Kim H. Veltman

Frontiers in Electronic Media

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1. Introduction

In the film, *Disclosure* (released December 1994), the production manager of the high tech firm, Digicom, provides an intriguing glimpse into the potentials 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 that bears an uncanny resemblance to Saint Peter's Basilica in the Vatican recently produced in virtual reality by Infobyte (Rome) with support from the Italian electrical company, ENEL. He 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 centres 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 then reads in turn. The documents include video clips of video-conferencing as well as electronic copies of letters.[1]

Is this truly a model for the future? Will the new technologies merely translate traditional methods of storing information into a new medium? Or will they bring completely new approaches? This paper offers a survey of some present trends, notably in the realm of new recording devices; collaborative work and design, universal libraries, translations, reconstructions, interpretations, conceptual navigation and agents, before suggesting how new media will transform publishing and entertainment.

2. New Recording and Presentation Devices

A series of new cameras are transforming the scope of what is recorded. The IBM "Brandywine" camera typically scans a painting or a manuscript at 20-50 megabytes a page. The VASARI scanner scans images at 1.4 gigabytes per square meter. Such cameras provide new levels of detail which can then be used for problems such as retrospective colour conversion. The Canadian National Research Council (NRC) laser camera typically records images from 1-50 megabytes which can be rotated on screen such that one can see all aspects of a three-dimensional object in a way analogous to that which VRML is doing with 3-D models. The NRC camera can be linked with stereo-lithography to produce completely three-dimensional reproductions. Sculpture on demand at any scale is now possible. Meanwhile the National Research Council of Italy (*Consiglio Nazionale delle Ricerche*) has 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.

3. Replacing Traditional Writing and Drawing Devices

The first phase of the so-called computer revolution was largely in the realm of replacement technology. Computers replaced typewriters but continued essentially the same functions: typing became work with electronic word-processing packages. Some persons assumed that computers would in turn replace secretaries but forgot that secretaries are much more than word-processors. Their key role lies in filtering persons and information for their employers. And although there may be a great deal of rhetoric about personal digital assistants and electronic butlers, the likelihood of such an electronic device seriously serving as this kind of filter has yet to be demonstrated.

Meanwhile, many architects have been replacing drawing instruments such as the rule(r), compass and other drafting tools with Computer Aided Drafting (CAD) tools. At the higher levels CAD became one of the four C's, along with Computer Aided Engineering (CAE), Computer Aided Manufacturing (CAM), and Computer Integrated Manufacturing (CIM). More recently these developments are becoming part of a larger trend whereby space and geography are becoming integrating metaphors (see 9 below).

At the same time, there are still enormous discrepancies between that which is claimed possible and that which 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. Recently there seems a trend to re-emphasize pen based assistants, notwithstanding the obvious shortcomings of the Apple *Newtons*. Complete integration of voice and translation still needs to be done.

4. New Liberties in Editing

One of the main reasons why computers replaced typewriters was because they made the editing much simpler. One could correct errors without the fuss and bother of erasing originals. This applied not only to words (e.g. *Word, Word Perfect*) but equally to charts (*Excel*), drawings, pictures and photographs (*Photoshop, Photostyler*). In studios this extended to photo-finishing. In the realm of television and video-conferencing it meant that sequences could be edited more readily (non-linear editing). There is presently much research on extending the concept of chroma-keying to produce blue rooms[2] and virtual sets, such that an actor in one site can be integrated with scenes at other sites.[3]

The advent of sektop publishing soon revealed that not everyone who is presnted with 200 fonts becomes a serious publisher. The same will prove true in the case of desktop film production as users try to become instant producers and directors. Yet some fascinating products will undoubtedly emerge from these new tools. All of which has 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.

5. Revision Control

To answer these needs the leading vendors introduced revision control. At the simplest level this merely entailed a clear record of which version was done earlier or later. The introduction of object-oriented programming and dynamic link libraries meant that in cases where there were multiple copies of a record, correcting a chart once led to its correction across the board. In a networked context this meant that correcting a spreadsheet in one office led to spreadsheets in other cities automatically being updated 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 it will be possible to include ever more complex materials in the packets which can be updated simultaneously. Companies such as Digital 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.

6. Collaborative Work, Training, and Design

The early stages of this computer revolution were effectively about documents which were static, or at least aimed at being static in spite of changes introduced through editing and revisions: letters, charts, pictures, photographs etc. The trend has been in the direction of dynamic situations where the information is constantly changing, where interactivity is essential to the process. Tele-conferencing is the simplest example of this kind of activity, followed by boardroom-conferencing and multimedia-conferencing. Here the challenge is not only to communicate at a distance, but also to record the proceedings

audio	telephone
video	video camera, TV
audio-visual	tele-conferencing, (audio-)video-conferencing
audio-graphic	smartboard, Vis-a-Vis
audio-visual-graphic	virtual reality

Fig. 1. Types of distance communication

of important meetings in ways such that individuals unable to make a given meeting will be able to make sense of them afterwards. IBM's *We-met* still in prototype at Yorkton Heights is an example. One of the most impressive free tools in this context is Web4groups.[4] The basic elements of these technologies are summarized in figure one 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 thereof. Audiographic packages such as *Vis-a-Vis*, which use smart boards represent a next stage in complexity. These permit persons in two centres to make written comments or markings on a common image together in so-called real time. A further stage in complexity is offered by Hiroshi Ishii 's clearboard at NTT, which extends the basic principle of the window and permits persons to mark things together while still maintaining eye contact.[5] Projects under 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] 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 rather cancels the innovative dimensions they could potentially have. Video-conferencing offers an excellent case in point. The fashion is to link up two or more sites and then have 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, simply send this by mail or asynchronously, and then use the live video-conference 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: i.e. the distance education class 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 programmes which permits one to trace a user's path. This is giving computers new roles in assessing the extent to which alternative features are employed by different users. This is also proving useful with respect to testing and goal assessment, which is of particular interest in the field of training where rote memory plays an important role.

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

Similar scenarios are being discussed in the context of tele-medicine. In Tokyo ambulances typically require up to two hours to return from the site of an accident to a hospital. Hence ambulance drivers are being equipped with head mounted displays which permit a doctor in a hospital to examine a patient at a distance and offer provisional advice before the patient is moved. In the LargeNet programme which links the University of Western Ontario with seven local hospitals and other institutions, there is conscious work on Interactive Collaborative Information Services (ICIS). Tele-presence, which was initially developed in the context of the military with respect to operating robots at a distance, is finding new applications in medicine. A doctor in one site is now able operate on an animal in another site. There have already been some experiments where this is extended to humans. So an ophthalmologist in London could do surgery in Hong Kong without either the doctor or the patient having to travel half way around the world.

In the realms of design and architecture, there is a quest to make the working environments for software packages such as 3-D Studio, Alias, and Softimage interactive, such 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 in 1990, the Department of Information Science at the University of Milan (Statale,1993) produced a "Virtual Space/Place Editor".[11]

This approach is also being extended to engineering. Companies such as Boeing are using a virtual reality wind tunnel which permits interactive study of scenarios of possible wind stress. Thus far most of these initiatives remain largely isolated efforts. A training package is designed to produce a short term result in a given discipline, or rather section of a discipline. There is 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 in the case of video-conferencing the various scenarios for tele-presence 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. Else what could be a great contribution risks being just a greater technological encumbrance.

There is also a danger that this leads to an ever more piecemeal approach, when the technology holds within it a capacity for a re-contextualization of knowledge. Any test reflects material in a textbook which is part of a course which is part of a curriculum and

in turn part of a corpus of knowledge. At present a person may get 100% on a test which represents only 20% of the textbook, 10% of the course, 2% of the curriculum and only .005% 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, such that an educator in India and the United States can make fair assessments of the relative preparation and achievements of students in their respective countries.[13]

These trends towards ever greater collaboration can be seen as part of a seemingly inexorable wave towards global connectivity, whereby anyone can be reached anywhere, at anytime, if not by video-conference, telephone or computer, then by cellular phone, satellite linked personal digital assistant or some related device. While these developments clearly have profound consequences, they also entail fundamental problems which require much closer attention.

In the past a person worked for a number of hours, 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-mails. Those that do find they no longer have any private space. Work becomes a permanent mode.

Being able to extend the range of one's teaching beyond the classroom via video-conferencing and the Internet is often attractive to administrators who see this as a source of savings by increasing the student-teacher ratio and thus decreasing the numbers of staff. This argument is all the more seductive in the case of 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 11 below).

In the realm of research where collaborative work is also becoming the fashion, another issue needs attention. Some fields are more conducive to collaboration than others. The Hubble telescope required the collaboration of 10,000 scientists throughout the world. An encyclopaedia or an Oxford English Dictionary require teams of scholars working together. On the other hand many studies require the careful, painstaking analysis of a single person. Most major monographs in the humanities, precisely because they entail a synthesis of facts and claims seen 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 where collaboration is neither needed nor useful.

7. Advertising and Selling

While some pessimists claim that the notion of the world wide web as a money making venture is naive and doomed to failure, most believe that computers linked by the Internet will have a great impact on advertising and selling. Precisely how they will do so is a matter of considerable debate. Some are convinced that the secret lies in creating virtual worlds for shopping on demand Some are confident that it simply requires putting up a web-page. Some believe that fancy web pages with clever advertising trap doors will do the trick.

Underlying all these solutions is a traditional view of advertising as something that interrupts a person while they are doing something else: a billboard while a person is driving, a page which they are reading in a magazine or a commercial while they are watching something on television. By these standards the more popular the thing one manages to interrupt, the more valuable the advertisement: i.e. a billboard on an expressway is better than on a regular highway; a page in a national magazine is worth more than a local one; a minute on prime time is worth more than an early morning spot.

Using this logic, many hits on web site make it more valuable than one with less hits and if one can trace how many times users went from such a site to the home pages of the vendors, then this is a more effective site. Yet the purpose of the Internet is to find things, not to be distracted along the way. Search engines and agents are being designed to make this process more direct. As this happens there will be fewer stops along the way and so hits will increasingly be at the destination. So the more effective the search engine, the less effective will be advertising along the way. Another alternative is proposed by Nicholas Negroponte who foresees the use of object-oriented television whereby "touching an actor reveals that his necktie is on sale this week."[14] Perhaps such salespersons and theoreticians are falling into the same traps as some educators who are trying to use new technologies to solve old problems, rather than examining how these technologies are transforming the problems themselves in the process.

Interestingly enough one alternative approach is offered by traditional yellow pages. Companies pay to be included in a readily accessible list to which a user instinctively turns the moment they need anything. An Internet equivalent might simply be one of the options whenever the user reaches an destination in their search. Just as users have a print function, there would be a product/buy function. This would be linked with the user's purpose and the topic searched. For instance, if a person chose tourism in Brazil then hotels and appropriate tropical camping materials would be advertised. If their purpose were university education, there would be lists of appropriate apparel, books etc. Advertisers would be given local, regional, national and international options. Hence a family business might choose only to appear in local directories, whereas a multinational company would wish to advertise globally.

Researchers at what were the Bell-AT&T Labs have been exploring knowledge representation in advertising using a home entertainment application as an example. A potential client is asked to define their budget and specific requirements. The programme

then guides them through a series of alternatives within that range, pointing out potential interoperability problems, thus illustrating that it is not so much individual items as integrated solutions that are important. This basic approach which contextualizes one's purchases will probably become increasingly important as more and more items become interconnected. There are some efforts to link this approach in turn to data-mining such that a persons' financial scope and purchasing tendencies are used in defining areas where they are likely to buy things.

8. Computers, Smart Objects and Ubiquity

Computers have evolved from bulky mainframes to personal computers, portables, laptops and ever smaller versions. In addition to the now familiar Personal Digital Assistants, (PDA)[15], The National Research Council of Italy (CNR) has developed [16]a telephone-like device, 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[17]. In Bologna personal digital assistants are being equipped with tourist information through wireless Internet connections.[18]

Some see these individual gadgets becoming completely pervasive and networked. For instance, Dr. Weiser, at Xerox PARC, has been preaching a notion of ubiquitous computing. Instead of a single machine on one's desk there will be hundreds of gadgets throughout one's home and office which are connected with 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 it should have ring with a personalized dial tone. Alternative models have been offered by Baudel and Beaudouin-Lafons; Feiner, MacIntyre and Seligmann as well as Fritzmaurice.[19]

In the sixteenth century an ever greater 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, televisions and connect with printers. We already have remote gadgets for operating our televisions and video cassette recorders. Why should these capabilities not be consolidated into a new hand held device which 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 aimed at third-world countries which will start at $100 and go down to about $20.

A more advanced version could contain a few gigabytes of space, separate programs for which would be downloaded from the Internet on arrival in each town. For example, a medical doctor visiting Rome on business, on arrival at his hotel, could download relevant information about local hospitals, clinics, doctors, and medical conventions. The same doctor arriving in Rome as a tourist could download information concerning the

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 future take their multi-valent 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 some global positioning system (gps) functionality (see below).

9. 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 have been moving towards 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, vegetation and crop patterns. These satellite images are becoming available in different scales and there are new methods for co-ordinating these and linking them systematically with maps at different scales. The Xerox map introduced a very simple method.[20] The Argus Map viewer linked maps of a city to different purposes: e.g. business, health, tourism[21] etc., while the University of Pennsylvania has created a more advanced viewer.[22] Such maps, in turn are being linked via global positioning systems such that one can start from any point on the earth, use satellites to provide one with co-ordinates which, in turn, serve to provide one with appropriate maps of where one is. In this context one should never really be lost, especially if this became part of a new universal communication device outlined above.

In the case of 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 goes down to the most immediate level of individual video cameras positioned at strategic points in rooms and buildings. All these hitherto isolated efforts are moving towards integration. A demo reel (1995) of *Terravision* (Art + Com, working with DT Berkom (Berlin), shows a near synthesis between satellite images, GIS, AM/FM such that one goes 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 (VRML).[23] A copy of the demo also went to the Mountainview headquarters of Silicon Graphics, who have taken the Berlin approach one step further in developing their demo (March 1996) with the attendant slogan: "From outer space to slam in your face". The innovation here lies in going from two-dimensional satellite photographs which, as one approaches the earth, dissolve into three-dimensional terrain maps such that one can then do fly-throughs of valleys in the Alps.

Where this is leading is a new global network connecting satellite data, GIS, AM/FM, GPS and local video cameras such that a user could begin with a view of the United

States from space, zoom down to the street level in Los Angeles and then use one of the traffic cameras to check congestion on the freeway at first hand. The potential uses of such integrated systems are being explored by police officers, particularly in Germany. While the danger that such networks could also be misused is beyond the scope of this paper, it is definitely within the scope of possibility.[24]

Considerable attention is being given to combining information from twin satellite images to create a 3-D stereographic image, as Page has done in the case of the Camargo Syncline in Bolivia.[25] These developments in satellite images are paralleled by others in regular photography, particularly with respect to combining stereo images in the context of photogrammetry in order to translate two-dimensional images of buildings into their three-dimensional equivalents as models. Companies such as Vectar have produced *Real View*, a software which permits translation of such two-dimensional photos into a three-dimensional CAD environment. Experiments at the ETH (Zurich), in conjunction with the Centre for Landscape Research (Toronto) are exploring how such 2-D photos can be mapped unto 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 the 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 Saint Peter's Basilica one can move seamlessly between the existing structure and the no longer existing previous basilica. 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 which will effectively make it possible to translate any two-dimensional stereographic photographs in order to arrive at a full three-dimensional model which can then be viewed from all viewpoints at will. 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 three-dimensional space and then 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 effectively be re-arranged to produce plots on demand.

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

Shared Virtual Spaces

The continuing convergence of methods is also evidenced by recent trends to combine collaborative tools with virtual spaces. An early example occurred in the game world with the Habitat project, where Lucasgames and Quantum Computer Services set up a

multiple participant environment in the San Francisco region (1985). This basic approach was popularized through games such as *Doom*, where 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. While this is conceptually intriguing, why one would want to interact in this way on a long term basis is not clear.

A second scenario of shared virtual spaces is provided by the German National Institute for Supercomputing (GMD, i.e. Gesellschaft für Mathematik und Datenverarbeitung, Sankt Augustin), who foresee a Communication wall.[26] 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). So the GMD researchers project this image onto a three-dimensional CAD model of a head which thus maintains the proportions of the speakers even as they turn.

A third scenario is being 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 with each other and point at architectural details.[27]

This has tremendous implications for teaching. Instead of showing a slide of the Abbey of Cluny or Saint 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 examine this feature more carefully and then study earlier and later examples in other churches.

In a recent article Philippe Queau outlined a dramatic vision of things to come,[28] whereby tele-virtuality offers an economical alternative to tele-conferencing. He predicts that there will soon be interactive games where one can don the costume of any character as they set out to fight or play with/against friends and adversaries who are wearing electronic costumes of their own and thus 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 full immersion effects are being developed. The most elementary approach is simply to display this virtual world on a monitor which can range from a simple desktop size to a large television monitor. A second entails stereoscopic glasses. A third alternative combines a head-mounted display with gloves which permit the user to navigate freely within the space. A fourth alternative uses a BOOM (Binocular Omni-Oriented Monitor) which is effectively a head mounted display on a balance so that the weight is not all on the user's head. A fifth alternative places one into a special theatre and projects images on large curved screens or all round to create a complete illusion of being surrounded. These were developed by the Canadian IMAX Co. which in turn has a series of variants. The simplest version is a large curved screen. A second version increases the field of the screen. A third version changes places the audience on transparent seats and adds a further screen below to give an illusion of a flying carpet. A fourth version includes stereoscopic glasses to produce three-dimensional images. Plans to link this with three-dimensional audio effects are being developed.

The Goto Optical Company[29] has developed new technologies for projecting images onto the walls of a planetarium to create an even more vivid sense of immersion which they term a *Vivarium*. This will allow audiences to share the experience of a trip through the body as shown in *Fantastic Voyage*, or walk through Infobyte and ENEL's reconstructions of Saint Peter's Basilica or the Roman *Colisseum*.

As fascinating as they are, all these developments raise more questions than they answer. Some enthusiasts argue that virtual communities have enormous potentials for extending human experience.[30] When should a person 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. Should individuals with spatial intelligence focus specifically on this mode of cognition, or should it rather be the case that precisely those with other kinds of intelligence are 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 a person going down an aisle with various consumer goods, coffee, cereals etc, being reminded of what they had chosen last time with an option to see alternative brands, before ordering electronically what they wanted. Variants of this were developed in Time-Warner's Orlando Trial and in IBM's latest versions of the virtual mall. This same idea is being applied to the idea of navigating through information[31]

Companies such as Silicon Graphics are exploring other potentials of using landscapes metaphorically as in their 3-D Fusion Information Landscape Prototype. Essentially this transforms a multiplicity of two-dimensional windows to objects in a three-dimensional landscape. The effect is impressive but does not solve the basic problem. A multiplicity

of 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 which only present us with the information we need at a given moment. Hence the assumption that everything should be translated into virtual landscapes is almost certainly misleading.

10. From Packaged Software to On-Line Applications

In the early days of computers there was a mainframe to which a series of dumb terminals were linked. The advent of the personal computer brought with it the rhetoric that each man's computer is an island unto itself and 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 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 on-line. While 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 world wide operations use the same method. The Ford Corporation, which has 50,000 networked computers is adopting this process. While some companies are assuming that the future lies in selling individual software, a number of major players assure us that we shall soon be able to download everything as and when it is required.

In terms of regular 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. There looms a larger problem of offering integrated solutions. As noted earlier, in industry there are now so-called office packages which combine word processing, spreadsheets, fax, e-mail capacities and revision control. Scholarly and everyday equivalents of such tools are still lacking. Needed are integrating solutions with coherent interfaces (see 14 below).

11. From Quantity to Quality

Early discussions about computers often resembled locker room discussions where size seemed to be all. How big is your hard drive? How many megabytes do you have? And so on. These discussions were very legitimate given the enormous discrepancies between the multimedia aims of users and the limited capacities of products offered by vendors. Most machines had hard disks of a few hundred megabytes or a gigabyte, whereas many applications require terabytes. Most machines have 8-64 megabytes of RAM (Random

Access Memory), while 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. There are now storage devices with 50 gigabyte cartridges combined in a juke box with 1000 cartridges to produce a 50 terabyte container. The technology is beginning to exist: it is not yet readily 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 above, the VASARI scanner presently being used at the Uffizi Gallery (Florence) is scanning paintings at a rate of 1.4 gigabytes per square meter. There are only some 1300 paintings in the Uffizi. Even if they were only one square meter on average that would mean 1820 gigabytes or 1.8 terabytes. Major photographic collections such as the Marburg Archive have 1.5 million images. To digitize all of these paintings and objects with the VASARI scanner would entail 2,100,000 gigabytes or 2,100 terabytes. IBM's Vatican Library Project entails scanning manuscripts at an average of 20 megabytes per page. An average manuscript might contain 100 pages. There are 150,000 manuscripts which will mean some 300,000,000 gigabytes or 300,000 terabytes. 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 readily 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, an icosahedron has twenty polygons etc. Complex objects such as hills and mountains are made up of thousands and thousands of these polygons which are used to approximate the complexities of their true contours. In 1995 the most advanced machine of Silicon Graphics Inc. (*Reality Engine 2*) dealt with 2 million polygons. The latest machine (the *Infinity Engine*) introduced in February 1996 deals with 10 million polygons. Human vision entails an estimated 80 million polygons. Engineers at SGI believe that they can reach this capacity within the next three to five years.

The same holds for bandwidth problems. At present most private homes are limited to 28,800 modems. The Canadian 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. At present the bottleneck is in the switches rather than the lines.

The point here is to note that the 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 challenges are 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 would be client checks the number of stars they have. This is not to say

that materials on the Internet should be dominated by rating systems and reduced to a popularity contest, but rather that we need methods for judging the reliability of what is made available on-line. Does this represent merely a personal view? Is it a position shared by a local club, a professional organization, and then is it 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 and yet he was right. 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 both at the product and the author. We need methods to trace the intellectual lineage of the individuals involved. Authors such as Copernicus, Leonardo and the others mentioned above 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 re-contextualizing the parameters of quality.

12. Universal "Libraries"

The rise of networks has introduced new possibilities of sharing knowledge particularly in practical realms. Teams are working on a product family based framework for Computer Aided Manufacturing (CIM).[33] Leading institutes such as the Centre for Landscape Research (Toronto), the ETH (Zurich) and the Graduate School of Design (Harvard) 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: doors, windows etc., to include the characteristics of a door or a window in all situations. Hence, if an architect is planning a fifty storey office building, the knowledge repository will "know" that a building of that height will require doors and windows which have certain characteristics in terms of thickness, usual size, strength etc. If, by contrast, an architect were building a simple one storey 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 then a "door object" will eventually integrate all our past and present knowledge of doors when planning for future applications. An emerging Global Engineering Network (GEN) sponsored by the European Community is aiming at a similar approach to all the principles of engineering.[34]

The concept of object-oriented programming can be extended to the whole 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 etc., that a given species is known to have first appeared several million years ago and since became extinct at a given period.

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, i.e. 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, i.e. when); all the techniques associated with that person (their inventions, their methods of teaching, their approaches, i.e. how) and all the motivations known for what they did (money, fame, honour, i.e. why).

While this goal is theoretically so sensible as to seem inevitable, in practice it is fraught with manifold 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. Then there 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 so he must have a date of birth and death. Scholars have several claims about these dates. So 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 there will have to be policies to be attentive in this respect. 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 persons suspect and will probably require a movement that provides a modern equivalent of the mediaeval monks to make it happen. It will demand a massive campaign of translation, reconstruction and interpretation.

13. 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 etc. 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.

Because they are linear in nature, books almost inevitably present a single story -line. A history text which set out to deal with each episode from all recorded viewpoints would be too long to be practical. So we have French histories which give one account of the Napoleonic wars, German histories which give another and English histories which have their own view of what happened at Waterloo. These histories are usually printed only 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 in both linear and non-linear fashion. 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 concerning the same person, object, text, place or period. However, this process is not automatic. It requires translation exercises of hitherto unparalleled proportions. For 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" in the form of 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 fifty different versions. Paradoxically fifty 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.[35] 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.

To scan 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 this site; French archaeologists had another; the Germans another as did the British, the Americans, the Swedes and so on. Recreating these different visualisations, tracing how they were modified in light of excavations of the actual site, herein lie future industries.

A preview of things to come is provided by Infobyte's reconstruction of the Roman *Colisseum* in virtual reality which allows persons 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. Persons 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 Holywood has a long tradition of interest in ancient themes. Steven Spielberg has already expressed an interest in Infobyte's *Colisseum* to create a theme park using Goto Optical's *Virtuarium*, not unlike Universal Studios' (Orlando), *Back to the Future*, but 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 would be like the ultimate video game. These could in turn be extended to include a series of networked contestants as well as the regular spectators. If this sounds like science fiction, Imax Corp. is already working with Playdium Entertainment Corp. to provide an Imax Ridefilm attraction at the Sega City Playdium, an interactive entertainment centre in Mississauga. Forty such centres are planned.[36]

As blue rooms and virtual sets enable an ever greater 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 potentials lie 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 such models of the *Colisseum* to examine various theories concerning its construction and re-construction. They could also compare these with other examples elsewhere as has already been done by a team at Bordeaux.[37] The reconstructions could also help everyone to recognize the cultural dimensions involved in all interpretations. A French model of Rome may be very different than a German one. A Jewish history of the Holy Land may be quite different than 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 reverse side to this wonderful coin which 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 which closes rather than opens interpretation. Concrete evidence of these dangers is visible in China and Russia[38] today.

It is easy to attack such blatant forms of totalitarian censorship in far away countries and brand them as the enemy. The greater danger probably lurks in more subtle forms in our midst which 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 some obscenity at him or calls him a name, Mr. *x* will not be pleased but

he will 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 presently considered a crime, although this tendency is being challenged.[39] A case was reported where a woman, recognizing a name similar to her own in a fiction story about a murder written by someone who did not know her, accused and successfully prosecuted the author for threatening her life. Is there some curious way in which, even before the notion of avatars is fully evolved, the detachment of the Internet is leading to a heightening of the fixations on propriety associated with political correctness and is imposing a new censorship of silence or is this simply an isolated instance of the trend towards political correctness gone mad?[40]

Most of us would not assume that persons who read murder mystery books or go to a thriller film are necessarily murderers or even mysterious. So why should we assume this of someone who reads of murder on a monitor? In films there is a well established convention to have a trailer reminding us that any resemblance to actual persons and places is purely co-incidental. We clearly need an equivalent in the realm of computers. Indeed we need methods to help us identify the intent behind what is on the screen. Video clips of different genres might, for example, be framed by different colours: a documentary in one colour; a satire in another, and a purely fictional movie in another. Such an approach might be extended to everything we see on the screen, including texts.

One of the reasons for these problems which we might all too easily be tempted to dismiss as silly and trivial is because the computer screen removes aspects of context which 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 this is a scholarly tome, or a cheap novel for bedtime reading. These clues disappear on a typical computer screen. So we need to devise new tools for re-contextualization 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.

14. Interfaces and Conceptual Navigation

Interfaces are a key element in developing these tools for re-contextualization. Interfaces, according to some, are merely reflections of evolving technology. First, there were only character based commands (DOS), then there icons and images (Windows). Now primitive three-dimensional 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 two-dimensional images and three-dimensional 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 which display strategy. At present these decisions are governed largely by budgets since very few persons have access to million dollar machines required for high level virtual reality. But this will change.

A whole series of questions need attention. Some experts such as Shneiderman, in his *Starburst* method, prefer to give all the data in a given field before focussing in on single items.[42] Alternatively one could begin with classes giving general surveys before focussing 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. With respect to voice tracking as a navigational aid, Intel at CEBIT 1992 (Hanover) presented an extension of vrTrader produced by Avatar Partner. This 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 MIT (Boston) has been among the most articulate on questions of interface which it treats in terms of three categories: spatial data, symbolic data and typography.
First, there is spatial data, which includes metaphors of the landscape and geography such as Silicon Graphic's 3-D Fusion Information Landscape Prototype and has already been dealt with earlier.

Second, there is symbolic data which transforms lists of terms into a variety of shapes. The Dutch MediaLab (Schellinkhout), notably Thijs Chanovski, has focussed on the role of visual symbols. For instance, he has been exploring 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*, designed by Kristina Hooper Woolsey, based on Scott Kim's principles of visualization, which could be seen as points of departure for a method.

Meanwhile, Xerox PARC has 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 which has also worked on a relevance circle (*Relevanzkugel*), Information Overviews Visualization (IOVIS) and other techniques for the presentation of 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, there is, typography which can also be used as a tool, highlighting important texts in terms of different fonts and colours. The Visual Language Laboratory at MIT has been exploring a combination of these three approaches, namely spatial data, symbolic data and typography. They envisage perspectival grids of terms, distinguished in terms of different fonts and colours. While this produces dramatic and sometimes spectacular effects, there is again a danger that the bravura of the effects distracts the user form the actual purpose of the exercise, namely to find new materials systematically. Needed is an interface 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 in this direction.

15. 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 these will replace the need for direct human searching; that a person can give simple instructions using a voice activated computer which will then find everything. In this view agents are merely passive 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 tele-virtuality 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 sceptical about this approach. Basic search engines such as Yahoo, Lycos, Altavista and Opentext are still painfully inadequate.

It is an old adage that those researchers who know what they will conclude at the outset are usually the least interesting. An essential dimension of research is about the materials one finds in the periphery of one's study, the book beside the one which one set out to find on the shelf, the tidbit which does not concern my main topic but which I file away and twenty years later produces a valuable insight. Hence if we can create agents that can find precisely what we think we want, then a 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 G7 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.[50]

16. 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 such that it could readily be reproduced on a computer screen. We have already shown that more is entailed, namely, linguistic translation, reconstruction and interpretation. In fact much more is entailed. Computers involve polymedial transformations: i.e. it is not just a question of translating various media into digital form but equally one of translating back from digital into other forms, such 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 entail much more than a simple translation: a) it invites retrospective image updating such that old articles which have poor photographs or rough drawings can also draw on proper colour photography, which could become a new service industry in itself; b) 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 retrospectively with the respective databases; c) 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 which may have 150 colour slides and five minutes of video is typically printed as a 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, etc. When an author writes a paper on the *Mona Lisa* or *Notre Dame,* hyperlinks are automatically made to all the source materials, drawings, photographs, video clips relating to that painting or church. In time, such materials can be organized in terms of levels of interest such that authors/readers can choose between a brief image which serves as an *aide-memoire* or a detailed survey of available materials. This process can be applied retrospectively to articles and books of the past such that one transforms the function of authors, the nature of new publications and the value of past publications.

This has fundamental implications for copyright. In the past an author or publisher producing books with many illustrations were burdened with writing separate letters to each individual museum. In the case of scholarly articles and books this usually resulted in a simple agreement to send the institution a copy of the publication. In other cases a small copyright fee was charged that was frequently less than the paperwork on all sides. If images and other multimedia features become a standardized feature of all publications, publishers might pay a set percentage of sales to partners with copyright. These percentages could be scaled: e.g. a set percentage for cases with still images only, another for cases with moving images and a third to include virtual reality links. This approach is fully complementary to the European Commission's recent extension of copyright to databases.[51] Given trends towards consortia as foreseen by the recent Memorandum of Understanding of the European Commission, such generic solutions

will be more practical, and save all the paperwork of dealing with each appearance of every image individually.

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 on-line amateur clubs, sold individually, or will a new kind of distributor make this their 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 theatre and theme park bring a revival of public media centres? 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 ten years to create an index of the writings of one great man, Saint Thomas Aquinas. Today that same task would take a major 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 they were studying. This often constituted a lifetime's work. Within the next generations such lists can also be reduced to a few minutes. So the kinds of questions which scholars have traditionally tackled will become obsolete, or rather they will become so easily solved that scholars can concentrate on other things.[52]

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 electronially. Initiatives such as the Perseus project[53] are making this available online. Tracing the etymology and all the uses of a word is 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 future there will be other kinds of questions for those who devote their lives to scholarship.[54] 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 in virtual reality in order to create various scenarios and test hypotheses concerning urban organization, social structure, economic factors.[55] Visualizations are becoming so realistic that these tools can no longer be dismissed as idle conjectures. Which is not to say that everything that is convincing will necessarily be true. Here again we need new criteria for veracity.[56]

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 future, those who by nature are loners will use the tools in seeing new patterns, trends, not just the facts but the contexts in which they arise and share the results on-line. Meanwhile, collaborative tools will allow persons inclined to co-operate to compare notes more regularly. Thus, the very tools which may seem to preclude the need for study for some, can provide incentives for a new revival of learning.

17. Conclusions.

Those introducing new technologies have frequently applied them to solve traditional or outdated methods of teaching and research. By way of introduction the pseudo-futuristic scenarios of *Disclosure* were cited. This led to a survey of major trends in computing. Some themes such as the military have not been examined.[57] We have focussed 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 on-line applications, from quantity to quality; towards 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 persons took the trouble to translate the great achievements of others. Alexandria became great because they 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 pocketbook 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 essay 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, such 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 while some continue to see computers mainly in terms of 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.

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[PLAN FOR THUMBNAIL SKETCHES each with Five Images mainly on Facing Pages]

1. Zoom from Space to a Building (Space-National Gallery of Art)
2. Zoom from a Building to an Object (National Gallery-Painting)
3. Zoom from Whole to a Detail (Infinite Resolution of Stanze)
4. Zoom from Whole to a Detail (Vasari Camera in Uffizi)
5. Layers of a Surface (NRC Camera on Painting)
6. Layers Below a Surface (Infobyte Ultraviolet on Adoration)
7. Reconstructions of an Object (Infobyte Colosseum at Rome)
8. Versions of an Object (Colosseums at Arles, Nimes, El Djem)
9. Analysis of a Painting
10. Versions of a Painting

(List of painters to Last Supper) (Last Supper)

11. Development of a Theme (Leda)

12. Development of a Theme (Leda)

13. Variants of a Painting (Virgin of the Rocks)

14. Variants of a Painting (Virgin and Saint Anne)

15. Continuity of a Theme (Flower)

16. Cultural Interpretations of a Site (Roman Forum)

17. Global View of Cycles of Saints

18. Left Walls from Cycles of Saints

19. Right Walls from Cycles of Saints

[PLAN FOR FULL PAGE IMAGES]

20. Scenes from a Given Cycle (Montefalco)

21. Scenes from a Given Cycle (Montefalco)

22. Reconstruction of S. Francesco Assisi (Infobyte, Rome)

23. Reconstruction of Space within a Fresco at Assisi (Infobyte, Rome)

24. Reconstruction Raphael's Stanze, Vatican (Infobyte, Rome)

25. Detail of same.

26. Reconstructions of the Abbey of Cluny (IBM, France)

27. Reconstructions of Frauenkirche, Dresden (IBM).

[CAPTIONS FOR THUMBNAIL IMAGES]

Space and Geography as Integrating Metaphors

1. 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). These allow viewers to begin (i) with 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.

2.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 ground-plan of the building, to (iii) a particular room devoted to Canadian art, (iv) acquire the equivalent of a card-entry file for a painting by Arthur Lismer, *A September Gale, Georgian Bay* (1921), and then (v) zoom in to have a full scale view of the painting.

3. Infinite resolution, a technique developed by Infobyte (Rome) early in 1996, allows viewers to zoom from the whole to various levels of detail (i-v) without any loss of clarity as shown in this version of Raphael's Rooms (*Stanze*) in the Vatican. (See figs. 24-25 below for full page illustrations of the same principle).

Infobyte has also reconstructed Saint Peters 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 G 7 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 mediaeval manuscript or early printed book.

4. The Vasari camera captures images at 1.4 gigabytes/square meter and allows viewers to zoom from the whole to various levels of detail (i-v) as shown in these details kindly provided by Professor Cappellini in this painting by XXXXXX (Florence, Uffizi).

New Recording and Presentation Devices

5. 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 Cornelius Krieghoff, XXXX (Ottawa, National Gallery of Canada) which reveals a series of unexpected details when photographed in this way (ii-v).

6. New technologies 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 (i) Leonardo's *Adoration of the Magi* (Florence, Uffizi) with various layers under the surface (ii-v).

7. The latest CAD versions go beyond simple reconstructions of an object. The (i) *Colosseum* at Rome, in Infobyte's treatment, allows viewers to see (ii) how the building looked in Roman times, (iii) how it looks today and (iv-v) how it would look under special lighting conditions.

Translations, Reconstructions and Interpretations as New Industries (Contextualization of Culture)

8. Traditional education typically focussed on one outstanding example as if it were the only one. The Colosseum in Rome is an excellent case in point. There were at least 76 such structures scattered throughout the Roman world in many cities including 1) Arles, 2) Nimes, 3) El-Djem, 4) Pula, 5) Bordeaux, and Italica,

9. 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; choose a list of drawings related to the *Last Supper* and (v) choose an example from this list such as the *Study for the head of Saint Bartholemew*. 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).

10. 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) Andrea Del Castagno (Florence, Sant'Apollonia); (ii) XXXXX (iii) Domenico Ghirlandaio (Florence, Museo di San Marco); (iv) Leonardo da Vinci (Milan, Santa Maria delle Grazie) and (v) Cosimo Roselli (Vatican, Sistine Chapel, Refectory).

11. The 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*.

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

13. This system will also allow one 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, Museo Poldi Pezzoldi; Milan, Chiesa di Affori, and Foglianise, Collection Pedicini).

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

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

16. One will also be able to trace different cultural interpretations of a site such as the Roman Forum, noting versions by (i) Martin van Heemskerk (Escorial, Sketchbook, 16th century), (ii) an early 19th century Italian painting, and compare these with a (iii) French, (iv) German and (v) Italian reconstruction of what it looked like in the days of its glory.

17-19 . 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 (i) the *Story of the True Cross* (Arezzo, San Francesco), and (ii) 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 (iii) *Saint Catherine of Alexandria* (Rome, San Clemente), iv) *Saint Augustine* (San Gimignano, Sant'Agostino), and v) *Saint Francis of Assisi* (Montefalco, San Francesco). The net effect of this enormous corpus of religious images was an awareness of an 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 fig. 17 shows global views of these five cycles, fig. 18 shows the left walls and fig. 19 shows the right walls respectively.

[CAPTIONS FOR FULL SCALE IMAGES]

20-21.

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 of the Cloak
iv. Trial by Fire Before Sultan
v. Expulsion by the Demons from Arezzo
vi6. 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.

22. Reconstruction 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 a 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 fig. 17-21.

23. 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.

24. Reconstruction of Raphael's Rooms (*Stanze*), Vatican (Infobyte). The concept of infinite resolution has already been explained above (fig. 3). This full page image gives some sense of the richness of these images when seen on a high resolution Silicon Graphics Infinite Reality Engine.

25. 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 site.

26. Reconstruction of the Abbey of Cluny (IBM, France). This was one of the first major reconstructions in which the notion of a virtual guide or tutor was explored.

27. 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 the basis for a physical reconstruction of the original building.

DETAILED DESCRIPTIONS

1. Zoom from Space to a Building
   (Space-National Gallery of Art)
    1. World
    2. Continent (North America)
    3. Country (Canada)
    4. Province (Ontario)
    5. City (Ottawa)
    6. Part of City (National Gallery Area)

2. Zoom from a Building to an Object
   (National Gallery-Painting)
    1. National Gallery Building
    2. Ground Plan of National Gallery
    3. View of a Given Room
    4. Detail of Same
    5. Painting with File Card
    6. Detail of Painting

3. Zoom from Whole to a Detail
   (Infinite Resolution of Stanze)
    1. General View
    2. First level of focus
    3. Second level of focus
    4. Third level of focus
    5. Fourth level of focus
    6. Fifth level of focus

4. Zoom from Whole to a Detail

(Vasari Camera in Uffizi)

1. General View of a Painting
2. First level of focus
3. Second level of focus
4. Third level of focus
5. Fourth level of focus
6. Fifth level of focus

5. Layers of a Surface

(NRC Camera on Painting from National Gallery of Canada for painting by Cornelius Krieghoff)

1. General View of Painting by Krieghoff
2. First detail
3. Second detail
4. Third detail
5. Fourth detail

6. Layers Below a Surface

(Infobyte Ultraviolet on Adoration)

1. Leonardo, *Adoration of the Magi*, Florence, Uffizi
2. First Level Below Surface
3. Second Level Below Surface
4. Third Level Below Surface
5. Fourth Level Below Surface
6. Fifth Level Below Surface

7. Reconstructions of an Object

(Infobyte Colosseum at Rome)

1. Colosseum (Photograph: General View of Building Now)
2. Colosseum (Infobyte, General View of Reconstructed Building Now)
3. Colosseum (Infobtye, View of Reconstructed Original Building
4. Same with Lighting Effects
5. Same without Texture Mapping
6. Same in Wire Frame

8. Versions of an Object (Different Colosseums)

1. Rome
2. Arles
2. Nimes
3. El-Djem
5. Pula

9. Analysis of a Painting (Zoom from list of painters to *Last Supper*)

1. List of Renaissance Painters

2. Leonardo da Vinci
3. List of Paintings by Leonardo
4. File Card with Last Supper
5. List of Related Drawings to Last Supper
6. Example of Related Drawing

10. Versions of a Painting (Leonardo da Vinci, *Last Supper*)
    1. Andrea Del Castagno, Florence, Chiesa di Ognisanti
    2. Andrea Del Castagno, Sant'Apollonia, Refectory.
    3. Leonardo da Vinci, Santa Maria delle Grazie, Refectory
    4. Cosimo Roselli, Vatican, Sistine Chapel, Refectory

11. Development of a Theme (Leonardo da Vinci and students, *Leda*)
    1. *Venus on Knees on a Tortoise*, Roman Sculpture, Prado, Madrid
    2. Gianpetrino, *Figure of a Headless Woman*, Drawing, Venice, Accademia, inv. N. 1136
    3. *Leda Kneeling*, Windsor, RL 12707
    4. *Leda Kneeling*, Painting, Staatliche Kunstsammlungen, Schloss Wilhelmshöhe, Kassell
    5. *Leda Kneeling*, Collection of the Duke of Devonshire, Chatsworth.

12. Development of a Theme (Leonardo da Vinci, *Leda*)
    1. Windsor, RL 12707
    2. Louvre, Paris
    3. Galleria Borghese, Rome
    4. MacNamara Collection, Dawlish
    5. Palazzo Vecchio, Florence (formerly Collection Spiridon)

13. Variants of a Painting
    (Leonardo da Vinci, *Virgin of the Rocks*)
    1. Paris, Louvre
    2. London, National Gallery
    3. Milan, Museo Poldi Pezzoldi
    4. Milan, Affori
    5. Pedicini, Foglianise (near Benevento)

14. Variants of a Painting
    (Leonardo da Vinci, *Virgin and Saint Anne*)
    1. Paris, Louvre
    2. Venice, Accademia
    3. Milan, Poldi Pezzoldi
    6. Poznan, National Gallery

15. Continuity of a Theme
    (Geometrical Flower Motif)

1. Roman Mosaic, Sousse, Museum
2. Leonardo da Vinci, Codice Atlantico, Ambrosiana, Milan
3. Goslar, Decoration on a House
4. Toronto, Royal Ontario Museum, decoration on Base of a Cauldron
5. Fish

16. Reconstructions of the Roman Forum
    1. Photo of Forum Today
    2. Maarten van Heemskerck, *Sketchbook*, Escorial
    3. French Interpretation
    4. German Interpretation
    5. Italian Interpretation

17. Global Views of Cycles of Saints
    1. Arezzo, San Francesco, Story of the True Cross
    2. Florence, Chiesa del Carmine, Brancacci Chapel, Life of Saint Peter
    3. Rome, San Clemente, Saint Catherine of Alexandria
    4. San Gimignano, Sant'Agostino, Saint Augustine
    5. Assisi, San Francesco, Saint Francis of Assisi

18. Left Walls from Cycles of Saints
    1. Arezzo, San Francesco, Story of the True Cross
    2. Florence, Chiesa del Carmine, Brancacci Chapel, Life of Saint Peter
    3. Rome, San Clemente, Saint Catherine of Alexandria
    4. San Gimignano, Sant'Agostino, Saint Augustine
    5. Assisi, San Francesco, Saint Francis of Assisi

19. Right Walls from Cycles of Saints
    1. Arezzo, San Francesco, Story of the True Cross
    2. Florence, Chiesa del Carmine, Brancacci Chapel, Life of Christ
    3. Rome, San Clemente, Saint Catherine of Alexandria
    5. San Gimignano, Sant'Agostino, Saint Augustine
    6. Montefalco, San Francesco, Saint Francis of Assisi

Full Page Illustrations

20. Scenes from a Given Cycle
    (Montefalco, San Francesco, Saint Francis of Assisi)
    1. Saint Francis Celebrates Christmas at Greccio
    2. Dream of Pope Innocent III, Pope Honorius Confirms the Franciscan Rule
    3. Birth of Saint Francis, Christ as Pilgrim, Spreading of the Cloak
    4. Trial by Fire Before Sultan
    5. Expulsion by the Demons from Arezzo
    6. Saint Francis gives a Soldier his Cloak, Saint Francis Dreams of a Heavenly Fortress

21. Scenes from a Given Cycle
    (Montefalco, San Francesco, Saint Francis of Assisi)
    1. Stigmatization of Saint Francis
    2. Saint Francis Preaching to the Birds, Blessing the Bishop and Dignitaries of Montefalco
    3. Saint Francis Denies his Father in Assisi, The Bishop of Assisi Clothes Saint Francis
    4. Saint Francis Ascends into Heaven, Death of Saint Francis
    5. Death of the Nobleman of Celano
    6. Vision of Saint Dominic, Meeting of Saint Dominic and Saint Francis

24. Four Walls of *Stanza della Segnatura,*Vatican

25. Detail of Raphael, *Stanze* (ibid).

26. Reconstructions of the Abbey of Cluny

27. Frauenkirche, Dresden.

We thank the following churches, museums, galleries, companies and individuals for permission to reproduce their paintings, drawings, frescoes and reconstructions:
Churches
Affori, Milan (fig. 13.iv)
Chiesa di Ognisanti, Florence (fig. 10.ii)
Chiesa di Sant'Apollonia, Refectory, Florence (fig. 10.iii)
Sistine Chapel, Vatican (fig. 10.iv)
Santa Maria delle Grazie, Milan (fig. 9.v; 10.i)

Collections, Museums and Galleries
Accademia, Venice (fig. 11.ii; 14.ii)
Archeological Museum, Sousse (fig. 15.i)
Biblioteca Ambrosiana, Milan (fig. 15.ii)
Brera Museum, Milan (fig.13.iii)
Duke of Devonshire, Chatsworth (fig. 11.v)
Galleria Borghese, Rome (fig. 12.iii)
MacNamara, Dawlish (fig. 12.iv)
National Gallery of Canada, Ottawa (fig. 5.i-v)
National Gallery of England, London (fig. 13.ii)
National Museum, Poznan (fig. 14.iii)
Louvre, Paris (fig. 12.iii; 13.i; 14.i)
Palazzo Vecchio, Florence (fig. 12.v)
Pedicini, Foglianise (near Benevento) (fig. 13.v)
Poldi Pezzoldi, Milan (fig. 13.iii; 14.iii)
Prado, Madrid (fig. 11.i)
Royal Ontario Museum, Toronto (fig.15.iii)
Staatliche Kunstsammlungen, Schloss Wilhelnshöhe, Kassel (fig.11.iv)
Windsor, Collection of Her Majesty the Queen (fig. 11.iii; 12.i)
Uffizi, Florence (fig. 4.i-v)

Companies
IBM, Manuela Rost-Hein (fig. 26-27).
Infobyte, Dr. Fabrizio Funto and Pier Luigi Zerbini of (figs. 6-7, 22-25)
National Research Council of Canada, Dr. George Forrester (fig. 5)

SUMS Corporation (figs. 1, 2, 9)
Worldsat maps (fig. 1).

Individuals
Cappellini, Dott.Vito (fig. 4)
Selwyn, Barry (15.iv)
Gerling, Dr. Rolf (fig. 15.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. 17); pp. 138; 44; 122; 63; 225;173 (fig. 18); p. 173 (fig. 20) and p. 174 (fig. 174).

Notes

[1] The footnotes that follow contain a series of references to projects being developed on the Internet. These are introduced by the letters http (hyper-text transfer protocol).
[2] For a recent example in the realm of games see: *Police Quest Swat*. I am grateful to Jeremy Meaghan-Cargill for this reference.
[3] A major project, led by the Gesellchaft für Mathematik und Datenverarbeitung (GMD), concerns Distributed Video Production (DVP). See: http://viswiz.gmd.de/DVP.
[4] See: http://www.soe.oeaw.ac.at/w4g.
[5] Hiroshi Ishii, Naomi Miyake, "Toward an open shared workspace: computer and video fusion approach of team workstation", *Communications of the ACM*, vol .34, no. 12, December, 1991, pp. 37-50. Hiroshi Ishii, Minoru Kobayashi, Jonathan Grudin, "Integration of interpersonal space and shared workspace: clearboard design and experiments", *ACM Transactions on Information Systems*, vol. 11, no. 4, October 1993, pp. 349-375.
[6] See: http://gopher://zserve.nist.gov:79/0:docs/atp/94010169.
[7] See: http:// www. nwu.edu/CoVis_Wellcome.html.
[8] See: 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 the author's "Space, Time, Information and Knowledge," *Proceedings of the Simposio Europeo Eco-Crea 1996. Spazio tempo informazione nella scienza, cultura, economia*, Venezia 24-25 maggio 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: Alfredo Ronchi, "Virtualità reale", *Bolletino D'Informazioni. Centro di Ricerche Informatiche per I Beni Culturali*, Pisa, IV, n. 1, 1994, pp. 7-31, especially pp. 26-27.
[12] For a significant description see: Linda Harasim, *Global Networks: Computers and International Communication*, Cambridge Mass.: MIT Press, 1993. For a critical review of same see: Robin Mansell, *Intermedia*, London, vol. 22, no. 1, February 1994, pp. 44-45.

[13] For a more detailed discussion of this topic see the author's "Content Ordering or Ordered Content? Active versus Passive Knowledge."
[14] Nicholas Negroponte, "Object-Oriented Television," *Wired*, San Francisco, July 1996, p. 188.
[15] The latest PDA is the Pilot from U. S. Robotics. See: Maarten Heilbron, "U. S. Robotics' Pilot soars above the rest of the PDA pack," *Globe and Mail*, Toronto, Saturday, 22 June, 1996, p. B20.
[16] This is called ECO: Sistema informatico vocale interattivo.
[17] James Sullivan, "Invisibly Interactive," *Wired*, San Francisco, July 1996, p. 64.
[18] See: http://www.omega.it/million/synopsis.html.
[19] For a description of these and a good survey of developments in virtual reality see Alfredo Ronchi, "Virtualità reale", as in note 11 above, pp. 7-31, especially p. 21.
[20] See: http:// pubweb.parc.xerox.com/hypertext/services.html.
[21] See: http://www.argusmap.com.
[22] See: http://tracy.esrin.esa.it:5555/query.html.
[23] See: http://www.hyperreal.com/~mpesce
[24] Most of us have become inured to the fact that we are being observed by video-cameras every time we enter a bank, a subway or some 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 co-ordinated? What are the consequences for privacy especially with respect to persons 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.
[25] See: http://www.eccs.uic.edu/~ddpape/gallery/RemSens.html.
[26] See: http://viswiz.gmd.de/cwall/cwall.html.
[27] See: http://www.ifi.uio.no/~sigar/vroslo/queau.html
[28] Philippe Queau, "Televirtuality, Virtual Communities, Real Time Image Processing, Facial Synthesis" (1996) at: http://www.ifi.uio.no/~sigar/vroslo/queau.abstract.html. See also the books by Philippe Queau, *Le Virtuel: Vertus et Vertiges*, Champ Vallon: Editeur INA, 1993; *Metaxu: Théorie de l'Art Intermédiaire*, Camp Vallon: INA 1989; *Eloge de la Simulation- De la Vie des Langages a la Synthèse des Images*, Champ Vallon: INA 1986.
[29] See: http://www.bekkoame.or.jp/~goto-co/GOTO_home.html.
[30] Howard Rheingold, *The Virtual Community*, Reading: Addison-Wesley, 1993.
[31] See: http://nemo.ncsl.nist.gov/~sressler/projects/nav/nav.html.
[32] Giovanni Valerio, "RV e arte. L'affresco che parla," *Virtual*, Milan, no. 31, May 1996, pp. 35-37.
[33] See: http://gopher://zserve.nist.gov:79/0/doc/atp/94030012.
[34] See: hans-guenter.thonemann@mch.sni.de.
[35] Ivan E. Sutherland, "The Ultimate Display", *Proceedings of the IFIP Congress*, 1965, pp. 506-508. Cf. Ivan E. Sutherland, "A Head-Mounted Three-Dimensional Display," *Fall Joint Computer Conference 1968*, pp.757-764.
[36] "Report on Business," *The Globe and Mail*, Toronto, 18 June 1996, p. B27.
[37] See: http://silicon.montaigne.u-bordeaux.fr:8001/HTML/TUNISIE/sites.html.

[38] See: http://www.nww.co/ruscrypto.html reproduces an edict of Boris Yeltsin which 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 into a serious crime. Cf. Brock Meeks, "Major loss for U.S. in Internet privacy war," *Now*, Toronto, June 13-19, 1996, p. 23. Related to this is the proposed use of clipper chips which potentially censor free speech.

[39] See, for instance, an article in the *Toronto Star, (*13.6.1996), "U.S. court blocked as unconstitutional a new federal law prohibiting indecency on computer networks," reproduced in http://www.aclu.org.

[40] Another example involves pictures. If Mr. *x* lives in one of the large cities, and not just the obvious ones such as Amsterdam, Hamburg or Brussels, they have no problem seeing naked ladies (or men). How they are referred to may differ: call-girls, escorts, geisha girls but their function is constant. If Mr. *x* wants pictures of such naked persons levels of choices present themselves. He can go to almost any local store and buy a copy of *Playboy*. If he wants more dramatic pictures specialized stores offer him a whole range of magazines and videos. In some places these materials are considered pornographic and yet for the most part, assuming a basic amount of discretion, no one would think of Mr. *x* as a criminal for buying *Playboy* or even something slightly more risqué. And yet, if he were to download the same images from the Internet onto his computer his activity would in many cases be considered criminal by the present laws.

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

[42] Cf. Ben Shneiderman, *Sparks of innovation in human and computer interaction*, Norwood, N.J.: Ablex Publishing Co., 1993.

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

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

[45] M. Hemmje, "Lyberworld- Eine 3D basierte Benutzerschnittstelle für die computerunterstützte Informationssuche in Dokumentmengen", Der GMD-Spiegel 1, 1993, Bonn-Sankt Augustin.

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

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

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

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

[50] *G7 Ministerial Conference on the Global Information Society. Round-table meeting of business leaders*, Brussels, 25 and 26 February 1995, Luxembourg: Office for Official Publications of the European Communities, 1995. H. Von Bose, *G-7 Information Society Conference Pilot Projects, Executive Summaries*, Brussels: European Commission, 1995.

[51] John Browning "Cyber View. Playing Facts and Loose," *Scientific American*, New York, June 1996, pp. 30, 32.
[52] See also the author's: "Computers and a new Philosophy of Knowledge", *International Classification*, Frankfurt, vol. 18, (1991), pp. 2-12.
[53] See: http:// www.perseus.tufts.edu/oldIndex.html.
[54] For additional thoughts on the these themes see the author's vision statements and essays concerning the System for Universal Media Searching (SUMS) at the website for the Perspective Unit at http://www.mcluhan.utoronto (now moved to www.sumscorp.com).
[55] 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*, Maggio 1996.
[56] See: William J. Mitchell, *The Re-configured Eye. Visual Truth in the Post-Photographic Era*, Cambridge, Mass.: MIT Press, pp. 56-86, 163-189. See also the author's "Electronic Media, the Rebirth of Perspective and the Fragmentation of Illusion": English translation of : “Elektronische Medien, Die Wiedergeburt der Perspektive und die Fragmentierung der Perspektive”: *Illusion und Simulation*, ed. Stefan Iglhaut, Munich: Klaus Boer Verlag, 1995 (in press).
[57] Douglas Waller," Onward Cyber Soldiers", *Time*, New York, Vol. 146, no. 8., August 21, 1995, pp.30-38.