience/ISKO.html; www.hud.ac.uk/schools/cedar/isko.html.
http://www.ewos.be/ewos/gii.htm;
http://www.gsf.de/MEDWIS/dokument/info_lit.html#allgemeines.
http://www.faxon.com/Standards/NISOcat/NISOcatTOC.html.
http://www.echo.lu/oii/en/oiistand.html#oiist and http://nemo.ncsl.nist.gov/oiw/.
http://www.ccg-gcc.ca/publishing/where/austria-e.html.
http://www.w3.org/pub/WWW.MarkUp/SGML
http://www-tei.uic.edu/orgs/tei/info/teij16.html.
http://www.ewos.be/goss/top.htm.
http://www.oclc.org:5046/oclc/research/publications/weibel/metadata/dublin_core_report.html.
http://www.sdsc.edu/SDSC/Metacenter/MetaVis.html#3 (provides electronic addresses for all of the above).
http://ds.internic.net/z3950/z3950.html (provides a list of available implementations).

[53] *G7 Ministerial Conference on the Global Information Society. Round-Table Meeting of Business Leaders* (Brussels, February 25 and 26, 1995), Office for Official Publications of the European Communities, Luxembourg, 1995. Von Bose, H. G-7 *Information Society Conference Pilot Projects, Executive Summaries.* European Commission, Brussels, 1995.
[54] See also Veltman, Kim. "Computers and a New Philosophy of Knowledge." *International Classification,* 18 (1991), Frankfurt, pp. 2–12.
[55] http://www.perseus.tufts.edu/oldIndex.html.
[56] For additional thoughts on the these themes see the author's vision statements and essays on the System for Universal Media Searching (SUMS) at the Web site for the Perspective Unit at http://www.mcluhan.utoronto.
[57] See Consiglio Nazionale delle Ricerche. Progetto Finalizzato Beni Culturali, "Strumenti di Realtà Virtuale e simulazione per il testing delle ipotesi archeologiche e per la esposizione e divulgazione al pubblico." In *Musei Virtuali in Rete. Progetto Beni Culturali,* Pisa, May 1996.
[58] See Mitchell, William J. *The Re-configured Eye. Visual Truth in the Post-Photographic Era.* MIT Press, Cambridge, MA, pp. 56–86, 163–189. See also the author's "Electronic Media, the Rebirth of Perspective and the Fragmentation of Illusion," *Electronic Culture: Technology and Visual Representation,* ed. Timothy Druckrey, Aperture, NY 1995, pp. 208-227. English translation of "Elektronische Medien, Die Wiedergeburt der Perspektive und die Fragmentierung der Perspektive." *Illusion und Simulation,* Stefan Iglhaut, ed. Cantz Verlag, Munich, 1995, pp.229-239.
[59] Waller, Douglas. "Onward Cyber Soldiers." *Time,* 146, 8 (August 21, 1995), pp.30–38.