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Interfaces for Cultural Heritage

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Abstract
The newspapers and popular media constantly draw attention to an incredible rise in the amount of information especially through the Internet. Knight-Ridder News, for instance, recently cited an IBM study claiming that only seven percent of all corporate data is ever used.[1] The amount of knowledge in great libraries and museums that is regularly used is less. Some major collections have as much as 94% of their holdings in storage. Thinkers such as Pierre Levy have written about these trends in terms of a second flood, as if there were no hope ever again of comprehending the masses of new information. Part one of this study, written as an independent paper[2], addressed how this great influx of information could be mastered, suggesting that a key lay in using the long tradition of ordering knowledge found in the library world. That paper outlined a System for Universal Media Searching (SUMS), focussed on the use of traditional two-dimensional lists and outlined briefly the potentials of three-dimensional presentation methods. It also outlined how such a system linked with a global digital reference room could lead to a new System for Universal Multi-Media Access (SUMMA).

This paper surveys different systems for visualising knowledge and emerging interface technologies such as three-dimensional spaces, voice-activated displays, haptic controls and direct connections to the brain. Since such technologies are often presented as solutions in search of an application, the main body of the paper focusses on functions and needs from a user's viewpoint. Five basic functions are identified, namely, 1) virtual guides, 2) virtual museums, libraries and spatial navigation, 3) historical virtual museums, 4) imaginary museums and 5) various kinds of cultural research. The role of metadata is addressed briefly. Particular attention is given to the realms of research, where it is suggested that the new technologies will transform our concepts of knowledge. The implications for cultural interfaces of each function is explored. The paper ends with a series of challenges.

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1. Introduction

The enormous rise in new information has been paralleled by an equally extraordinary rise in new methods for understanding that information, new ways of translating data into information, and information into knowledge. New fields are emerging. For instance, at the frontiers of science and in the military, scientific visualization is a thriving discipline with close connections to virtual reality, augmented, enhanced and mixed reality. In business, database materials are being linked with spreadsheets to produce new three-dimensional visualisations of business statistics (e.g. companies such as Visible Decisions). In industry, data mining is emerging as an important new field. In the field of culture, where immediate profit is less obvious, these techniques remain largely unknown.

Interestingly enough, standard books on human computer interface by Shneiderman[3] do not give a complete picture of techniques now available or in development, nor even recent books with promising titles.[4] There are a few journals, organizations[5] and some conferences[6] devoted to the subject of which the present is the most prestigious. Meanwhile, on the world-wide-web itself, there are a series of useful sites, which offer the beginnings of a serious overview into these developments. For instance, Martin Dodge (Centre for Advanced Spatial Analysis, University College, London), has produced a useful *Atlas of Cyberspace*,[7] with examples of at least four basic map(ping) techniques, namely, conceptual, geographic, information (landscapes and spaces), and topology (including ISP and web site). A more thorough survey is provided in an excellent study by Peter Young, (Computer Science, Durham University), on *Three Dimensional Information Visualisation*.[8] Here he lists twelve basic techniques: surface plots, cityscapes, fish-eye views, Benediktine space, perspective walls, cone trees and cam trees, sphere-visualisation, rooms, emotional icons, self-organising graphs, spatial arrangement of data and information cube. He also has a very useful list of research visualization systems. Chris North (University of Maryland at College Park), has also produced a useful and important *Taxonomy of Information Visualization User Interfaces*[9] (see Appendix 1. Cf. the list of individuals in Appendix 2). Pat Hanrahan[10] (Stanford) has made a taxonomy of information visualization, while Mark Levoy (Stanford) also has a taxonomy of scientific visualization techniques.[11]

The significance of emerging interface technologies will be considered, namely, voice activation, haptic force, mobile and nomadic, video activation, direct brain control, brain implants, and alternative methods. A problem with such taxonomies and the technologies which they class, is that they are mainly from the point of view of the technology's capabilities, as if we were dealing with solutions looking for a purpose.

In order to arrive at a taxonomy of users' needs, a deeper understanding of their potential purposes is required, the whys? This paper offers preliminary thoughts in that direction. It begins with an outline of five basic functions relating to cultural interfaces, namely, virtual guides, virtual museums, libraries and spatial navigation, historical virtual museums, imaginary museums and various kinds of cultural research. The role of metadata is considered briefly. Particular attention is given to the realms of research, since it is felt that the new technologies will transform our definitions of knowledge. The conclusion raises some further questions and challenges.

Bibliographical references to Human Computer Interaction[12] specifically with respect to Graphic User Interfaces (GUI)[13] and Network Centred User Interfaces (NUI)[14] are provided in the notes. The appendices provide a taxonomy of information visualization user interfaces by data type (Appendix 1), a list of individuals and their contributions (Appendix 2) and a survey of other developments mainly in Canada, Germany, Japan, the United Kingdom and the United States (Appendix 3).

2. Emerging Interface Technologies

It is generally assumed that the two-dimensional spaces of current computers are largely a reflection of hardware limitations, which will soon be overcome. Hence there are numerous initiatives to create three-dimensional spaces. Alternative interfaces and input devices are also being developed.

Three Dimensional Spaces

Dr. Henry Lieberman (MIT) is exploring the use of very large three-dimensional navigation spaces, with new techniques which allow "zooming and panning in multiple translucent layers."[15] Silicon Graphics Inc. (SGI) foresees the use of landscapes.[16] Dr. Stuart Card (Xerox PARC) and his team have been working on a series of tools for visualizing retrieved information using techniques such as a galaxy representation, spiral calendar, perspective wall, document lens and cone tree .[17] There is an analogous project at the Gesellschaft für Mathematik und Datenverarbeitung (GMD) in Darmstadt called Lyberworld.[18] This takes a concept, searches for related terms, links these with the concept in question and presents them spatially in a cone. Alternatively the concept in question is positioned in the centre while various related terms are placed along the circumference of a circle where they exercise the equivalent of a centrifugal gravitational force. If all these surrounding terms are equal in strength they exercise an equal force on the central concept. As one of the terms becomes more significant it exercises a greater force on the central concept. Another GMD project, SEPIA, foresees a hypermedia authoring environment with four concurrent spaces: a content space, planning space, argumentation space and rhetoric space.[19]

At the level of abstract ideas a series of new products are being developed. For instance, a group at Rensselaer Polytechnic is developing an Information Base Modelling System (IBMS)[20] which allows one to visualize relationships in parallel perspective. At the Pacific Northwest National Laboratory[21] (Richland, Washington) a team led by Renie McVeety is developing a Spatial Paradigm for Information Retrieval and Explanation (SPIRE,[22] cf. Themescape[23]), while John Risch is developing Text Data Visualisation Techniques as part of the Starlight project. At Carnegie Mellon University the Visualization and Intelligent Interfaces Group[24] is creating a System for Automated Graphics and Explanation (SAGE) and related methods (Sagebrush, Visage[25]) for Selective Dynamic Manipulation[26] (SDM). At the Sandia National Laboratory, Chuck Myers, Brian Wylie and a team at the Computational Sciences, Computer Sciences and Mathematical Center are working on three dimensional Data Analysis[27] Data Fusion and Navigating Science,[28] whereby frequency of articles can be visualized as hills in an information landscape. This is part of their Advanced Data Visualization and Exploration initiative called EIGEN-VR. Another project at Sandia is an Enterprise Engineering Viewing Environment[29] (EVE). This:

> multi-dimensional user-oriented synthetic environment permits components of the model to be examined, manipulated and assembled into sub-systems and/or the final structure. A movable clipping plane allows internal structure examination. Craft wall displays provide schematic or cut-away views of an assembled model.

The Sandia team is also working on Laser Engineered Net Shaping (LENS) and has been exploring the implications of these techniques for modelling and simulation in manufacturing and medicine. The implications thereof for culture are no less impressive as will be suggested in the section on research and knowledge (see below section 7).

Alternative Interfaces and Input Devices

While monitors controlled by a mouse remain the most popular form of navigation at the moment, a number of other alternatives are being developed. Bill Buxton has, for instance, produced what appears to be the most thorough list of existing input devices. This includes: aids for the disabled, armatures, bar code readers, boards, desks and pads, character recognition, chord keyboards, digitizing tablets, eye and head movement trackers, foot controllers, force feedback ("haptic") devices, game controllers, gloves, joysticks, keyboards and keypads, lightpens, mice, MIDI controllers and accessories, miscellaneous, motion capture, speech recognition,[30] touch screens, touch tablets and trackballs. [31] A full assessment of the pros and cons and philosophical implications of all these devices would be a book in itself. For our purposes, it will suffice to refer to some of the main alternative human web interaction systems.

Video Interaction

One very innovative technique entails using video cameras to capture human movements and use these as cues for manipulating virtual environments. For instance, David Rokeby, in the *Very Nervous System*, links human movements such as dance to acoustic environments. As one moves more slowly or quickly, a different range of sounds is produced.

Vincent John Vincent and the *Vivid Group* have developed other aspects of this approach in their *Mandela* software, such that the video camera and a blue screen essentially allow the user's movements in the real world to be transposed to the virtual space within the screen. This permits a person to interact as a player in a virtual space on screen. For example, at the Hockey Hall of Fame in Toronto one can stand in a real goal, see oneself standing in a virtual goal on screen and interact with other virtual players there. This complex software requires customized programming for each site or special event. By contrast, the *Free Action* and *Human Object Reactor* software of a new company called Reality Fusion,[32] offers more simplified versions of this approach allowing persons "to interact on screen with the body using video cameras".

Such techniques are potentially of great interest not just for physically challenged persons. One could imagine a museum or gallery carefully equipped with video cameras such that one needed only to point to an object, or part of a painting and one's notebook computer would give one an explanation at the level desired. Hence, if one had identified oneself as a grade school child at the outset there would be an elementary explanation, whereas a research student would be given a much more thorough description.

Voice Activated Interfaces and Visualization Space

In the 1960's there was considerable fanfare about dictation machines which, it was claimed, would replace the need for secretaries. After more than thirty years of hype, the first reliable products for the general public have been made available in the past year through companies such as Dragon Systems[33] and IBM. Such systems presently entail vocabularies of 10-20,000 words, but will soon expand to vocabularies of 100,000 words and more. At the same time, researchers such as Mark Lucente[34] (IBM Watson), working in conjunction with MIT have been developing futuristic scenarios whereby a person can control a wall-sized computer screen using voice commands.

There are related projects elsewhere. The Gesellschaft für Mathematik und Datenverarbeitung (GMD) has an Institut für Integrierte Publikations und Informationssysteme (IPSI), which is working on a *Co-operative Retrieval Interface based on Natural Language Acts* (*CORINNA*).[35] Such methods are attracting attention within the cultural community. In the United States, the Information Infrastructure Task Force (IITF) has created a Linguistic Data Consortium [36]to develop a *Spoken Natural Language Interface to Libraries*.

Voice activation clearly opens many new possibilities. For instance, many lists are tree-like hierarchies, which means that choices inevitably require burrowing down many levels until one has the set of choices one seeks. If these choices are voice activated then one can go directly to the appropriate branch of a decision tree and skip the levels in between. The effectiveness of the technique will, however, depend, very much on the situation. In the case of public lectures voice commands can help dramatic effect. In a classroom, if everyone were talking to their computers the results might border on chaos.

Meanwhile, there is increasing study of the ways in which visual and auditory cues can be combined. For instance, a team at the Pacific Northwest National Laboratory[37] (Richland, Washington) is working on the *Auditory Display (AD) of Information* “to take advantage of known strengths of both visual and auditory perceptual systems, increasing the user's ability to glean meaning from large amounts of displayed information”:

> An *Auditory Display Prototype* adding non-speech sound to the human-computer interface opens a new set of challenges in the system's visual design; however, there are many reasons why one would want to use auditory display. The human auditory system has acute temporal resolution, a three-dimensional eyes-free `orienting' capacity, and greater affective response than the visual system. Especially promising for analysis applications is the natural ability to listen to many audio streams simultaneously (parallel listening) and the rich quantity of auditory parameters (pitch, volume, timbre, etc.) that are intuitively apparent to musicians and non-musicians alike. Current software leaves the potential of audio at the interface almost completely unused, even while visual displays (subject to well-understood limitations) are increasingly cramped. Auditory display poses a way to expand the human-computer interface by taking advantage of innate properties of the human perceptual system.[38]

Such combinations of visual and auditory cues, are also being studied by Richard L. McKinley[39] (Wright Patterson Airforce Base) in the context of a new field of bio-communications. If we truly learn so much better when we see and hear things in combination or at least in certain combinations then we clearly need to find ways of incorporating such experiences within the learning framework.

Haptic Force and Tactile Feedback

Research into artificial arms and limbs, by pioneers such as Professor Steven J. Jacobsen[40] (University of Utah, Salt Lake City) has led to new awareness of haptic force and tactile feedback as potential aspects of input systems. Corde Lane and Jerry Smith[41] have made a useful list of a number of these new devices. Grigore Burdea,[42] in a recent book, offers a very useful survey of this emerging field, showing that present applications are limited mainly to the military (combat simulation, flight simulator), medicine (eye surgery and arthroscopy training simulator) and entertainment (virtual motion three-dimensional platform).

In the military, these principles are leading to tele-presence in the sense of tele-manipulation or tele-operation, whereby one can carry out actions at a distance. In the case of a damaged nuclear reactor, for instance, from a distance a person could safely control a robot, which would enter a space lethal for humans and do a critical repair. In medicine, these same principles are leading to tele-surgery.[43]

In the field of culture such haptic force and tactile feedback mechanisms could well lead one day to new types of simulated conservation experiments. Before trying to restore the only extant example of a vase or painting, one creates a model and has various simulations before attempting to do so with the actual object. Not infrequently, there will only be one or two experts in the world familiar with the techniques. These could give tele-demonstrations, which advanced students could then imitate.

In the eighteenth century, the *Encyclopédie* of Diderot and D'Alembert attempted to catalogue all the known trades and crafts. Within the next generations it is likely that these will be recorded in virtual reality complete with haptic simulations. These techniques will continue to change with time, such that in future one could, for instance, refer back to how things were being done at the turn of the twentieth century.

Mobile and Nomadic Interfaces

The advent of cellular telephones and Personal Digital Assistants (PDA's) such as the Apple *Newton* or Texas Instruments' *Palm Pilot* has introduced the public to the general idea of mobile communications, an emerging field, which involves most of the major industry players[44]. At the research level the Fraunhofer Gesellschaft (Darmstadt) is working on *Mobile Information Visualization*,[45] which includes *Active Multimedia Mail* (Active M3) and *Location Information Services* (LOCI)

To understand more fully the larger visions underlying mobile communications it is useful to examine Mark Weiser's (Xerox PARC) vision of ubiquitous computing.[46] This goes far beyond the idea of simply having a portable phone or computer. Instead of thinking of the computer as an isolated machine, he sees all the technological functions of a room integrated by a whole series of co-ordinated gadgets, which are effectively miniature computers. Employee A, for instance, might always like a big lamp shining at their desk, have their coffee promptly at 10:30 a.m. each morning and not take calls from 2-3 p.m. because that is a time when the person writes letters. Assuming that the room could "recognize" the person, say through their badge, all of these technology "decisions" could be activated automatically, without employee A needing to turn on the big lamp at 8:30, the coffee machine just before 10:30 and turn on the answering machine from 2-3 p.m. In Weiser's vision this recognition process would continue outside one's own office. Hence, if employee A had walked down the hall and was visiting the office of employee C, the telephone would "know" that it should not ring in their now empty office and ring instead in C's office for employee A, using a special ring to link it with A. Such challenges are leading to an emerging field of adaptive and user modelling.[47]

In the military, where mobile computing is frequently called nomadic computing, this vision is taken to greater extremes. Here one of the leading visionaries is a former director of the Defence Advanced Projects Agency (DARPA), Professor Leonard Kleinrock[48] (University of California at Berkeley). In his vision, a computer should simply be able to plug into a system without worrying about different voltage (110, 220, 240) or needing new configurations of IP addresses. A soldier on the ground with their view obstructed by a hill, could communicate with an aircraft overhead, which would then relay to the soldier a bird's eye view of the situation. Companies such as Virtual Vision[49] are exploring some of the non-military implications of this approach.

While museums and galleries are far removed from the life-threatening aspects of the battlefield, one can readily see how the greatly increased interoperability of devices being developed in a military context, has enormous implications for museums and galleries. Imagine a notebook computer that "knows" which painting is in front of one, and thus downloads the appropriate information without needing to be asked. Imagine a computer that immediately sought the information one might need for a city the moment one arrived in that city. Hence, on landing in Rome, it would download an appropriate map of Rome, complete with information about the relevant museums and their collections.

Direct Brain Control and Brain Implants

Those concerned with universal access for persons with various disabilities[50] have developed various devices such that one can, for instance, control computers simply by eye movements or other minimal motions.[51]

A number of projects are moving towards direct brain control whereby intermediary devices such as a mouse are no longer necessary. In Germany, the main work is occuring at the International Foundation of Neurobionics in the Nordstadt Hospital (Hanover),[52] at the Institute for Biomedical Technique (St. Ingbert)[53] and at the Scientific Medical Institute of Tübingen University (Reutlingen).[54] In Japan, Dr. Hinori Onishi[55] (Technos and Himeji Institute of Technology) has produced a *Mind Control Tool Operating System* (MCTOS). In the United States, Masahiro Kahata (New York) has developed an *Interactive Brainwave Visual Analyser* (IBVA).[56] At the Loma Linda Medical Center work is being done on controlling computers with neural signals.[57]

Dr. Grant McMillan[58] (Wright Patterson Airforce Base) has been exploring the potentials of brain waves (namely, Alpha, Beta, Theta, Delta and Mu) on control mechanisms. For example, a pilot may be in a flight simulator and find themselves flying upside down. Every time one thinks, the brain produces electric pulses. By harnessing these waves a pilot has only to think and the resulting waves can act as a command to return the simulator to an upright position.

A more futuristic and potentially disturbing trend entails direct brain implants in a manner foreseen in the film *Strange Days*. Part seven of a BBC television series *Future*

Fantastic[59] directed by Gillian Anderson, entitled *Brainstorm*, discusses the work on brain implants by Dr. Dick Norman and Dr. Christopher Gallen.[60]

Given such developments, phrases such as “I see what you mean”, “sharing an idea”, “look at it from my viewpoint” or “giving someone a piece of one’s mind” a may one day be more literal than we now imagine. As noted above, it is already possible to activate certain commands simply by eye movement or through bands which measure one’s thought waves. In future, instead of voice activation, there might well be thought activation. Dictation would then simply require thinking the words which could conceivably lead some to forget how to speak properly. Will we be able to let others into our dreams and daydreams? Such questions lead quickly beyond the scope of this essay and yet the problems they entail may well become central to interface design sooner than we think. In order to assess more realistically the potentials of such applications it will be useful to step back and explore some basic functions of cultural interfaces.

3. Virtual Guides and Physical Museums

At the simplest level, one can imagine a physical museum endowed with different kinds of virtual guides. Instead of having a traditional tour guide, trying to shepherd a group of twenty or thirty visitors through various rooms, standing around a painting and having to shout to make themselves heard above the noise of the crowd, a visitor could simply rent a walkman-like device and listen to descriptions of paintings as they go. At the Museum in Singapore, for instance, such a device is already available. Certain displays and paintings are specially marked and for these a virtual guided tour is available. In Italy, the National Research Council (CNR[61]) is developing a similar device, which will function much like a push-button dial on a telephone. However, instead of dialing a telephone number, one will key in the painting or monument number to receive the desired description. In Germany, the GMD is developing a system called Hyper Interaction within Physical Space (HIPS),[62] which allows visitors to listen to information using earphones and make notes on a Personal Digital Assistant (PDA). This system will be tested in the Museo Civico of Siena. In Japan, Rieko Kadobayashi (Kyoto), is working on a meta-museum which would link visitors with specialists on various topics.[63]

It is foreseen that these descriptions will be on-line. Hence, when a tourist arrives in a new city such as Rome for the first time, they will simply download the appropriate tours for that city, not unlike the way one now buys cultural videos of the city in question, except that all this will be on-line over the Internet. Given new electronic billing procedures, the “rental” of the tour can be arranged to allow only one hearing, or be limited to a series of hearings, or to tours within a set time-frame of a day, a week or a month.

The walkman-like guide is but one possibility. As notebook computers move increasingly towards electronic versions of notepads (cf. the *Newton* and *Palmtop*), much more than a pleasant description of a painting or monument is possible. The notepad computer can give a visitor images of related paintings. For instance, standing in front of Uccello’s *Battle of San Romano* in the National Gallery of England (London), the viewer can be reminded exactly how it differs from the two other versions by Uccello in the Louvre and the Uffizi respectively. More advanced viewers could use this technology to compare minute differences between originals, versions by students of the painter, members of their workshop, copies and so on. The *Victorian Laptop*[64] project at MIT has similar goals with respect to literature of the past.

Those not able to visit an actual painting would still be able to do such comparative study from their desktops even if these were far from major centres of culture. To be sure, seeing the original has and always shall be preferable to seeing surrogates. But in the past those in remote areas were typically doomed to seeing nothing other than occasional – usually poorly reproduced images in books. Now at least they will potentially have access to an enormous array of heritage wherever they happen to be.

For those able to visit the famous museums there are still numerous barriers to seeing the painting as directly as one might wish. In extreme cases such as the *Mona Lisa* the work resides in a cage behind a solid sheet of glass which often refracts light in a way that hinders careful viewing. In most cases there are ropes or other barriers to keep one from getting very close to a picture. Even if one could get as close as one would like, many of the most intriguing aspects of paintings are invisible to the naked eye. Often, for example, there are subtle variations beneath the surface (*pentimenti*) as a result of a painter having changed their mind: changes in the position of a figure, or sometimes its complete removal. In the past, the only way of studying such changes was by means of x-ray photographs, which were only seldom available to a general viewer. Recently (1997), a new method called infrared reflectography allows one actually to see the different layers of paint beneath the surface. For instance, in Leonardo da Vinci's *Adoration of the Magi* (Florence, Uffizi) there are elephants, which he drew and were subsequently painted over. It is likely that future tourists will rent a notepad computer, which allows them to see all the layers beneath the surface, thus giving new meaning to the concept of looking closely at pictures.

The role of virtual guides is, of course, not necessarily limited to the interfaces of hand held devices as one goes around a real museum. They can be adapted for virtual and imaginary museums. IBM's pioneering reconstruction of Cluny Abbey, had such a virtual guide or avatar, in the form of a mediaeval nun, who took one around the virtual reality model of the famous church. If Phippe Quéau's visions of tele-virtuality come about, then we shall, in the near future, be able to choose the kind of avatars we wish and have them take us around whichever monuments may interest us.

In the past, a day at a museum often ended with a visit to the museum shop, where one bought postcards or posters of the images which one particularly liked. Those available were typically a small selection of the holdings of a museum, and often it seemed that these invariably omitted the ones one wanted. In future all the images of a museum can be available on line and can be printed on demand. These images will include three-dimensional objects. At the National Research Council of Canada (Ottawa), a laser camera has been developed which produces fully three-dimensional images, which can be rotated on screen. Using stereo-lithography, three-dimensional copies of such objects can be "printed" on demand.

Virtual reality permits one to create full-scale three-dimensional simulations of the physical world. Augmented reality goes one step further, allowing one to superimpose on that reconstruction additional information or layers of information. There are a number of such projects around the world. For instance, at Columbia University, Steve Feiner[65] has been exploring the architectural implications of augmented reality in the context of various projects.[66] One is termed *Architectural Anatomy*.[67] This allows one to view a virtual reality version of a room and then see the position of all the wires, pipes and other things hidden behind the walls.

A second is called *Urban Anatomy* and entails a method aptly termed *X-Ray Vision*.[68] Here one can look at a virtual reality view of a street or a whole neighbourhood, superimposed or more precisely underlying which one sees the various layers of plumbing, wires and tunnels that one would see in a Geographical Information System (GIS). Except that, in this case, it is as if the earth were fully transparent and one can see precisely how they are collocated with the actual space. Similar techniques are being developed by researchers such as Didier Stricker at the Institut für Graphische Datenverarbeitung[69] (IGD, Munich) which is linked with the Fraunhofer Gesellschaft's Zentrum für Graphische Datenverarbeitung e.V. (ZGDV, Darmstadt). In this case augmented reality is being used to superimpose on real landscapes, proposed designs of bridges and other person-made constructions. Other projects at the same institute are working on *Multimedia Electronic Documents* (MEDoc) and *Intelligent Online Services* to create *Multimedia Extension[s]* (MME).

Of even greater direct interest for cultural applications are the research experiments of Jun Rekimoto at Sony (Tokyo). Using what he terms augmented interaction, he has created a *Computer Augmented Bookshelf*,[70] with the aid of *Navicam*. This "is a kind of palmtop computer, which has a small video camera to detect real-world environments. This system allows a user to look at the real world with context sensitive information generated by a computer." Hence, looking at a shelf of magazines, the system can point out which ones arrived today, in the last week and so on. A related invention of Dr. Rekimoto[71] for use in theatres is called the Kabuki[72] guidance system:

> The system supplies the audience with a real time narrative that describes the drama to allow a better understanding of the action without disturbing overall appreciation of the drama. Synchronizing the narration with the action is very important and also very difficult. Currently, narrations are controlled manually, but it is possible for the system to be automated.

Applied to libraries, versions of such a system could essentially lead a new user through the complexities of a major collection. In the case of a regular reader, it could remind them of the location of books previously consulted. The reader might know they were there last year in June and that the book was somewhere in section C. The system could then identify the books in question.

This approach also introduces new possibilities in terms of browsing. Instead of just perusing the titles on a shelf, a person could ask their notepad computer for abstracts and reviews with respect to the book in question using the SUMS interface. Alternatively, if a person were tele-browsing from their home computer they could call up these features while sitting at their desk at home.

4.Virtual Museums and Libraries

Complementary to the above scenarios, are cases where virtual museums and libraries create digital versions of their physical spaces. Perhaps the earliest example of such an experiment was the Micro-Gallery at the National Gallery of England (London), a small room within the physical gallery with a handful of computers, where one could view images of the paintings in the collection and plan a tour in keeping with one's particular interests. This approach has since been copied at the National Gallery in Washington and is being adapted by the Rijksmuseum at Amsterdam.

Some of the early experiments in the field of cultural heritage pursued one metaphor to the exclusion of others. For instance, the Corbis CD-ROM of the *Codex Leicester* fixed on the image of a virtual museum for both paintings and books, such that the manuscripts appeared on the walls as if they were paintings. While optically appealing, such attempts were unsatisfactory because they eliminated many of the essential characteristics of books. Physical books give important clues as to thickness, size, age and so on. Their surrogates in terms of virtual books also need to convey these characteristics.

Present research is actively engaged in creating such surrogates. For instance, Professor Mühlhauser (Johanneum Research, Graz), is working on virtual books, which will indicate their thickness. Dr. Stuart Card and colleagues (Xerox PARC), are exploring the book metaphor in virtual space and developing ways of moving from representations of concrete books to visualisations of abstract concepts which they contain. Companies such as *Dynamic Diagrams*[73] have created a simulation of file cards in axonometric perspective for the *Britannica Online* site and for IBM's web site. IBM (Almaden,[74] Visualization Lab) has developed views of pages in parallel perspective as part of their *Visualization Data Explorer*, such that one can trace the number of occurences of a given term in the course of a text.

Such virtual museums and libraries can exist at various levels of complexity and their viewing need not, of course, be limited to some ante-room of the actual museum. As noted above, a number of museums include Quick-Time Virtual Reality (VR) tours on CD-ROMS of their collections. Meanwhile, others such as the Uffizi, have recreated online a version of their entire museum complete with simple Quick Time VR models of each room, such that one can look around to each of the walls as if one were there. These relatively simple images reflect the present day limitations of Internet connectivity, which will probably be overcome within the next decades.[75]

At the frontiers, an Italian company, Infobyte, is developing software called *Virtual Exhibitor,* which will allow museums to create such virtual galleries with a minimum of effort. Although this presently requires a Silicon Graphics machine, within two years regular PCs will be powerful enough to perform the same tasks. This software, along with SUMS are part of the European Commission's Museums over States in Virtual Culture (MOSAIC) project in the context of their Trans European Networks (TEN) intitiative.

Such virtual visits can go much further than simply visiting the rooms of museums ahead of time. In Tarkowsky's famous film (1972) of Stanislaw Lem's *Solaris* (1961), the viewers of Breughel's *Winter Landscape* (Vienna, Kunsthistorisches Museum) enter into the painting and walk around in the landscape. Professor Robert Stone (VR Solutions, Salford), in a project called *Virtual Lowry*, uses virtual reality to take viewers through the spaces of Lowry's painting. In Infobyte's version of Raphael's *Stanze,* viewers are able to view the *School of Athens* and then enter into the space and listen to lectures by famous ancient philosophers and mathematicians. Museums and galleries typically have one or more rooms where visitors can watch slide-shows, videos, or attend lectures pertaining to some aspect of their collections. In future such virtual visits could reasonably occur in such rooms or halls.

In the context of museums, a series of cultural interfaces thus present themselves. In the equivalent of an ante-room, viewers are able to prepare for tours using monitors or more elaborate technology. For on-site tours there will be computer notepads. Monitors linked to printers in the museum shop will allow one to print postcards and full size posters on demand. For research purposes visits will occur sometimes on a computer screen, a large display panel, an IMAX type screen (which will probably be available on-line in the next generation[76]), on planetarium ceilings[77] or in entirely immersive CAVE environments (cf. below in section 7), within the museum or gallery rooms. In future as bandwidth increases these materials will become available on-line such that visitors (children and adults alike), can prepare for visits to museums and galleries by studying some their highlights or their detailed contents ahead of time, either at school or in the comfort of their homes.

Museums and galleries have traditionally been famous for their "do not touch" signs. Many visitors, especially children, want to know how things feel. This is an area where virtual reality reconstructions of objects, linked with haptic feedback, could be of great help, thus adding experiences to museum visits which would not be possible in the case of original objects. Prostheses of sculptures, statues, vases and other objects can provide visitors with a sense of how they feel without threatening the original pieces.

In most cases, these museum interfaces increase interest in seeing the original. Their purpose is to prepare us to see the "real" artifacts. Only in the case of special sites such as the caves at Lascaux or the Tomb of Nefertari, will the new technologies serve as a substitute for seeing the actual objects in order to protect the originals. By contrast, in the case of library interfaces, virtual libraries[78] will very probably replace many functions of traditional libraries. Instead of using card catalogues to find a title and then searching the shelves for related books on a given topic, readers will use on-line catalogues and then do tele-browsing. Having found a book of interest, they will print them on demand.

The continuing role of libraries will be defined in part by the kind of information being sought. Much of the time readers are searching for a reference, fact, a quote or a passage. Such cases can readily be computerized and replaced by on-line facilities. On the other hand historians of palaeography and of the book are frequently concerned with the feel of the cover, details of the binding or subtle aspects of hand-painted miniatures. In such cases, electronic facsimiles may help them answer preliminary questions, but consultation of the actual manuscript or book will remain an important part of their profession which only libraries can fulfill.

Why even print when one can read on screen? Physiological experiments have shown that one sees about a third less when light comes to the eye directly from a monitor screen rather than being reflected from the surface of a page.[79] Hence, while computer monitors are an excellent interim measure, they are not an optimal interface for detailed cultural research. A new kind of device, similar to a slide or film projector, is needed that projects images onto a solid surface.

Spatial Navigation

Knowing how to get there, spatial navigation, is one of the fundamental concerns in the organization and retrieval of all knowledge including culture. The use of maps for this purpose is almost as old as civilization itself. Since the Renaissance there have been enormous advances in relating different scales of maps. In the past decades rapid developments in Geographical Information Systems (GIS) have begun linking these scales electronically (as vector images). Parallel with this has been a linking of scales of satellite and aerial photographs (as raster images). The 1990's have seen increasing translation between raster and vector images such that there is a potential interoperability between maps and photographs (figure 1).

Scales of Abstract	Scales of Concrete
Map of-	Satellite Photos of - World
	- Continent
	- Country
	- Province
	Aerial Photos of - City
Plan of -	- Building (GIS)
	Quick Time VR of -Room
	-Objects in Room

Figure 1. Basic scheme of scales of abstract images (maps and plans) and concrete images (satellite photographs, aerial photos and Quick Time VR images).

Projects such as *Terravision* in the United States and *T-Vision* in Germany can be seen as first steps in this direction. This means a potentially seamless integration of all spatial data such that we could move at will from views in space down to any painting on a wall or sculpture in a room. In *Powers of Ten*, a famous film by Charles and Ray Eames, a viewer was taken along one such visionary set of connections using photographs alone. Today it is technically feasible to do this interactively with any object in the world.

Implicit in these breakthroughs is a reconciliation of methods which earlier generations perceived as different and even potentially incompatible. For instance, Gombrich (1975),[80] in his Royal Society lecture distinguished between the mirror (photographs) and the map. Dodge, in his *Atlas of Cyberspace*, distinguishes between topological maps and the photographic type maps of information landscapes. While such distinctions may continue, the breakthroughs mentioned above will increasingly permit us to move seamlessly between categories, such that we can switch from viewing a topological map to a topographical map or an aerial photograph. By this same principle it will be possible to move seamlessly between photographs of physical rooms and Computer Aided Design (CAD) reconstructions of those same rooms used for Area Management/Facilities Management (AM/FM). This will bridge many earlier oppositions between abstract and concrete, making it clear that both can be correlated with the same reality. This has implications also for temporary and imaginary tours discussed below.

Thus far only isolated aspects of this integrated vision have been adopted in the cultural context. For instance, city guides on the Internet are beginning to list maps with major museums and galleries. CD-ROM's of galleries such as the Louvre, Pushkin, or the Uffizi typically have Quick Time VR views of the individual rooms. The technology exists to link together all these individual elements.

Virtual reality allows complete reconstructions of objects, archaeological sites and historical monuments in three-dimensions. Some of the best examples of these possibilities are being created by Infobyte (Rome). These include reconstructions of the *Upper Church of San Francesco* (Assisi), *Saint Peter's Basilica* (Vatican) and more recently the *Rooms* (*Stanze*) of Raphael as part of an ongoing project which may one day recreate the whole of the Vatican museum complex and become integrated with IBM's Vatican Library project. The enormous number of such reconstructions, listed in a very useful book by Maurizio Forte,[81] attests that such examples are part of a much larger phenomenon and that some of the cultural implications are clearly appreciated.

Many of these reconstructions are typically viewed on a computer monitor. Sometimes glasses are used to permit stereoscopic viewing of the images. Sometimes this effect is achieved using a Binocular Omni-Oriented Monitor (BOOM). It is of course possible to make this experience fully immersive by projecting images on all the walls of a room as in the case of CAVE environments. Alternatively, one could project them onto the hemi-spherical surface of a planetarium using multiple projectors to create a fully immersive effect as Infobyte is doing by working in conjunction with the Japanese firm GOTO. Under discussion is the possibility that Infobyte's reconstructions could be projected onto IMAX screens.

One of the leading pioneers in the field of virtual reality is the German Gesellschaft für Mathematik und Datenverarbeitung (GMD, Sankt Augustin), which has a section on Visualisation and Media System Design.[82] Among its many projects is *Virtual Xanthen*. Besides its well-known mediaeval church, Xanthen has a famous Roman archaeological site. The GMD project transforms a regular projection screen into an entire wall. A viewer standing in front of the wall sees an entire landscape from a bird's eye view. The small platform on which they are standing serves as a navigating instrument, permitting one to "fly" higher above the landscape or get closer to the earth. This adds a whole new dimension to virtual visits.

Traditional blue screens permit an actor to stand in front of a screen and be projected into a scene with a completely different background, as happens, for example, with the weatherman after the evening news on television. A limitation of this technique is that the backdrop is two-dimensional whereas the actor typically moves in a three-dimensional space. The GMD's Distributed Video Project (DVP) takes these principles considerably further[83]. The blue screen is transformed into a blue room and the actor's movements in three-dimensional space are accompanied by three-dimensional perspectival adjustments in the background. Some of the obvious applications of this new technique are in the field of television and film production. Suppose for example, that one wished to do a film about the Sahara desert. Instead of needing to take a crew out to extreme conditions of the North African desert, one could simply digitize views of the desert and project them onto the equivalents of four walls and then use the blue room technique for actors to be virtually transported to the Sahara. The implications of this approach for culture are considered below in section 5.

Viewpoints

Museums typically give an official mode of presentation (and implicitly an official interpretation) to a collection of objects. This presentation ranges from a classic ordering in which objects dominate, such as the Cairo Museum, to newer approaches where the instruments of interpretation are almost at par with the original objects as in the Heinz Nixdorf Museum Forum (Paderborn). The collections of a number of museums can be collected together in on-line networks as is the case, for instance, in the European Commission's Museums Over States in Virtual Culture (MOSAIC) project and is also part of the G7's vision in pilot project five: Multimedia Access to World Cultural Heritage. One of the challenges of such projects is to offer a coherent interface for all museums while at the same time reflecting the idiosyncrasies of individual museums.

The methods outlined above lend themselves not only to entire museums but also to special exhibitions within museums. This includes blockbuster exhibitions of famous artists such as Picasso and movements such as the Impressionists. These can re-enact earlier classic exhibitions and serve as ways of looking at sections of collections through the eyes of a given school of interpretation, a distinguished scholar or an outstanding curator. This interpretation could potentially cover the entire history of a field as in the case of Rene Berger's *World Treasures of Art*.[84]

By the same token, such virtual collections can represent the personal view of a scholar or an artist on an epoch, an event, a concept or their own work as, for example, with George Legrady's *Anecdoted Archive from the Cold Wars*.[85] This approach can be expanded to include multiple interpretations or viewpoints of a given work. In the case of Shakespeare, for instance, both IBM[86] and MIT[87] have produced versions of the plays which include readings of the same passage by a series of different actors. Implicit in the development of such multiple viewpoints is a need for more detailed methods to identify the levels of competency and authority of those involved – a challenge which should be solved by the emerging Resource Description Format (RDF) of the World Wide Web. There is also a need to classify different types of virtual museums, a project being pursued by a group at the Academy of Media Arts (Cologne).[88]

While such a translation of physical into virtual space constitutes the most obvious application of the new technologies, it is in a sense the least exciting. For the cultural field the most fascinating challenges lie in a new series of combinations of real and virtual, some of which will now be considered.

5. Historical Virtual Museums

In the case of major museums and galleries, one virtual museum will not suffice. The buildings of the Louvre, for example, have existed on the premises of the present museum since at least the eleventh century. So one will need historical virtual museums, reconstructions, which help us to understand how what began as a mediaeval fortress gradually evolved into one of the world's great picture galleries. These reconstructions will trace not only the physical growth of various rooms and galleries but also help to trace the changing arrangements of the permanent and temporary collections of paintings therein. Where was *Mona Lisa* hanging in the eighteenth and nineteenth centuries, as opposed to today and what do these changing configurations tell us about the history of exhibitions, taste and so on? Such digital versions of earlier spaces and former versions will allow simulations of temporal travel.

This principle is also being applied to urban landscapes to create historical virtual cities. For example, CINECA[89], as part of the MOSAIC project, is reconstructing the mediaeval city of Bologna such that one can trace the growth of the city and changes in its basic structure in the course of several centuries. This reconstruction using virtual reality modelling language (VRML) allows one to walk through the streets and watch how they change as if one were in a time machine. Traditionally, some historians have claimed that Bologna developed an elaborate water and sewage drainage system during the Middle Ages. Other historians have challenged this. The model is sufficiently detailed that it can be used to check the validity and veridity of such claims. In such cases reconstructions of cultural heritage become significant for social and even economic history.

Similarly, in the case of archaeological sites, this approach offers further possibilities. Today, a major museum typically has a photograph and/or a small model of the *Acropolis* at Athens. Students studying Greek history at school typically only have access to poor black/white images. Those with Internet access can, of course, consult a number of colour images through the *Perseus Project*.[90] Much more is technically possible. Most European countries have their own archaeological schools in Athens and have developed their own theories about the *Acropolis*. So one could theoretically call up photographs of the site as it exists today. One could then call up various historical photographs and drawings in order to appreciate how it looked before Elgin took his marbles, what the Greek temple looked like when it became a Muslim mosque and compare it with how it looks today. One could then view various reconstructions by Greek, American, British, French, German and other archaeologists. Instead of just looking at buildings as static entities, one could examine how they change in the light of different cultural and scholarly traditions. Such reconstructions could be available on-site using notepad computers, as well as on-line for study at school and home.

Professor Iwainsky[91] has explored further potentials in his reconstruction of the Pergamon Altar, complementing the virtual reality reconstruction of the altar now in Berlin with filmed video clips of the original landscape in Pergamon, thus helping viewers to see how it would have looked in its original context. The GMD’s Distributed Video Production initiative introduces new techniques to develop this approach. One can, for instance, theoretically film views of and from the Acropolis, then, using a blue room, combine this with virtual reality reconstructions of the Parthenon and other buildings such that one could walk through the buildings as they might have been and have realistic views of the landscape. Given sufficient bandwidth such reconstructions can be on-line, permitting students and others around the world to get a realistic sense of sites long before they have a chance to actually visit the original.

6. Imaginary Virtual Museums

Imaginary museums[92] in a true sense will show paintings, sculptures and other artifacts, which never physically existed together, as coherent collections. Renaissance painters such as Botticelli, Leonardo and Raphael were typically commissioned to paint works for a church, monastery or a private patron with the result that their works were dispersed from the outset. To overcome this, art historians developed the *catalogue raisonnée*, but the high costs of printing typically meant that these catalogues offered only black-white images of paintings and often poor ones at that. Imaginary museums will allow one to see the collected paintings of an artist. This can happen in different contexts. In an actual museum such as the Uffizi, using one’s notebook computer one could stand in front of a *Madonna and Child* by Raphael and ask for other images by that painter on the same theme in other collections. This same principle can be extended to apply to thematic study also. Standing in front of a *Baptism of Christ* by Piero della Francesca (London, National Gallery) one would ask *Baptisms* within a given temporal or geographical framework. Alternatively one will acquire the equivalent of a CD-ROM which allows one to make these comparisons on one’s computer at home or at school. Increasingly these materials will be available on-line and future equivalents of hard disks will function in the manner of personal libraries today. They will have subsets on topics that are of particular interest to a given scholar, amateur or member of the general public.

Imaginary museums can also offer viewers a whole range of interpretations concerning the structure and history of paintings. Standing in front of Piero della Francesca's *Flagellation of Christ* (Galleria Nazionale delle Marche, Urbino), one could see the different interpretations of its perspectival space. Standing in front of Leonardo's *Last Supper* (Santa Maria delle Grazie, Milan), one could compare it with other copies, see alternative reconstructions of its perspectival space and impressions of what it once looked like as well as having access to details of restorations concerning individual figures.

Major collections such as the National Gallery (London) have an *Art in Focus* series, which are effectively special exhibitions focussing each time on an in depth analysis of special effects or characteristics of a given painting. Today such materials are typically available in an exhibition catalogue, which soon goes out of print. In future, such analyses could be available using notebook computers such that one could see such special characteristics at any time. This will give extended life to the concept of special exhibitions and indeed change their significance. A series of basic functions for cultural interfaces thus emerge. A first is virtual guides in physical museums; a second is virtual museums; a third is virtual historical museums and a fourth is imaginary museums. A fifth basic function of cultural interfaces entails research. Before exploring this and its implications for changing definitions of knowledge, an excursus on meta-data is necessary.

7. Metadata

In seeking to find data, information and knowledge on the web, system designers and scholars have devoted increasing attention to metadata[93] in the sense of data about data.[94] Initial efforts in this direction were focussed on identifying basic keywords and minimal descriptors (such as those being developed in the context of the Dublin Core) in order to permit identification of an article or book. The World Wide Web Consortium introduced a potential for rating quality through their Protocol for Internet Content Selection (PICS), the scope of which is being extended within their Resource Description Framework (RDF) to include Intellectual Property Rights and Privacy Management. In a recent keynote (Brisbane, April 1998), Tim Berners-Lee outlined a considerably more ambitious goal of adding a veridity parameter to information. His vision is to develop a global reasoning system within the world wide web, whereby individual items of knowledge function as distributed axioms, which can be combined to reach truth statements.

5	Rights	Agreements
4	Privacy	Copyright
3	Quality	Ratings, Reviews
2	Veridity	Truth Value, Axioms
1	Summaries	Keywords, Descriptors
0	Contents	Facts, Claims

Figure 2. Schema showing basic levels of metadata.

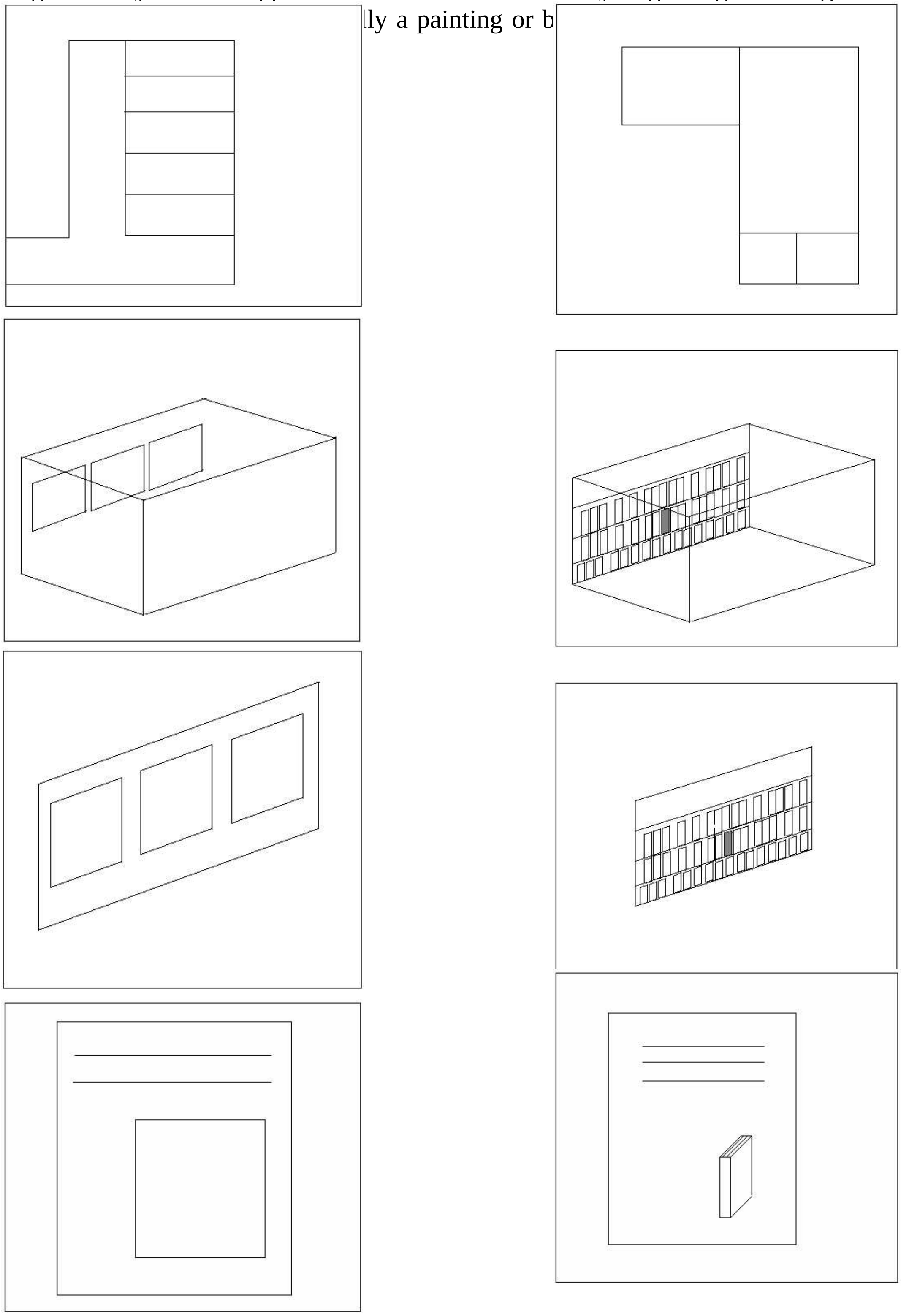
Implicit in the above is a new approach to information and knowledge whereby facts and claims will no longer exist in isolation. Knowledge packages will be surrounded by five layers of metadata (figure 2). On the basis of such added parameters it will be possible to search for various subsets of materials. If one were searching for adventure films, one could ask, for instance, for all five, four, three, two, and one star examples separately or all films irregardless of their rating and then explore what percentage belong to each of the categories. One could compare the percentages in other fields. Are there more five star films, relatively speaking, in the mystery, thriller, childrens or other category?

One could also begin mapping relationships of texts to commentaries about texts, statements of objective truth versus subjective claims about those truths. Levels of certainty might be depicted in different diaphanous colours, such that one could visualize a given verity and all claims surrounding it becoming further removed as their levels of certainty decrease. Not all materials will be certified. So one can choose whether one wishes only certified, officially sanctioned, materials or all materials pertaining to a given book, painting or other cultural object. A cultural object will no longer be a single entity, it will have associated with it a series of attributes defining not only its physical characteristics but also its quality. In terms of object oriented programming there will be objects of objects.

It is important to recognize that the increasing importance of metadata is part of a larger shift whereby there is a separation between knowledge and views of that knowledge. The 1960's, for example, saw the rise of databases. These allowed one to enter basic facts into fields of information, which could then be called up in a number of different ways as reports without needing to alter the original facts. The rise of Standardized General Markup Language (SGML) took this approach considerably further by effectively devising one set of tags for the original content and a second set of tags for ways of viewing that content. To put it slightly differently an SGML knowledge object has a "content" section and a "views" section. The evolving Extensible Markup Language (XML)[95] uses exactly the same principle with the exception that it is designed for less complex situations than SGML and according is easier to use. In the case of both SGML and XML one can change or add to the "views" section without altering the basic content. This is fundamentally different from the print world where the content and layout become inextricably mixed to the extent that any decision to alter layout requires all the work of a new edition.

Metadata, in the sense that it is being used by the World Wide Web Consortium, takes the basic approach of databases and SGML another significant step forward. It continues the distinction between content and views, but adds to the content section basic parameters concerning veridity and value. Facts remain constant. The ways of viewing them, using them, presenting them change. This opens the way to reusable knowledge in a new sense. The same repository can be used to tailor views for a beginner and an expert, without needing to rewrite the repository each time.

Figure 3. Systematic approach to a museum or library beginning with a ground-plan, [illegible]ly a painting or b[illegible] basic



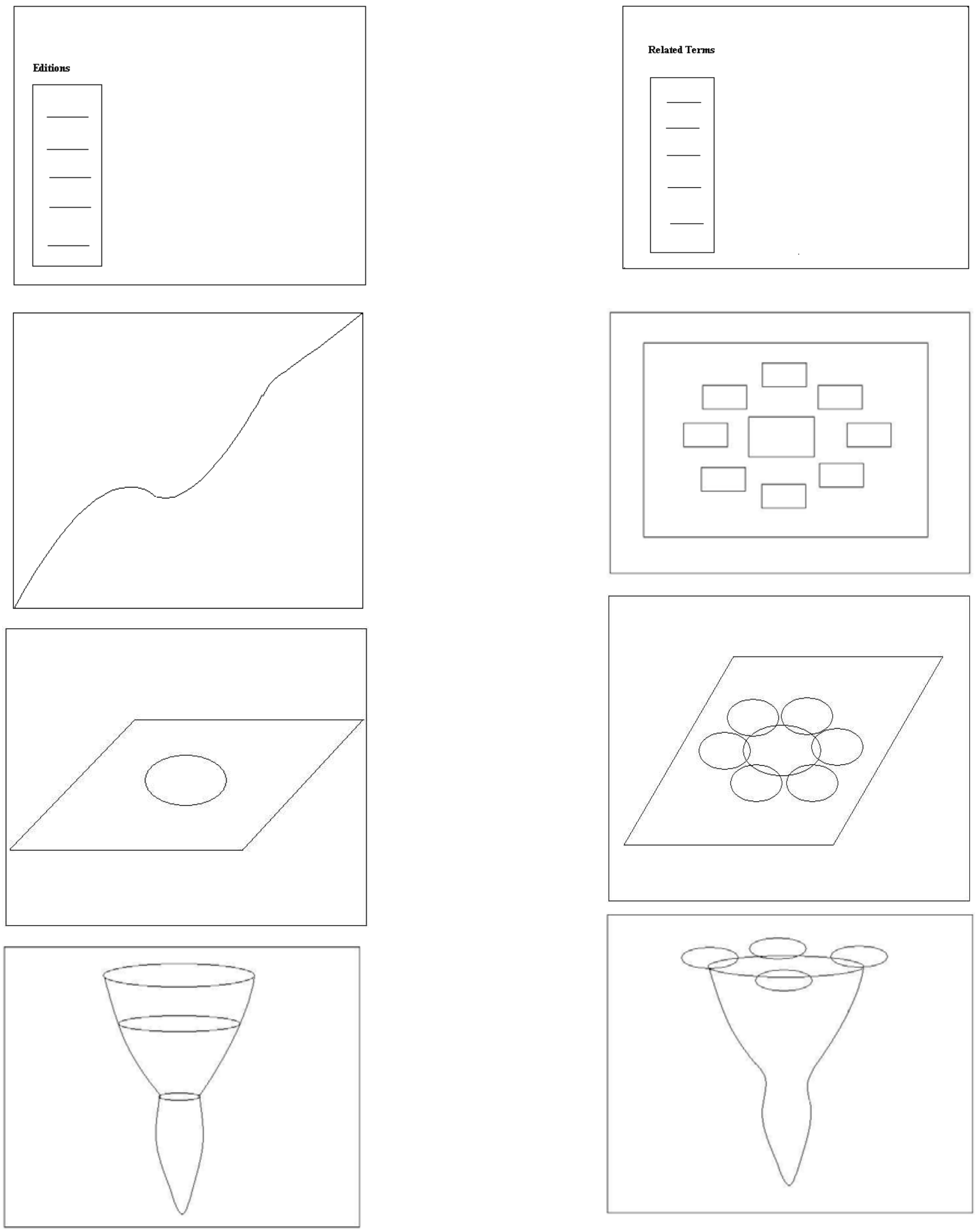


Figure 4a. Visualization of editions as a list, a graph, as a circle or as an undulating inverted cone. b) Visualization of related terms as a list, as a series of surrounding terms (cf. Hotsauce), as a series of intersecting circles or as other undulating inverted cones.

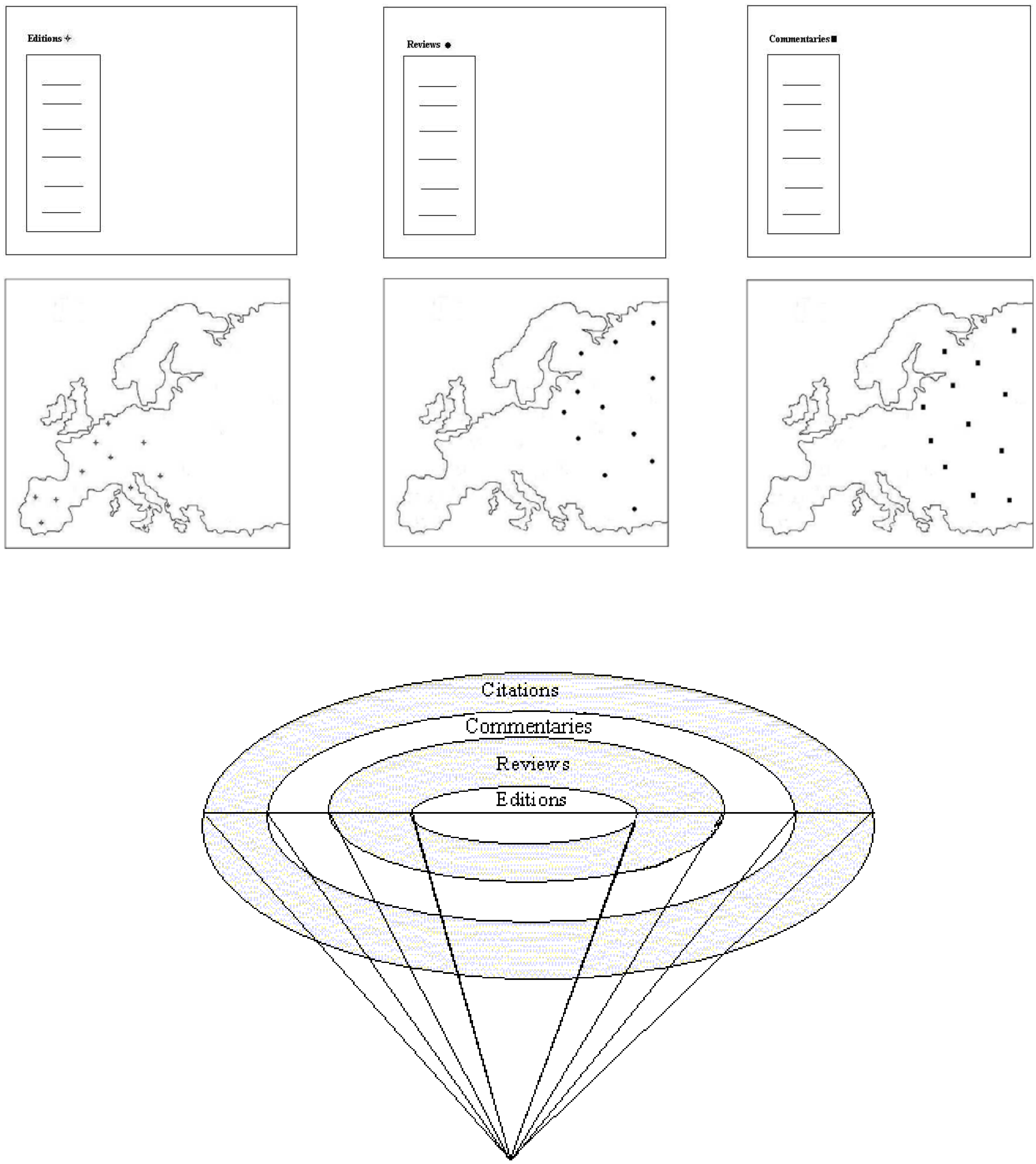


Figure 5. Lists of editions of a work, reviews, and commentaries thereof, translated into spatial locations and then into inverted cones. In this approach unimportant writings become narrow cylinders and influential important works become broad cones.

Marshall McLuhan characterized the history of the West as a constant shift in emphases among the three elements of the trivium: grammar (substance or structure), dialectic (logic) and rhetoric (effect). Does the multimedia world of metadata mark a return the structural dimensions of grammar or does it mark an entirely new chapter in the evolution of knowledge? One thing is certain. As will become clear in the pages that follow, metadata is changing the nature of knowledge and the horizons of study.

8. Research and Knowledge

Quick Reference

With respect to research, appropriate interfaces will also depend very much on the purpose at hand. Often a reader or visitor is interested in questions of Who? What and Where? In such cases requiring quick access to basic facts, they will need on-line access to the digital reference room outlined in part one of this paper. At the simplest level, this will give them factual information about persons, places and things. Standing in front of Botticelli's *Birth of Venus* (Uffizi, Florence), or looking at an image of that painting on the Internet, a viewer might want to have biographical facts. This can range from wanting the most elementary listing of when he born and when he died, through a one page synopsis of his life, to reading a standard biography. Standing in front of Leonardo's *Ginevra de Benci* (National Gallery, Washington), one could ask about the history of previous owners in order to learn how it got from Florence via Liechtenstein to Washington.

Today paintings are in galleries. Cultural artifacts are in museums. What we know about those paintings and artifacts is usually in articles and books in libraries, particularly in the reference section of libraries which contain terms (classification systems), definitions (dictionaries), explanations (encyclopaedias), titles (bibliographies, catalogues), and partial contents (abstracts, reviews). Given a universally accessible, digital reference room, viewers and readers will readily be able to find definitions and explanations without having to run to dictionaries, encyclopaedias, bibliographies and the like. Such searches can readily happen on a regular PC or a portable notebook computer. In these cases simple lists and paragraphs in a coherent interface will usually suffice.[96]

Objects and Subjects

This type of quick reference or hunting after basic facts about objects and subjects, is the most elementary level of conceptual navigation which interests us. It sounds very straightforward and yet to achieve even this will require an enormous reorganization of knowledge. It would, for instance, be highly inefficient, and very time consuming, if everyone who wanted to know about an artist such as Botticelli, had to search every database around the world. Even searching through every database relating to art would take too long.

Using the principles of object-oriented programming, we need to develop objects of objects, a richer kind of metadata, which will contain key information concerning them.

In the case of Botticelli, for instance, this will include his variant names, his date of birth and death, where he worked, and a list of all his drawings, paintings and other works. This will build on the authority files for artists' names such as Thieme Becker's *Allgemeine Künstler Lexikon (AKL*),[97] those of museums and libraries. In addition to this key information about his primary works there will be a reference to all secondary sources about Botticelli, in books, refereed journals and elsewhere. To achieve this will require the development of individualized agents which seek extant materials, gather them and are then vetted by the leading experts on that artist, author or individual. The net result of such efforts will be a Botticelli "object," with all the metadata pertaining to a traditional "complete works."

In the case of a given painting this will include preparatory drawings, versions by students, members of the workshop, school and followers; copies, different owners, restorers and details of their restorations; their locations and dates. In the case of a manuscript this will entail all copies, all book versions, quantities published, editions, locations, and dates.

Once these "knowledge objects" of artists, books, paintings, sculptures and other cultural heritage exist, they can be combined in new ways. If, for example, one were beginning from the context of a virtual museum, one might zoom in from a view of the world, to the continent of Europe, to the country of Italy, the city of Florence, the ground plan of the Uffizi, to a wall in the Botticelli room, and focus on his *Adoration of the Magi* (figure 3a). This would bring up basic information about the painting. One could then choose to see preparatory drawings, copies, other versions, other paintings by the same artist, or other paintings on the same theme by different artists.

Three-dimensional navigation spaces are particularly valuable for such contextualisation of knowledge. A two-dimensional title or frontispiece of a book tells us nothing about its size. A three-dimensional scale rendering helps us to recognize at once whether it is a pocket sized octavo or a folio sized book: a slender pamphlet or a hefty tome[98]. Hence, having chosen a title one will go to a visual image (reconstruction) of the book; see, via the map function, where it appears on the shelf of a library, do virtual browsing of the titles in its vicinity or wander elsewhere in the virtual stacks (cf. figure 3b)[99].

In the case of such a book, one might choose to see various editions in a chronological list. One could then choose to see the same list of editions as a graph showing fluctuations over time. Alternatively one might visualize the original edition as a small circle linked with successive editions in the form of an inverted cone which sometimes contracts and then expands further (figure 4a). Or one might begin with all the keywords related to a given edition, render these spatially either as a series of concepts surrounding the original, or as circles intersecting a central circle in the manner of a Venn diagram, each of which can in turn be visualized as inverted cones (figure 4b).

Value

In the excursus on metadata we mentioned a trend toward creating objects of objects, which will describe their physical characteristics and their quality. There will be numerous ways of visualizing quality. An author’s primary literature could define a circle, surrounded by a larger circle of secondary literature. Influential authors would have large surrounding circles. Unimportant authors would have only their initial circle: a visualization of “no comment.” Alternatively, one could have a small circle for an edition, surrounded by larger circles for reviews, commentaries and citations: effectively a section of the cone in figure 5. In some cases there will be specific ratings such that one can identify specifically the grade or rating and not just the popularity of a book, painting or cultural artifact. Not all materials on the Internet will be certified. So one can visualise an object as a circle, surrounded by a certified circle and a larger uncertified circle. Combinations of these approaches are possible, such that one might discern which portions of reviews, commentaries and citations are certified or uncertified.

In itself the creation of such circles may seem a rather fatuous exercise. If, however, they are produced on a specific scale and applied systematically to a subject, a field, a region, a country, a period, a movement or a style, or combinations of these, then the approach can be very useful in helping us to see new patterns of development. What correlations are there between the most influential books and the most important books? Does the production of important books in a field change over time? Does it shift from country to country? Can the reasons for the shift be determined?

The attentive reader will have perceived that the systematic approach here outlined does not pretend that computers will use artificial intelligence (AI) or other algorithms to arrive at new insights in isolation. Rather the claim is that their systematic treatment of data and information will expand the range of questions which can reasonably be answered. By providing comprehensive treatment of the four basic questions: Who?, What?, Where?, and When?, they will prepare the ground for new answers to questions of How and Why? In this sense computers will help in intelligence augmentation (IA rather than AI in the senses of Doug Engelbart and Fred Brooks).

Transformation of Knowledge

This quest to achieve objects of objects which contain information concerning all the physical and qualitative characteristics of the original is analogous to the quest for determining the structure of DNA and the mapping of nature in the human genome project. It is much more than just another cataloguing project. It is a quest, which will transform the very meaning of knowledge.

On a seemingly quite different front, companies such as Autodesk have extended the notion of object-oriented programming to the building blocks of the man-made world through what they term industry foundation classes. A door is now treated as a dynamic object which contains all the information pertaining to doors in different contexts. Hence if one chooses a door for a fifty-storey skyscraper, the door object will automatically acquire certain characteristics which are very different from those of a door for a cottage or a factory warehouse. This is leading to a revolution in architectural practice because it means that architects designing buildings will automatically have at their disposal the "appropriate" dimensions and characteristics of the door, window or other architectural building block which concerns them. There is a danger that this could lead to stereotyped notions of a door or window, a McWorld effect, whereby buildings in one country are effectively copies of those in other countries, and travel loses its attractions because everywhere appears the same.

This same technology can be used with very different consequences if one extends the concept of foundation classes to include cultural and historical dimensions. If this occurs, an architect in Nepal wishing to build a door, in addition to the universal principles of construction applying to such objects, will be informed about the particular characteristics of Nepalese doors, perhaps even of the distinctions between doors in Khatmandu or those near Annapurna. Similarly an Italian restorer will be informed about the particular characteristics of doors in Lucca in the fifteenth century.

All this may seem exaggerated and unnecessary. During the second World War, however, some of the key historical houses with elaborate ornamental carvings in Hildesheim (e.g. the *Knochenhaueramtshaus* or Bone Hacker’s administrative office) were bombed and it took a small group of carpenters several decades to reconstruct the original beam by beam, carving by carving. They did so on the basis of detailed records (photographs, drawings etc.). If this knowledge is included in the cultural object-file of Hildesheim doors, windows and houses, then rebuilding such historical treasures will be much simpler in future.

At stake is something much more than an electronic memory of cultural artefacts, which would serve as a new type of insurance against disaster. The richest cultures are not static. They change with time gradually transforming their local repertoire, often in combination with motifs from other cultures. The Romanesque churches of Northern Germany adopted lions from Italy for their entrances. The church of San Marco in Venice integrated Byzantine, Greek and local motifs. The architecture of Palermo created a synthesis of Byzantine, Norman, Arabic and Jewish motifs. The architects in Toledo and at Las Huelgas near Burgos created their own synthesis of Jewish, Arabic and Christian motifs.[100] A comprehensive corpus of variants in local heritage thus leads to much more than a glorification of local eccentricities and provincialism. It can prove an inspiration to multi-culturalism in its deepest sense.

The same principle, which applies to doors and windows, applies equally to ornament, decoration, various objects such as tables and stools and different building types: temples, colosseums, monasteries, cathedrals, and churches. This transforms the meaning of knowledge. According to Plato, knowledge of a temple was to recognize in some particular manifestation the “idea” of some ideal temple. Knowledge did not require knowing the exact dimensions of the Parthenon or any other temple. According to Aristotle knowledge lay in the precise characteristics of a temple such as the Parthenon. Plato was interested in a universal concept, Aristotle in a particular example. Their mediaeval successors became embroiled in philosophical debates whether knowledge lay in universals or particulars. Even in schoolbooks today[101] this problem has not been resolved. History texts typically refer to one example, the Colosseum in Rome, as if it were the only example, as if the particular were synonymous with the universal class.

The new object oriented approach to knowledge is very different from all of these precedents. For a “temple object” will not only contain within itself the precise description of the Parthenon, but also the exact descriptions of all the other temples including those at Segesta, Selinunte, Agrigento, and Syracuse in Sicily, at Paestum and Rome in Italy, at Ephesus, Miletus, and Uzuncaburc in Turkey and elsewhere.[102] This new definition of knowledge resolves the age old opposition between universal and particular, for it can describe the essential characteristics which all the temples have in common (universal) and yet render faithfully all their individual differences (particular).

Knowledge now lies in a combination of the two. The Platonic idea of a temple reduced individual complexity to common characteristics, destroyed individual differences and thereby the notion of uniqueness. The modern “temple object” centres knowledge on the fundamental significance of differences. Thus temples gain universal value through the richness of their local variation. The universal becomes a key to particular expression. Knowledge lies not in recognizing how good a copy it is but rather in how well it has created a variation on the theme.

Spatial

The Colosseums in Rome (Italy) and El-Djem (Tunisia) were built in the same style. Nonetheless their effect is profoundly different due to their spatial settings, one in the midst of the Roman Forum, the other in a near desert setting. Hence knowledge of spatial location, the co-ordinates familiar to Geographical Information Systems (GIS), and Area Management/ Facilities Management (AM/FM) will also be an essential part of a “colosseum (knowledge) object”.

Temporal

The Colosseum in Rome was built at a given time. It was not, however, a static building, in the sense that it remained exactly the same in the course of the centuries. We know, for instance, that a large portion of it was dismantled in the Middle Ages to construct other buildings. Hence a “colosseum (knowledge) object” will need to include all our knowledge about changes over time: i.e. its complete history, including all restorations and interventions for its conservation. Knowledge now includes time as well as space.

A New Encyclopaedia

Some will say that this new approach to knowledge is merely a revival of an age-old encyclopaedic tradition. This is potentially misleading because the encyclopaedic tradition itself has undergone fundamental shifts in its goals. Aristotle was encyclopaedic but his quest was to create summaries, which were subsets of the originals such that the originals could be abandoned. That is why we have what Aristotle said about many of the ancient authors rather than the ancient authors themselves. Their works were allowed to go lost because it was assumed that the Aristotelian summary replaced them. Vitruvius was also encyclopaedic in this sense, except here there was an added goal of making the subset readily memorizable, an aide-mémoire, rather than creating a record of all that existed.

Such decisions were not only guided by profound philosophical reflections. They were partly pragmatic reflections of the available storage media. If knowledge is writ on stone tablets, the burden of knowledge is truly great. The advent of parchment, manuscripts and then printing expanded those horizons considerably. Ironically the same Renaissance which introduced the medium of printing, introduced also a tendency to use media to separate knowledge[103]: books were put into libraries, pictures into galleries, drawings into print galleries (*cabinet de dessins*), engravings into engraving galleries (*Kupferstich Kabinett*), maps into map rooms and cultural objects into museums. Knowledge was decontextualized.

The 18th century Encyclopédistes re-introduced a vision of encompassing all knowledge. But as the rate of knowledge continued to increase, even the organizers of the *Encyclopaedia Britannica,* decided, after 1911, to abandon the quest for universality. Recent innovations in terms of macro-paedia and micro-paedia sections have neither re-contextualized knowledge nor re-introduced a quest for an inclusive encyclopaedic approach.

The new “knowledge objects” distinguish themselves from earlier efforts in several ways. First, computers remove both the barriers of storage capacity and any need to separate knowledge on the basis of media. Second, the “knowledge objects” require a new kind of encyclopaedic approach: one that is globally inclusive of all the variants rather than merely a local summary thereof. This will change the meaning of “objects” insomuch as we shall have collected in one place all quantitative and qualitative information about an object.

Multiple Views

In the past scholars typically spent a majority of their time trying to locate basic facts about an object: Who painted it? Where was it made? When was it finished? For the next few generations scholars will likely be pre-occupied with assuring that the new “knowledge objects” are reliable and as comprehensive as they claim. Once all such information is at our fingertips, will scholars find themselves redundant in the face of automation as in the case of many traditional manufacturing jobs? The answer is definitely not. It is simply that the tasks will be different. In the Middle Ages it took one hundred monks ten years of full-time effort to create an index to the works of Saint Thomas Aquinas. Today that same task can theoretically be performed in minutes by a computer. Having an index spares us the need of reading the complete works everytime we are looking for some particular thought, argument, or fact. But this does not remove the challenge of choosing thoughts, arguments and facts and deciding how or why to apply them. The process of thinking remains.

Once the basic facts have been arranged, scholars will find themselves devoting more attention to presentation. Professors will become view masters in a new sense. Their challenge may lie less in conveying basic facts, than in teaching students to look at facts and concepts in new ways: as a list, a chart, on a map or more abstractly. To take a simple example, any book has a series of key words associated with it, which provides us with some clues concerning its scope. Few keywords indicate a specialized title. Many keywords suggest a title with many applications. Such keywords can be visualized as sides of regular and semi-regular shapes and solids. In this configuration, specialized authors produce points, lines and triangles. Generalists produce increasingly many-sided solids. This introduces new possibilities for looking at the authors in a given field, or of a certain distinction. Were Nobel laureates in 1908 mainly generalists or specialists? Were there significant differences between the arts and science? Did geography play an obvious role? For instance, were the Nobel laureates from Europe more specialized than those from America, or conversely? Did this pattern change over time? Implicit in such activities is a shift from questions about substance (Who? What? Where? When?) to those of function (How?) and purpose (Why?). The old notion of scholars as philosophers may witness a revival.

Presentation is much more than deciding whether to use overheads or slides, whiteboards or virtual reality. It is ultimately concerned with new methods of structuring knowledge, not just individual objects, but also the larger frameworks into which they can be arranged. This is the *terra incognita* of future scholarship. Knowledge organization will become as important as knowledge acquisition and raise many new challenges for cultural interfaces.

One aspect of this structuration process will lie in integrating hitherto disparate knowledge elements. For instance, to continue with our earlier example, the “colosseum (knowledge) object” will entail all the physical characteristics of the colosseum at Rome and those of all the other colosseums at Arles, Nimes, El Djem, Pula and elsewhere in the empire. Using a map one will be able to see where all these places are. Linking a time line with this map one will be able to trace the order of their appearance. Were there close connections between the rise of colosseums and theatres? If so were these connections geographical and chronological or only one of the above? Or were the rise of colosseums and theatres two quite distinct phenomena? Similar questions could be posed with respect to the rise of monasteries, churches and cathedrals.

One can imagine scholars devoting their energies to posing what they think could be fruitful or significant questions. One can also imagine a future generation of agents automatically generating questions and comparisons and only reporting on cases where some significant correlation emerged. In which case the challenge of scholarship would focus less on finding patterns and more on explaining their significance. There would be various levels of patterns, some local, others regional or national, a few international or even global. These patterns will lead to new attempts to characterize periods, movements and styles.

How will these differ from the periods of traditional historical studies? Because they encompass a much larger sample of evidence they will frequently come to very different conclusions. By way of illustration, it is useful to cite the case of the Renaissance. In traditional studies, ancient Greece marked a period of enlightenment. During the "Dark Ages", the story goes, the lights went out. Then around 1400, someone found the light switch and there was a Renaissance, literally a rebirth. The light switch, we are told lay in the rejection of the Dark Ages and a return to the wondrous insights of Antiquity. Thus far the received wisdom.

In this stereotypical view, Renaissance art is usually reduced to the achievements of a handful of remarkable painters including Botticelli, Leonardo, Raphael and Michel-angelo, and museums such as the Uffizi and San Marco are of central importance. And although passing reference is made to the importance of Assisi and the Arena Chapel of Giotto, standard books tend to ignore the predominant role played by fresco cycles in all the major churches of the Renaissance, not only in Florence and Venice, but equally in Castiglione d'Olona, Milan, Montefalco, Perugia, San Gimignano, Sansepolcro, Siena, Rome and lesser known centres such as Atri. A careful examination of these cycles reveals that they focussed on the lives of the saints, from Christ's contemporaries such as Saint John the Baptist and the Apostles (such as Peter and Paul), through the early martyrs (Steven and Lawrence) and church fathers (Augustine, Jerome), right though the Middle Ages (including more recent saints such as Thomas Aquinas and Saint Francis of Assisi). Seen as a whole this corpus points to some very different conclusions about what was happening in the Renaissance. The artists of the Renaissance discovered an uninterrupted continuity between the time of Christ and their own period provided by the lives of the saints. Far from rejecting entirely a so-called Dark Ages, one could argue that they recognized for the first time its essential role. In short the entire history of what happened in the Renaissance needs to be rewritten.

In the longer term there is a larger challenge of finding ways to show how the complexity of cultural activities in the period 1300-1600 could be so reduced as to make the myth about rejecting the Middle Ages a temporarily convincing misrepresentation of the truth. This is another manifestation of the relationship between content and views. Let us posit, hypothetically, that there were 10,000 buildings of cultural interest during the Renaissance. Every major art historian such as a Berenson, a Chastel, or a Gombrich focusses on some subset thereof. So we should have interfaces which show us how schools of scholarship in a given country both bring into focus some aspects while at the same time obscuring many other aspects. We need to make visible the way secondary literature functions as a prism that leads us to overlook complexity while at the same time explaining other bits.

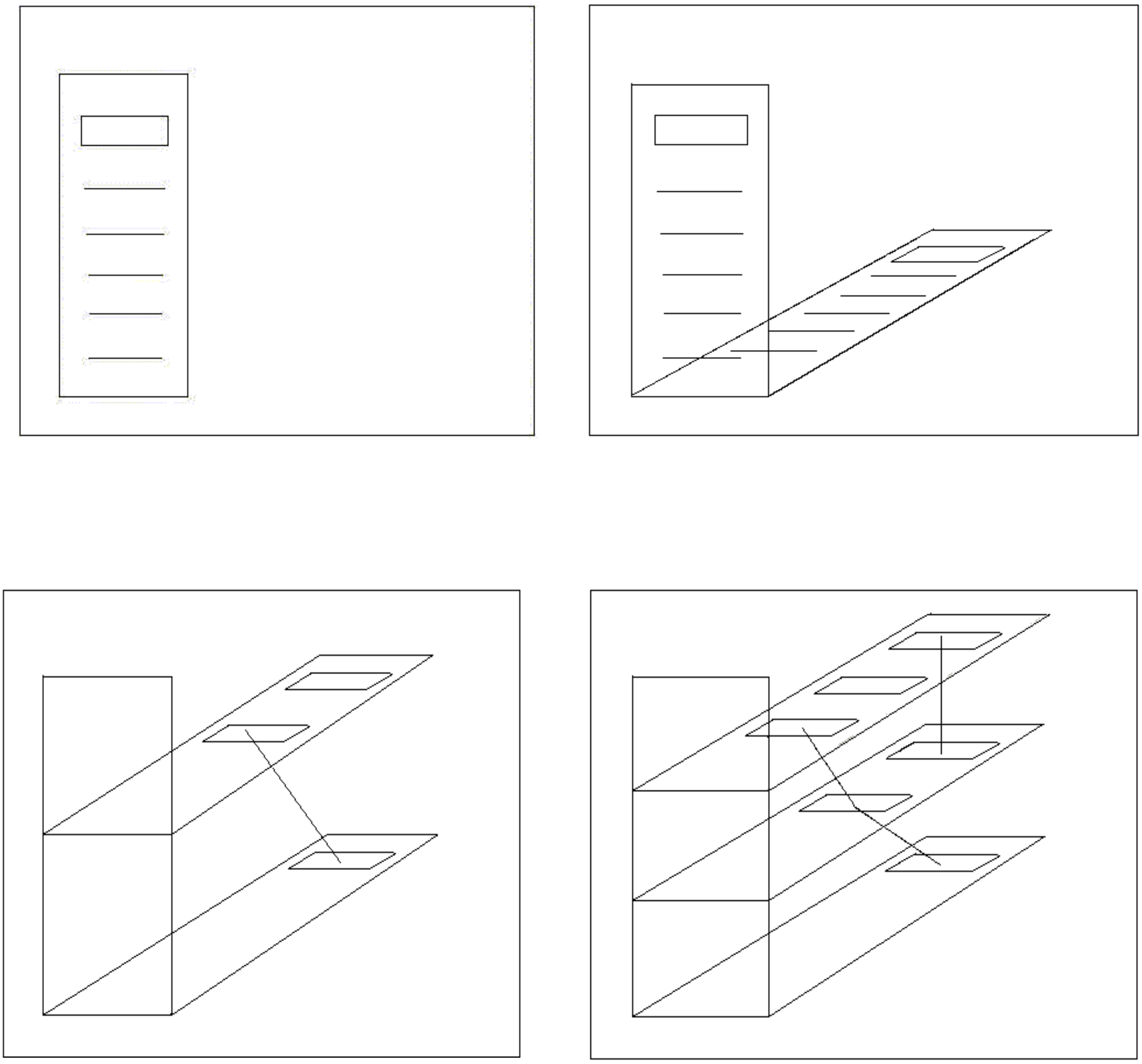


Figure 6. A term in a classification system shown as a two-dimensional list. This list is folded ninety-degrees to a plane at right angles to the screen. Another classification system is introduced in a plane parallel to the first. A third classification system is introduced in like manner. This is used to visualize links between the term in the three systems.

Classification

An important dimension of knowledge structuration lies in classification systems. The major international systems are relatively few. They include Bliss, Dewey, Göttingen, Library of Congress, Ranganathan, Riders International for books as well as the Art and Architectural Thesaurus and Iconclass for art. To a certain extent these reflect national differences. The United States has the Library of Congress and Dewey. Germany has the Göttingen system and others. India has the Ranganathan system. In terms of lesser systems or systems specialized on some particular field there are at least 950 others. Each of these presents different ways of classing the world, with different branches, facets, alternative associations, different broader and narrower terms. These systems also change over time. Ranganathan initially had little about art compared to western systems, yet a great deal about consciousness and higher states of awareness.

When we find a cultural object it can be classed in many ways. Traditionally museums have developed one way of classing, art galleries another and libraries another again. Yet a given painting may well represent an object which exists physically in a museum and about which there is written material in a library. This is why we need meta-data and meta-databases in order to discover the commonalities required to create integrated knowledge objects.

To study a cultural object systematically we need authority lists to have their standard names and recognize which are their variants. Classification systems reveal how that object has been classed as a subject, topic, theme, field, discipline and so on. Such systems also reveal the hierarchies or trees within which objects have been placed. These structures change with time. So we need ways of visualizing equivalences either geographically, chronologically or both. We might begin, for example, (figure 6) by treating the term on the screen as a plane, make this transparent, rotate it downwards by 90 degrees such that it becomes the top surface of a transparent box. The x-axis now becomes the time-axis such that we can literally trace the connections between various subjects. Such an example outlines a means of moving seamlessly from two-dimensional lists to three-dimensional conceptual maps of subjects with their related topics and also offers a whole new way of seeing interdisciplinarity.

One of the challenges in moving between different cultures lies in knowing where to look for equivalent terms. So a person from Canada familiar with the Library of Congress (LC) might choose a series of Library of Congress Subjects. If they were interested in India, the system would then find the closest related terms in Ranganathan and use these to search other catalogues and lists. At a next stage this set of terms can be used to create a cluster of closely related terms and use these for searching.

Related Objects and Subjects

As noted above the quest for equivalent terms leads almost inevitably to a search for related terms, objects and subjects, much in the way that browsing in a library while looking for one book, very frequently leads us to find others, which are as relevant or perhaps even more so than the book we originally set out to find. Classification systems provide another means of contextualising our search: i.e. seeing relations between one subject and another. When we are studying a subject, we typically want to know about related subjects.

In the past we went to a library catalogue, found a title and saw the related topics at the bottom of the card. Electronic versions thereof exist. Recent software such as Apple's *Hotsauce* allows us to go from a traditional two-dimensional list of terms, choose one, and then see all the related topics arranged around it. These related subjects evolve with time, so with the help of a simple time scale we can watch the evolution of a field's connections with other subjects. This idea can easily be extended if we translate the main topic into a circle and the related subjects into other (usually smaller) circles intersecting the main one to create a series of Venn diagrams. This visualisation allows us to choose subsets common to one or more related fields, which is important if one is trying to understand connections between fields (figure 4b).

Relators

Classification systems typically take us to broader and narrower terms in our quest for related terms. But as thinkers such as Perrault[104] and Judge[105] have noted there are numerous other means to acquire related terms including: alternatives, associations, complementaries, duals, identicals (synonyms as in *Roget's Thesaurus*), opposites (antonyms), indicators, contextualizers and logical functions such as alternation, conjunction, reciprocal, converse, negative, subsumptive, determinative and ordinal. It is feasible that these will eventaully become part of the "knowledge objects," such that if one has a term, one can see its synonyms without needing to refer to a thesaurus. All these kinds of relations thus become different hooks or different kinds of net when one is searching for a new term and its connections.

Ontologies

Such classification systems are the most familiar, important efforts at bringing order to the world in terms of subjects. But subjects in isolation are still only somewhat ordered information[106]. Meaning which brings knowledge and wisdom requires more, namely a systematic ordering of these subjects in terms of their logical and ontological relations. Efforts in this direction go back at least to the *I Ching*. Aristotle, Thomas Aquinas, Ramus, Francis Bacon and Roget were among the many contributors to this tradition. In our generation, Dr. Dahlberg presented these fundamental categories in a systematic matrix[107]. More recently these have been adapted by Anthony Judge into a matrix of nine columns and nine levels (figure 6), which generates a chart of 99 subjects. These range from fundamental sciences (00), astronomy (01) and earth (02) to freedom, liberation (97) and oneness, universality (99)[108]. Anthony Judge is using this as an "experimental subject configuration for the exploration of interdisciplinary relationships between organizations, problems, strategies, values and human development".

	Matrix columns	Matrix levels
9	Condition of the whole	Experiential (modes of awareness)
8	Environmental manipulation	Experiential values
7	Resource redistribution	Innovative change (context strategies)
6	Communication reinforcement	Innovative change (structure)
5	Controlled movement	Concept formation (context)
4	Contextual renewal	Concept formation (structure)
3	Differentiated order	Social action (context)
2	Organized relations	Social action (structure)
1	Domain definition	Biosphere
0	Formal pre-conditions	Cosmosphere/Geosphere

Figure 7. An integrative matrix of human preoccupations by Anthony Judge (Union Internationale des Associations) adapted from Dr. Ingetraut Dahlberg.

Heiner Benking, builds upon the framework of Dahlberg and Judge (as in figure 7 above), to produce his conceptual superstructure or cognitive Panorama Bridge, which is the basis of his Rubik's *Zauberwürfel* [*Cube of Ecology* or *Magic Cube*].[109] He argues that one can use planes in order to see patterns in thought. These planes, he claims, can include continua between the animate and the inanimate on one axis and between micro-, macro- and meso-scales on another axis. Planes, he claims, can be used to compare different viewpoints at a conceptual as well as a perceptual level; to see relations among different actions, options and strategies.

Seen in this context, it becomes evident that our discussion thus far has been rather narrow. It has dealt primarily with physical objects in the cosmosphere/geosphere (level 0) although the comments on classification have touched briefly on concept formation (level 4). From this point of view the amount of knowledge structuration that remains to be done is staggering indeed. Scholars are not about to be without work.

If we were trying to achieve a truly big picture involving the interplay of two or more of the planes in this matrix, then a three-dimensional interface with the kinds of planes outlined earlier will be essential (cf. figure 6). Parallel planes can be used to see different levels of abstraction. A challenge remains how precisely we are to navigate between such conceptual landscapes and the knowledge structures of libraries, which have been a main focus of this paper. At a programming level this should be relatively straightforward. Each of the ninety-nine subjects is tagged with its equivalents in the main classification schemes. At the user level, this and similar matrices then become a natural extension of the system. When we use these categories as a filter to look at publications in the Renaissance or research trends in the late twentieth century, we have another means to comprehend which areas were the focus of attention and which were abandoned, or even forgotten. Search and access systems must help us to see absence as well as achievement, and possibly provoke us to look more closely at the spaces which are being ignored. Were they truly dead ends, have they surfaced in a new guise or do they now require new study?[110]

Visualising Connections in Conceptual Spaces

The third dimension has many uses beyond producing such electronic copies of the physical world. Pioneers of virtual reality such as Tom Furness III,[111] when they were designing virtual cockpits, realised that pilots were getting too much information as they flew at more than twice the speed of sound. The challenge was to decrease the amount of information, to abstract from the myriad details of everyday vision in order to recognise key elements of the air- and land-scape such as enemy planes and tanks.

This principle is equally important in knowledge organisation and navigation. A library catalogue gives me the works of an author. Each catalogue entry tells me under how many fields a given article or book is classed. Adding these fields together leads to an alphabetical list of that author's intellectual activities. Producing such a list in electronic form is theoretically simple. What we need, however, is a conceptual map. To what extent did an author work as a generalist in large subject fields and to what extent as a specialist?

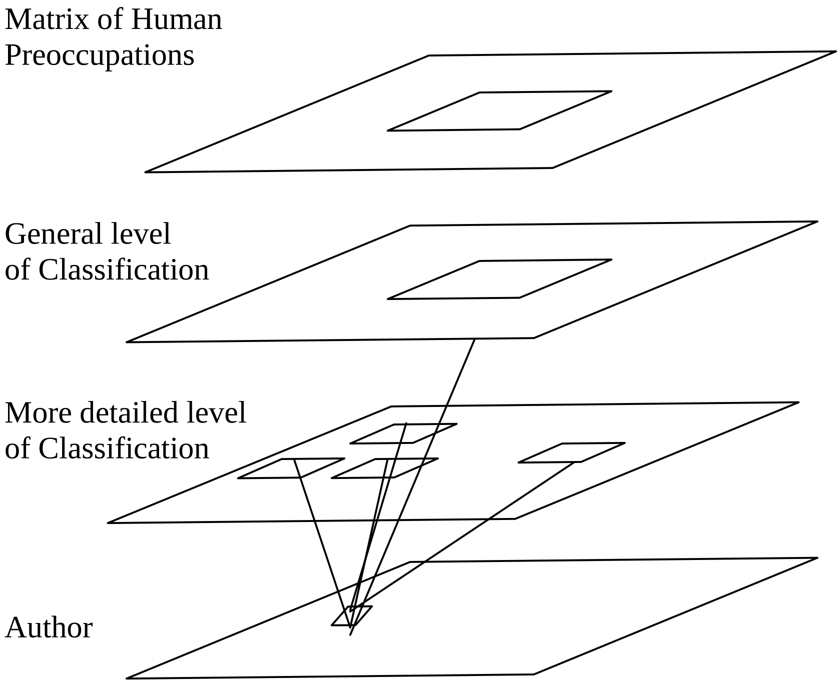


Figure 8. Visualisation of an author's activities whose specialist activities touch on four fields (three of which are closely related) and whose more generalist activities are limited to one major field. This can, in turn, be linked with the matrix of human preoccupations. Further layers could be added to show how the same concepts recur in different places in various classification systems.

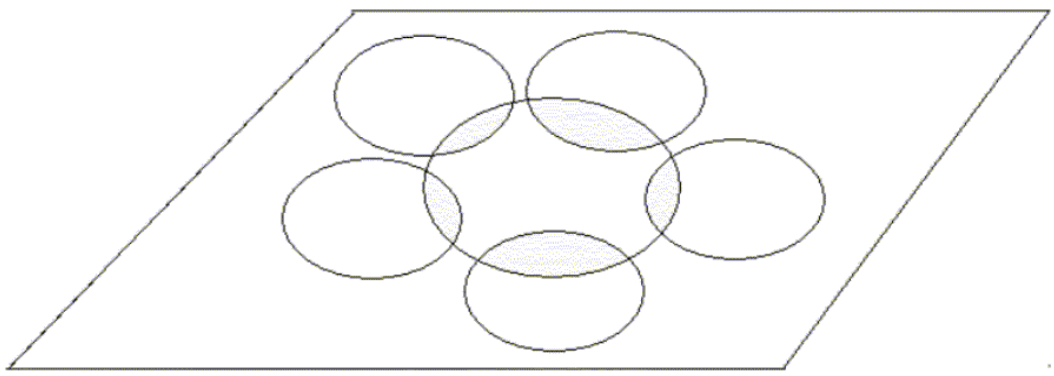


Figure 9. Venn diagram of a subject and its related subjects, shown as intersecting circles. In addition to regular searches by subject, this visualisation allows a user to choose subsets common to one or more related fields, which is important if one is trying to understand interdisciplinary relationships. Cf. fig. 4.

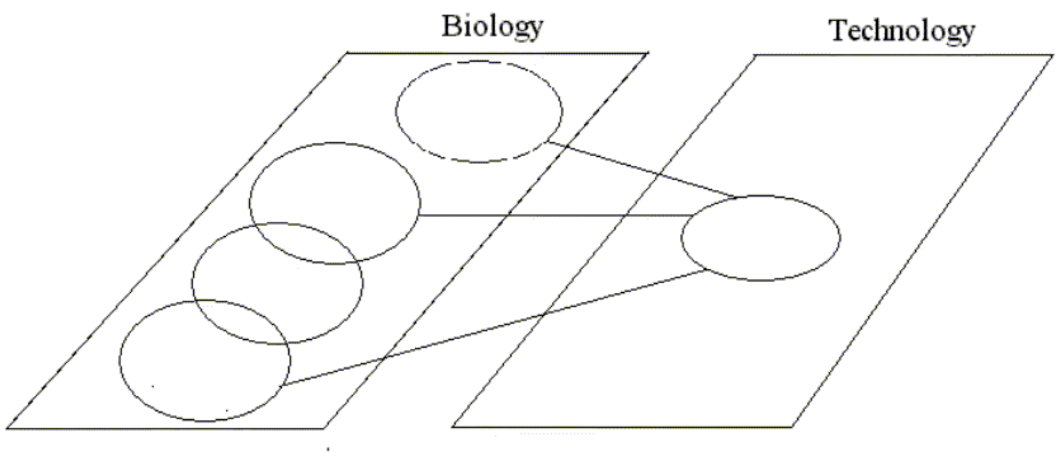


Figure 10. In this diagram the large circles again represent two fields and the smaller circles represent branches of these fields. The lines joining them represent work linking hitherto different branches. These lines thicken as the amount of articles and other research activities increase and thus become a new means of tracing the growth of an emerging field.

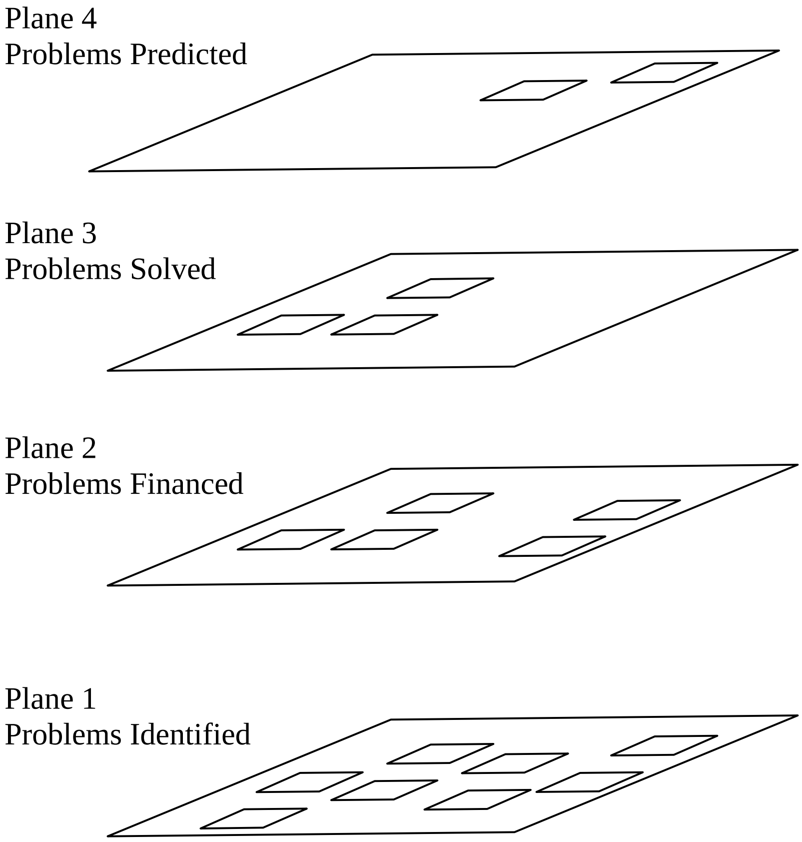


Figure 11. Using spatial arrangements of concepts to map problems identified and to visualise which subsets thereof were financed as research projects, which were solved in the sense of producing patents, inventions and products and which led to new predictions in the form of hypotheses and projections.

This lends itself to three dimensions. Author A is in one plane and the subject headings of their works are on other planes. These are aligned to relative positions in classification systems such that one can see at a glance to what extent this person was a generalist or a specialist and linked with the matrix of human preoccupations to discern how they relate to this (figure 8). This principle can be extended in comparing the activities of two authors.

Social

This approach can in turn be generalised for purposes of understanding better the contributions of a group, a learned society or even a whole culture. Scholars such as Maarten Ultee have been working at reconstructing the intellectual networks of sixteenth and seventeenth century scholars based on their correspondence. A contemporary version of this approach would include a series of networks: correspondence, telephone and e-mail which would help us in visualising the complexities of remarkable individuals be it in the world of the mind, politics or business.

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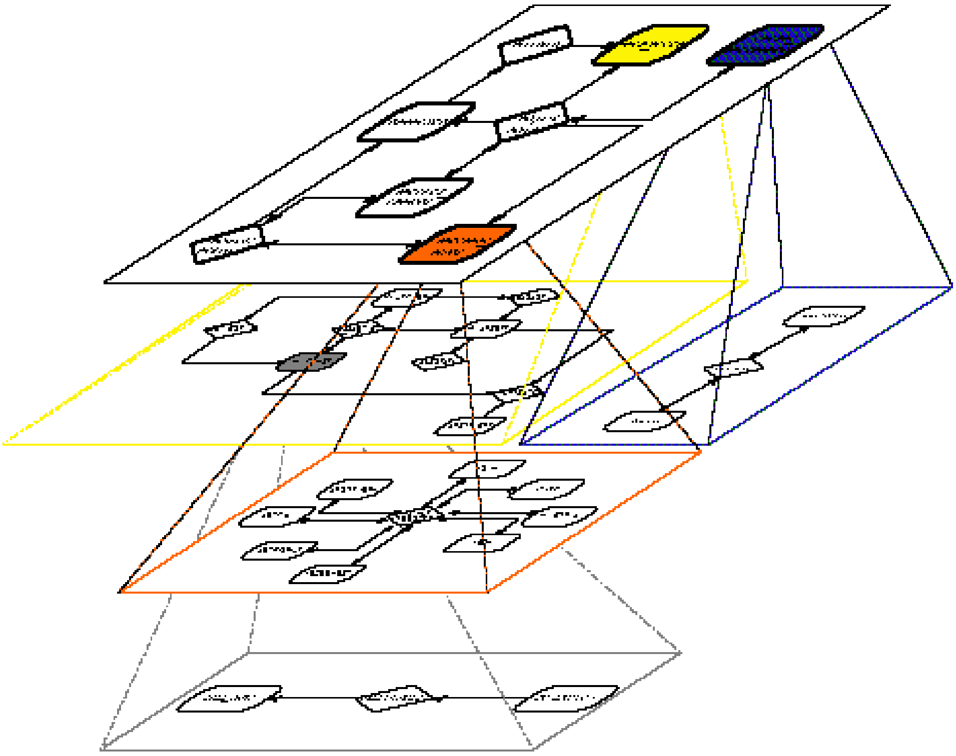

Figure 12. Diagram relating to metadatabase research at Rensselaer Polytechnic in conjunction with Metaworld Enterprises entailing a Two Stage Entity Relationship (TSER) in the context of an Information Base Modelling System.

The geographical aspects of these intellectual networks can be visualised using maps. Conceptually the subjects of the letters, (and the e-mials to the extent that they are kept), can be classed according to the layers outlined above such that one gains a sense of the areas on which they focussed. For instance, what branches of science were favoured by members of the Royal Society? Did these change over time? It is a truism that Renaissance artists were also engineers and scientists

What particular fields did they favour? Can one perceive significant differences between artist-engineers in Siena, Florence, Rome and Venice? We could take the members of a learned society or some other group and trace how many layers in the classification system their work entailed and then study how this changed over time. Are the trends towards specialisation in medicine closely parallel to those in science or are there different patterns of development? Alternatively by focussing on a given plane of specialization we could trace which authors contributed to this plane, study what they had in common in order to understand better which individuals, networks of friends and which groups played fundamental roles in the opening of new fields. Such trends can in turn be linked with other factors such as research funding or lack thereof. In addition to universities, major companies now have enormous research labs. Nortel, for instance, has over 17,000 researchers. Hitachi has over 30,000. We need maps of Who? is doing What? and Where? In our century we could also trace where the Nobel and other prizes have gone both physically and conceptually. Navigation provides virtual equivalents of journies in the physical world. It is also a means of seeing new patterns in the conceptual world through systematic abstraction from everyday details in order to perceive new trends.

If we were trying to trace the evolution of a new field, we could begin by using a dynamic view of classification systems described above. We could also use combinations of these intersecting Venn diagrams. For example, the last generation has seen the emergence of a new field of bio-technology. This has grown out of two traditional fields, biology and technology. These could be represented as large circles surrounded by smaller ones representing, in this case, their related branches and specialties. Any academic work would be represented in the form of a line, which thickens in proportion as the connections increase. These connections are of differing kinds. Initially they tend to be in the form of sporadic articles, conferences, or isolated research projects, which have no necessary continuity.

Later there are books, journals, professorships, research institutes and spin-off companies which bring a conscious cumulative growth to the new field. Each of these phases could be identified with different colours so arranged that one can distinguish clearly between sporadic and cumulative activities (figure 10). We can integrate these circles within the context of frames as described above. For example, the two fields of biology and technology could be on one plane. Major universities could be on a second plane. We could then trace which universities are producing the most papers of these two fields and specifically on what sub-sections thereof. On another plane we could list the major research institutes in order to determine other trends. Are these areas being studied more in the United States than Europe or Japan? If so what are the percentages? Which companies dominate the field? What links are there between research institutes and universities? Are these increasing or decreasing?

Experiments in the realm of metadatabase research at Rensselaer Polytechnic[112] provide a preliinary idea of how a concept at one level can be linked via planes with a series of concepts at another level. Such a notion of planes can be extended to see further patterns. Plane one can list all the known problems or potential research areas in a given area of science. Plane two lists which subset of these problems is presently being studied. Plane three shows which problems have been solved or rather have some solutions in the form of inventions, patents, trademarks and products. Plane four lists a further subset for which solutions are predicted or which have hypotheses for their solution (figure 12).

Such comparative views can help scientists and decision-makers alike to understand more clearly trends in rapidly developing fields. Such matrices of problems can in turn be submitted to problem structuring methodologies whereby technical, practical and emancipatory dimensions are submitted to frameworks in order to discern where they fit into what some have called a Methodology Location Matrix.[113]

Returning for a moment to the framework outlined in figure 7, one can envisage the direction which a future encyclopaedia will take. For instance, level seven in this framework outlines context strategies including logic, philosophy, security, community, peace and justice. These will be related to the context of concept formation (level five) and its structure (level 4), the context of social action (level 3) and its structure (level 2).

Earlier we discussed the spread of ancient temples, of mediaeval monasteries, churches and cathedrals. These would be linked with the growth of religious ideas and the religious orders which followed from them. Which were the ideas that led to mainstream religions? Which were the ideas that led to peripheral sects? Which ideas led to the development of significant groups, organizations, parties, political movements? Earlier we outlined the development of objects in spatio-temporal terms. The history of ideas will need to be explored in spatio-temporal-socio-conceptual terms, each represented by levels in the third-dimension, which can be translated back to two-dimensional lists and descriptions as appropriate.

Seeing Invisible Differences

During the Renaissance the discovery of linear perspective brought new skill in visualising the physical world, but it began by illustrating episodes from the lives of saints, which none of the artists had witnessed personally. Hence it helped simultaneously in expanding the horizons of the visible world of nature and the invisible world of the mind. This dual development continues to our day. Three-dimensional visualisations, especially using virtual reality help to illustrate both the visible and invisible, and to introduce many new possibilities.

If, for instance we take the Library of Congress classification, as above, and link each layer in its hierarchy with a different layer, then we arrive at a truncated pyramidal shape beginning with twenty initial topics at the top and increasing to many thousands as we descend. Say we are interested in total publications in the Library of Congress. At the top level, these publications can be linked to each of the twenty basic fields, such that each major subject is represented proportionately as a square or circle. We can thus see at a glance to what extent the number of books on science is greater than those in the fine arts. By going down a level in the hierarchy we can see how those figures break down, e.g. to what extent there are more books on physics than chemistry or conversely. At another level we can see whether and if so to what extent astro-physics has more publications than bio-physics or quantum physics. We are thus able to see patterns in knowledge which we could not see simply by looking at the shelves, although even shelves can give us some hint that one topic has more books than another.

A slightly more refined version would link this approach to book catalogues such that we can trace how these trends in publications change over time. From a global point of view we could witness the rise of the social sciences in the nineteenth century. At a greater level of detail we could see the rise of psychology as a field. This same approach can also be applied to usage patterns as studied by scholars in reception theory.[114] In future usage patterns by on-line readers will become important for scholars as well as those doing market studies.

In our quest to see significant patterns it will sometimes prove useful to have agents examine trends and draw our attention only to cases where there are considerable changes, of say 10 or 20%. This will be another way to discover emerging subjects. This same methodology has a whole range of other applications including marketing, advertising, stock markets and even network management. Say, for example, that we want to monitor potential trouble spots on the system. Agent technologies measure usage at every major node of the system in terms of a typical throughput and usage. When these ratios change significantly the system identifies where they occur, and introduces standard adjustment measures. If these fail, the system visualises relevant points in the neighbourhood of the node such that operators can see remotely where the problem might lie and take appropriate action. Hence, instead of trying to keep everything visible at all times, the system only brings to our attention those areas where trouble could occur: an electronic equivalent of preventative medicine. Such strategies will no doubt be aided by the further development of sensory transducers whereby significant changes in heat within the system would also be rendered visible. Seeing the otherwise invisible is a key to navigating remotely through complex environments.

Comprehension and Prediction by Seeing Absence

In the early days of the scientific revolution there was great emphasis on the importance of inductive as opposed to deductive research, which entailed an emphasis on experience, experiment, often on a trial and error basis. As scientists gained a better understanding of the field to the extent that they were able to create physical and conceptual maps of their objects of study, it became possible to deduce what they had not yet observed. For example, from a careful observation of the motions of the known planets, astronomers were able to predict the location of Uranus and subsequently other planets. In combination with induction, deduction regained its role as an important ingredient in science. The same proved true in chemistry. Once there was a periodic table, chemists found that the known chemicals helped them to chart the positions of as yet unknown compounds. Once we have a matrix we can see where there is activity and where activity is missing. By now, chemistry is expanding with enormous speed. It is estimated that every week over 14,000 new chemical combinations are discovered. As in the case of pilots flying at twice the speed of sound we need methods for abstraction from the day to day details, new ways of seeing patterns. Access, searching and navigation are not just about seeing what we can find, but also about strategies such that we see the appropriate subsets at any given time.

Until a generation ago mainframe computers typically relied on punch cards with holes. Each hole represented a specific configuration of a subject or field. Rods or wires were then used to determine which cards had the same fields. Early versions of neural networks adopted a virtual version of the same principle by shining virtual lights through configurations of holes. When the holes co-incided the subjects were the same. Database indexes effectively accomplish the same thing with one fundamental difference: we see the results but have no means of seeing the process.

To see a bigger picture we need to see how the tiny details fit into the larger categories of human endeavour so that we can discern larger patterns. Roget as we saw had six basic classes (figure 1). Dewey had ten: 0) generalities; 1) philosophy and related disciplines; 2) religion; 3) social science; 4) language; 5) pure sciences; 6) technology; 7) the arts; 8) literature; 9) general geography and history. The Library of Congress has twenty such fundamental classes. Beneath these universal headings are many layers of subordinate categories hierarchically arranged. If we treat each of these layers as a plane, and have a way of moving seamlessly from one plane to the next, then operations performed at one level can be seen at various levels of abstraction.

Suppose, for example, that we have been searching for Renaissance publications by Florentine authors. Moving up to the highest level we can see on which fields they wrote: religion, science, art and so on. Moving back down a few levels we can identify which particular branches of science and art concerned them most. Going back to the top level we can also see that there were many topics which they did not discuss. The Renaissance view was supposedly universal in its spirit. In practice, it often had distinct limitations. If we have access to multiple classification systems, then we can see how these patterns change as we look at them say, through the categories of Duke August and Leibniz at Wolfenbüttel or through the categories of Ranganathan’s system. These approaches become the more fascinating when we take a comparative approach. How did German Lutheran cities differ from Italian Catholic or Swiss Calvinist cities in terms of their publications? How does religion influence the courses of study and research? What different cultural trends are evident from a comparison of publications in India, China, Turkey, Russia and Japan?

In the GALEN project (Manchester), magic lenses are being used to determine where there are gaps in relations between parts of the body, and their functions. One could imagine how the planes, which were outlined above, would be imbued with the qualities of lenses in order to develop their systematic potentials.

9. Challenges

Most discussions of challenges today focus on input, capacity and transmission. How can the vast materials be scanned in as efficiently and quickly as possible? How can we develop storage facilities capable of dealing with thousands of exobytes of material? How can we develop bandwidth, which will be capable of dealing with such vast quantities? These are hardware problems, which are being overcome and will soon dwindle to everyday maintenance problems. In our view the deeper challenges lie elsewhere, namely, problems of translating verbal claims to visual viewpoints, questions of advanced navigation in terms of scale and problems of cultural filters.

Pictures and Words

The quest to develop systematic ways of comparing objective dimensions with different subjective views is important and potentially very useful for cultural interfaces. However, the integration of verbal subjects and objects into a visual scheme, may be more problematic than it at first appears due to fundamental differences between words and pictures.

There is a long tradition of comparisons between pictures and words. Already in Antiquity, Horace made comparisons between the pictures of painting and the words of poetry[115]. In our century, famous art historians such as my mentor, Sir Ernst Gombrich, began by assuming that pictures and words were effectively interchangeable. His famous *Art and Illusion* began as a series of Mellon lectures entitled the *Visibile World and the Language of Art*. He gradually reached the conclusion that there were very significant differences between the two.

One of the fundamental differences between pictures and words is that pictures can use space systematically in a way that words cannot. Pictures are potentially perspectival, words are not. Gombrich attempted to express this through his distinction between the "What and the How"[116] and in his essay on the "Visual Image.[117]" Pictures can show what happened and precisely how it happened. Words can only convey what happened, e.g. that a given person was shot from a particular position, not all the details of how it happened.

Notwithstanding, this fundamental difference between pictures and words, there have been surprising parallels between the growth in depicting stories in pictures and the quest to tell them in words. The rise of narrative in painting and literature are connected. Attempts to show pictures from a specific point of view and efforts to tell stories from a given "viewpoint" in the sense of first person narrative also seem to be connected.

Metaphorically perspectives of pictures are closely linked with those of words. Luther, referring to his dogmatic position, wrote, "Here I stand". The great philosopher Kant, wrote an essay on "standpoint" as a fundamental philosophical act. Today, typically, we speak of literary viewpoints and even literary perspectives. We even speak of seeing a person's point of view after listening to their story. It is essential, however, to remember, that all these are metaphorical acts rather than literal ones. Herein lies a key to understanding why is easy to speak verbally of seeing another person's viewpoint, but almost impossible to depict this verbal viewpoint pictorially. We may speak of another's space, entering into, sharing their space, but this is hardly the same as actually seeing or depicting the world as they see it.

Words are about universals. The noun, dog, refers, to all dogs. Pictures are about particulars. One may attempt to depict all dogs, but if the picture is precise, it shows a given dog such as the neighbour's three-month old, brown pet, rather than some abstract, universal concept of dogginess.

For this reason, the moment we try literally to represent pictorially a metaphorical verbal position or viewpoint, we encounter enormous difficulties. The verbal description is almost always much less precise than a visual depiction and therefore open to a whole series of alternative possibilities. This does not necessarily mean that the quest is futile. One solution would be the direct brain interfaces, which are being explored by scientists today (cf. above p. 8*). Until these become available an interim solution is to create alternative reconstructions, from which the author of a position can choose in deciding which is an accurate visual translation of their verbal description.

As noted earlier, in terms of virtual museums, Infobyte has already developed a Virtual Exhibitor software, which allows museum directors and curators to explore a series of hypothetical arrangements of paintings in designing the layout for their regular museum and for special exhibitions. In terms of verbal viewpoints, perhaps we need a variant of this software, a type of Virtual Verbal Viewpoint Exhibitor, to help bridge the gap between metaphorical and literal sharing of viewpoints. It is quite possible, of course, that we shall, on closer reflection, conclude that there are profound reasons for keeping these viewpoints metaphorical and not translating them into potentially banal literal versions. Or it may well become a matter of choice, just as a number of persons prefer to remain silent in difficult situations rather than spelling out the situation in boring detail. The ability not to use functionalities is both a prerequisite of culture and one of its highest expressions.

Scale

In the film *Powers of Ten*, viewers were taken from a person lying on the beach upwards by tenfold scales to the universe and then back to the microcosmic level. More recently, Donna Cox adapted this principle for the IMAX film, *Cosmic Journey*. This film used both real photographs and computer simulations. A project at the Sandia Labs is creating a *Dynamic Solar System* in scale:

> The scale model of the solar system covers a spatial range of 10 km with an individual positioning resolution of ~20km. It contains 73 objects, each with appropriate motion. Tethering or locking permits a viewer to attach to an object and travel with it, duplicating all or part (e.g., center of mass) of its inertial motion while retaining the ability to move independently. Here, tethering also triggers a search of available NASA data. Photographs and associated text information are displayed on the craft wall while tethered.[118]

Recently, thinkers such as Ullmer,[119] have speculated how one could use similar principles of changing scales for navigation in extremely large data spaces. Proper contextualization of knowledge requires being able to move seamlessly between the nano-structures of the atomic particles to the macro-structures of galaxies at the cosmic level. Being able to do without getting "lost in space" is truly a challenge.

Cultural Filters

Getting at the essential facts concerning objects of culture is a worthy and important goal. More subtle and elusive are the challenges of interfaces reflecting a variety of cultures: problems of learning to see things in different ways, through the eyes of different cultures. This entails a whole range of challenges including terms, languages, symbols, narratives, values and questions.

Terms

As noted earlier one of the great challenges in research lies in finding equivalent and/or related terms to the topic which interests us. Classification systems offer one method. Synonyms, antonyms and indicators offer another. Such terms vary culturally and often do not lend themselves to a simple translation: a public house or pub in English is quite different from a *maison publique* in French. *Burro* in Italian is very different from *burro* in Spanish. We need new methods for mapping systematically between different classification systems to continue finding equivalent terms when they are classed in very different places.

Languages

Cultural filters can potentially provide translations from one language to another. At the most obvious level this could entail taking a virtual tour in English and translating it into French, German or some other language. In other cases, it might well be looking at a painting, which has a Latin or Chinese caption. Given the rapidly evolving field of optical character recognition, one could have a simple video-camera attached to one's notebook computer, point this camera at the caption in question, which would relay the caption via the computer to an on-line databank, and provide a summary translation thereof.

Within a major language there are many levels of expression ranging from formal, through informal, to dialect and slang. Cultural filters will eventually need to provide translations in both directions. Sometimes, for instance, there will be an expression in dialect or slang for which one wants to have the formal equivalent, as when Dante or Shakespeare use colloquial terms which require explanation. At other times, a particularly formal turn of phrase by a Proust would need explication in a less formal style. In traditional publications standard editions of a famous play or novel typically relegate such explanations to footnotes. In future, these can also be offered on demand either as visual captions or as verbal commentaries.

Symbols

At the level of symbolism, cultural filters are more obviously important. In Europe, white is symbol of purity, the spirit, and life. In China, white is typically a symbol of death and mourning. On the other hand, in Europe a white cala lily is a symbol of death, whereas in other parts of the world it has a more joyous meaning. As a result an interface with colours designed for one culture, may well have unexpected effects on persons form another culture. Having identified one's culture, the interface should "know" the appropriate colours and adjust itself accordingly.

Colours are but one small aspect of very complex traditions of symbols. In Germany, the swastika is associated with all the horrors of Nazi fascism. In the Far East the swastika is sometimes a symbol of the sun or of the Buddha's heart. In Chinese the swastika is a pun on the word ten thousand and the bat a pun on happiness. Hence a bat with a swastika dangling from its mouth means "may you have happiness ten thousand-fold."

As an extension of the quick reference provided by the digital reference room, one would thus be able to choose a symbol and explore its meanings in different cultures. This assumes, of course, that one knows the name of the item in one's own culture. Once again, given rapid developments in pattern recognition with software such as IBM's Query by Image Content (QBIC), new solutions are likely to present themselves in the near future. Using a video camera attached to one's notebook computer as described above, one would point the camera at the symbol in question, which would relay it via the computer to an on-line databank. This would identify the object and provide the viewer with the multiple meanings thereof according to various cultures.

Narratives

Often cultural and especially religious symbols entail much more than some isolated object. They typically entail narratives, stories, based on a sacred text (e.g. the *Bible* or the *Mahabharata*) or epic literature (e.g. Homer's *Iliad* or Dante's *Divine Comedy*). Persons within an established culture take these narratives for granted and frequently define themselves in terms of familiarity with that corpus. Outsiders find these narratives confusing or meaningless. For example, a Catholic standing in front of a painting of *Moses in the Desert,* unconsciously calls to mind the appropriate text in the *Old Testament* or at least the gist of the event. Similarly, in viewing *Christ Walking on Water* they call to mind the appropriate *New Testament* passage. In seeing the *Saint Sebastian* they recall Jacobus de Voragine's *Golden Legend* or some more simplified *Lives of the Saints*. To a non-Christian unfamiliar with these sources, images of a person walking on water, or of a man remaining calm while being pierced by multiple arrows, may well seem curious, confusing or simply incomprehensible. Similarly a Christian unaware of Buddhist traditions will encounter incomprehension when they confront Tibetan *Thankas*, or Chinese scrolls.

The digital reference room serving as a cultural Baedeker will thus offer tourists much more than a geographical map of sites and artifacts. It will provide access to the narratives underlying all those otherwise enigmatic titles of paintings, sculptures, and dances such as *Diana and Actaeon*, *Majnun and Leila*, or *Rama and Krishna.* This may, in turn, have fundamental implications for battles in other areas of academia. In the context of deconstructionism and its various branches, for instance, there have been enormous debates concerning the viability or non-viability of speaking about a canon of literature. Whereas earlier generations were fully confident in their ability to define the "greats" and "classics", many would argue that these lists have become so fluid that they are almost meaningless. In Canada, for instance, only a generation ago, the *Bible* and Shakespeare would have been seen as fundamental titles in such a canon.

Today, a number of persons would argue that no single canon is possible, that instead we need to speak of canons for black, feminist, queer and other literature, rather than a basic heritage shared by all civilized persons. For those who define culture and civilization in terms of a common heritage, abandoning the idea of a shared corpus, implies the loss of a shared heritage by means of which we feel at ease with one another. Meanwhile, others argue that a true corpus can no longer be Euro-centric. It cannot be limited to Homer, Virgil, Dante, Shakespeare and Goethe. It must include the great literature of India, China, Persia, and other cultures. Here another problem looms. The corpus will become so large that no one will have time to master it unless they make this their sole profession.

From all this it will again be apparent that the question of "viewpoints" is much more complex than is generally imagined. Viewpoints are not just about comparing abstractions. They are also about different bodies of knowledge, which are an essential ingredient of culture. An Englishman sees the world through the prisms of Shakespeare and Milton, an Italian through the verses of Dante, and a German through the poetry of Goethe and Schiller.[120] Each of these geniuses did more than create poetry: they launched a heritage of associations which are shared by every cultured person in that tradition, such that there is a manageable corpus of phrases that is mutually recognised by all members. In order better to comprehend these shared traditions in the case of cultures completely foreign to us, it may prove useful to develop agents familiar with all the standard literature of those cultures such that they can help us to recognise quotes which are so familiar to natives that they are expressed as ordinary phrases, e.g. *To be or not to be* (Shakespeare) *Every beginning is difficult* (Goethe), *One must live to eat, not eat to live* (Molière), and yet evoke a wealth of associations which the outside visitor could not usually expect.

Here, at the end, we can only touch upon this most elusive aspect of navigation, which is not only about what a culture says or writes. It is about what one culture asks and another does not, about which one culture discusses and the other is silent, for which one culture has a hundred terms (snow among the Inuit) and of which another culture has no experience (a nomad in parts of the Sahara).

Values

More elusive than any of these are problems of cultural values. Anthony Judge[121] of the International Union of Organizations has drawn attention to nine *Systems of Categories Distinguishing Cultural Biases.* Maruyama (1980),[122] for instance, identifies four epistemological mindscapes. Geert Hoftede (1984),[123] outlines four indices of work related values power distance, uncertainty avoidance, individualism, and masculinity.
Mushakoji (1978)[124] focusses on four modalilities through which the human mind grasps reality: affirmation, negation, affirmation and negation, non–affirmation and non-negation. Will McWhinney (1991)[125] uses four modes of reality construction: analytic, dialectic, axiotic and mythic. Pepper (1942)[126] expresses four world hypotheses: formism,

mechanism, organicism, and contextualism. Mary Douglas (1973)[127] employs four systems of natural symbols: body conceived as an organ of communication; body as a vehicle of life, practical concern with possible uses of bodily rejects, life seen as spiritual and body as irrelevant matter. Gardner (1984)[128] relies on six forms of intelligence: linguistic, musical, logical/mathematical, spatial, bodily-kinaesthetic, and personal. Jones (1961)[129] uses seven axes of methodological bias: Order vs. disorder, static vs dynamic, continuity vs. discreteness, inner vs outer, sharp focus vs. soft focus, this world vs. other world, spontaneity vs. process. Meanwhile, Todd (1983) [130] identifies eight family types with different socio-political systems. A complete analysis of these systems would take us beyond the scope of the present essay. What interests us here is that each of the authors has chosen between four and eight concepts in order to explain fundamental orientations in thought. The challenge is, how can these alternative approaches be visualized in such a way that they can be integrated into the system.

Questions

The subtle aspects of culture extend not only to the kind of answers one gives but also to the questions one asks. In some older cultures it is not polite to ask what a person's father does, the assumption being that if the person is properly established that question would be redundant, and if they were not properly established then the question could lead to an embarassing result. A person from such a culture may feel they are being polite in not asking only to find themselves accused of disinterest in another culture. As usual these variations find various humorous expressions. It is said that the English always know with whom one sleeps but would never think to ask what one did, while the French will happily supply detailed descriptions of what they did without ever asking with whom? Such pleasantries aside, there are always topics, which can be discussed, questions, which can be raised in one culture, which are quite taboo in others. In Irish polite society one may find persons asking detailed questions about politics including for whom one voted, questions which be considered indiscreet or completely taboo even in some other parts of the Anglo-Saxon tradition. The Internet has drawn attention to frequently asked questions (FAQs). We need new means to examine how such questions vary culturally and new interfaces, to help persons discover which questions should or should not be asked where.

Taking into account all these factors could readily leave us with a fear of being over-whelmed. In the field of training, such a threat of being overwhelmed reached critical proportions in the late 1960's. By way of a solution, manuals and training materials were put on-line and made accessible as and when they were needed, under the slogan of "learning on demand." A cultural Baedeker as outlined above, would use technology to provide "cultural learning on demand." Some may object to the ideas of "just in time culture" as being uncivilized. However, if the alternative is being uncivilized pure and simple, then surely this is the preferable way, especially if it can save us from undue feelings of inadequacy when faced by many different cultures as we travel around the world. This is not to say that we should abandon our efforts to read the great literature in our culture and as many other cultures as possible. Rather, we need to discover that although the world may be shrinking in terms of physical access, its horizions continue to expand in keeping with our capacity.

10. Two, Three and Multiple Dimensions

The above analysis suggest that the question of appropriate cultural interfaces is considerably more complex than might at first be apparent. It depends largely on function. In the case of virtual guides in physical museums, for instance, two-dimensional lists will typically be appropriate. Such lists will also serve well in the case of research involving quick reference. In the case of virtual, historical virtual, and imaginary virtual museums and libraries, three-dimensional recontructions will usually be appropriate whether these are perspectival representations, or virtual reality versions complete with walkthroughs. In moving from an image of a painting on a wall to a record outlining the basic characteristics thereof, one will wish to move from a three-dimensional space back to a two-dimensional electronic equivalent of a file card, with an ability to return to the three-dimensional space as desired.

With respect to research involving maps, one will typically move from two-dimensional maps as in the case of satellite images, to three-dimensional scenes as one approaches images of the physical landscape. Conceptual research will frequently begin with two-dimensional lists of persons, subjects, or objects, some item of which is then shifted to a plane, thence to be treated in the third-dimension. Such analyses typically become four-dimensional when these planes are, in turn, subjected to temporal variations. Hence a cultural interface needs to move seamlessly into and out of a number of dimensions.

One of the important innovations of the Virgilio[131] project at the GMD (Darmstadt) has been the linking of object relational (Informix) databases, with Virtual Reality Modelling Language (VRML) such that three-dimensional answer spaces are generated on the fly on the basis of queries as they are made. In this approach it is assumed that metaphors such as halls and rooms are useful means of presenting positive results from queries. One could, however, imagine how the same technology could be used to generate different information lists in keeping with their complexity. If there were less than ten choices they could be generated simply in the form of a SUMS meter. If there were hundreds of choices they would be generated as a traditional list. If there were thousands of choices they would appear in the form of three-dimensional planes in order to obtain an overview before examining details. Hence, the choice of interface generated by the system would itself provide clues about the complexity of the results.

Historically, the advent of three-dimensional perspective did not lead artists to abandon entirely two-dimensional (re-)presentations. There were many cases such as cityscapes where three dimensions were very useful; others where two-dimensional solutions remained a viable and even preferable alternative. Text is an excellent example, which helps explain why text-based advertisements remain predominantly two-dimensional. If we are searching for a simple name (Who?), subject (What?), place (Where?), event (When?), process (How?) or explanation (Why?), two-dimensional lists are likely to remain the most effective means for searching and access. As suggested earlier, long lists benefit from alternative presentation modes such that they can be viewed alphabetically (Who?), hierarchically in tree form (What?), geographically (Where?), and chronologically (When?) if appropriate. A complex spatial interface may be technologically attractive. The challenge, however, lies in integration with historically relevant interfaces, in being able to encompass earlier structuration methods rather than merely replace them with unfamiliar ones.

11. Conclusions

This paper opened with a brief outline of taxonomies of information visualization user interfaces by data type (cf. Appendix 1) and a survey of emerging interface technologies, namely, voice activation, haptic force, mobile and nomadic, video activation, direct brain control, brain implants, and alternative methods. It was claimed that while such technological solutions in search of applications are of some interest, a more thorough understanding of interface problems requires an analysis of user needs. The main body of the paper addressed this challenge with respect to culture. An outline was given of five basic functions relating to cultural interfaces, namely, 1) virtual guides, 2) virtual museums, libraries and spatial navigation, 3) historical virtual museums, 4) imaginary museums and 5) various kinds of cultural research. The implications of these functions for cultural interfaces were explored.

This led to a brief consideration of metadata and consideration how these new developments are transforming our concepts of knowledge. Knowledge objects will include not only basic characteristics but also information about their quality and veridity. The Platonic idea destroyed individual differences and thereby the notion of uniqueness. The new concept of objects centres knowledge on the fundamental significance of differences. The universal becomes a key to particular expression. Knowledge lies not in how good a copy it is but rather in how well it has created a variation on the theme. This will transform the scope and horizons of knowledge.

The paper ended with an outline of further challenges such as problems of translating verbal claims into visual viewpoints, questions of scale and cultural filters. It will be a long time before all these challenges are overcome. Yet if we recognise them clearly, there is no need to be overwhelmed by them. We must continue the process of sense making and ordering the world, which began with our first libraries and schools and shall continue, we hope, forever. For in this lies our humanity. Technology may offer many solutions looking for an application. Nonetheless, cultural interfaces still pose many applications looking for solutions.

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Appendix 1. Taxonomy of Information Visualization User Interfaces by Data Type
Chris North, University of Maryland at College Park[132]

DataType	Title	Institution/Author	Links to pages, publications
Temporal (i.e. Timelines, histories)			
	LifeLines	HCIL-Maryland	Homepage
	LifeStreams	Yale	Homepage, Company
	MMVIS: Temporal		
	Dynamic Queries	U Michigan: Hibino	Thesis
	Perspective Wall	Xerox	CHI91, (Information Visualizer)
	VideoStreamer	MIT	Homepage
1 Dimensional (i.e. Linear data, text, lists)			
	Document Lens	Xerox	(see Info. Visualizer)
	Fractal Views	UEC-Japan: Koike	TOIS'95
	SeeSoft	Lucent / Bell Labs	HomePage, Brochure, IEEE Computer 4/96
	Tilebars	Xerox	CHI'95, (see Information Visualizer)
	WebBook	Xerox	(see Info. Visualizer)
2 Dimensional (i.e. Planar data, images, maps, layouts)			
	ArcView	ESRI	Homepage
	Fisheye/Distortion views		Resource Page
	GroupKit	Calgary	HomePage
	Information Mural	GVU-GeorgiaTech	Homepage
	Pad++	New Mexico	Homepage
	Powers of Ten		Homepage
3 Dimensional (i.e. Volumetric data, 3D images, solid models)			
	The Neighborhood Viewer	Minnesota	Homepage
	Visible Human Explorer (VHE)	HCIL-Maryland	Homepage
	Volvis	SUNY-SB	Homepage
	Voxelman	IMDM-Hamburg	Homepage
Multi-Dimensional (i.e. Many attributes, relational, statistical)			
	Filter-Flow	HCIL-Maryland	Paper
	Dynamic Queries, Query Previews (HomeFinder, FilmFinder, EOSDIS)	HCIL-Maryland	HomePage

Influence/Attribute Explorer	Imperial College	HomePage
LinkWinds	JPL-NASA	HomePage
Magic Lens	Xerox	Homepage
Parallel Coordinates		Thesis
Selective Dynamic Manipulation (SDM)	CMU	Homepage
Spotfire	IVEE Development	Homepage
Table Lens	Xerox	CHI94, (Info.Visualizer)
Visage	CMU	Homepage
VisDB	Munich	Homepage
Worlds Within Worlds	Feiner	UIST90
XGobi	AT&T Labs, Bellcore	Homepage

Hierarchical (i.e. Trees)

Cone/Cam-Trees	Xerox	CHI91,(Info. Visualizer)
Elastic Windows	HCIL-Maryland	Homepage Report
Fractal Views	UEC-Japan: Koike	VL'93
Hyperbolic Trees	Xerox	CHI95
Info Cube	Sony	Homepage
TreeBrowser (Dynamic Queries)	HCIL-Maryland	Abstract
TreeMap / WinSurfer	HCIL-Maryland	Viz91, Homepage, Winsurfer, Widget
WebSpace	U Minnesota	Homepage

Network (i.e. Graphs)

Butterfly Citation Browser	Xerox	CHI'95,(Info. Visualizer)
Fisheye		Paper
Galaxy of News	MIT	Description
Graphic History Browser	GVU-GaTech	HomePage
IGD (Interactive Graphical Documents)	Columbia: Feiner	Homepage
Intermedia	Brown	Homepage
Multi-Trees	Furnas	Homepage
Navigational View Builder	GVU-Gatech	HomePage, CHI'95
NETMAP	ALTA Analytics, Inc.	Homepage
RMM	Isakowitz	Homepage
SemNet	Bellcore	Paper
Themescape / SPIRE	PNL	Homepage, Abstract

WorkSpaces

CASCADE	Pittsburgh	Paper
Information Visualizer / 3D Rooms / Web Forager	Xerox	CG&A, DLib, Paper
Pad++	New Mexico	Homepage
Personal Role Managers	HCIL-Maryland	Homepage

Appendix 2. Key individuals in Human Computer Interface (HCI) and Visualization

Aalbersberg, IJsbrand Jan		SIRRA
Ahlberg, Christopher[133]	Chalmers University of Technology	Filmfinder
Arents, Hans Christiaan[134]	Katholieke Universiteit Leuven	Cube of Content
Bardon, Didier[135]	IBM, Austin	
Belew, Richard K.[136]	University of California, San Diego	
Benford, Steve [137]	Nottingham	VR-VIBE
Bier, Eric[138]	Xerox PARC	Magic Lenses[139]
Boyle, John[140]	University of Aberdeen	Amaze
Bryson, Steve[141]	NASA	Virtual Windtunnel
Bulterman, Dick[142]	Vrije Universiteit, Amsterdam	
Buxton, Bill[143]	Alias/Wavefront, Toronto	
Card, Stuart[144]	Xerox PARC	Web Forager
Catarci, Tiziana[145]	Rome, La Sapienza	
Chalmers, Matthew[146]	Ubilab, Zurich[147]	Bead-point cloud, Bead-landscape
Church, Ken[148]	AT&T	Dotplot
Citrin, Wayne[149]	University of Colorado, Boulder	
Colebourne, A.[150]	Lancaster University	
Crouch, Donald B.[151]		Component Scale Display
Cruz, Isabel	Tufts[152]	
Dieberger, Andreas[153]	Emory University	Vortex[154]
Dix, Alan[155]	Staffordshire University	
Eick, Stephen	AT&T	
Faieta, Baldo		Social Insect
Fairchild, Kim Michael[156]	Singapore National University	
Foley, James D.[157]	Georgia Inst. of Technology, Mitsubishi	User Interface Design Env.
Fox, Edward A.[158]	Virginia Tech	Envision
Fowler, Richard H.[159]	Panamerican University	Information Navigator
Garg, Ashim[160]	Brown University	
Glinert, Ephraim P.[161]	University of Washington	
Gray, Peter M.D.[162]	Aberdeen University	
Gray, Philip[163]	University of Glasgow	
Grudin, Jonathan[164]	University of California, Irvine	
Hearst, Marti[165]	Berkeley	Cougar, Tilebars
Helfman, Jonathan	AT&T	Dotplot
Hendley, Bob[166]	Birmingham University	
Hemmje, Matthias[167]	GMD, Darmstadt	Lyberworld
Hollan, James D.[168]	University of New Mexico	Pad++
Ingram, Rob[169]	Nottingham University	
Ioannidis, Yannis E[170]	University of Wisconsin	
Jacob, Rob[171]	Tufts	
John, Bonnie E.[172]	Carnegie Mellon	
Johnson, Brian[173]	University of Maryland, Synopsys	
Kimoto, Haruo	NTT[174]	
Keim, Daniel A.[175]	Munich now Halle	(VisDB)

Kling, Ulrich[176]	GMD Darmstadt	
Korfhage, Robert[177]	University of Pittsburgh	(BIRD)[178]
Krohn, Uwe	Wuppertal	VINETA
Kurlander, David[179]	Microsoft	
Lin, Xia[180]	University of Kentucky	Reading Room HyperLibrary
Lunzer, Aran[181]	Glasgow University	Reconaissance
Mariani, John	Lancaster University	TripleSpace[182], QPIT[183]
Mendelzon, Alberto[184]	University of Toronto	Hy+
Munzner, Tamara[185]	Stanford	
Myers, Brad[186]	Carnegie Mellon	
Navathe, Shamkant B.		Tkinq
Nuchprayoon[187]	Pittsburgh	GUIDO
Olsen, Dan R.[188]	Carnegie Mellon	VIBE
Peeters, E.	Philips	
Pejtersen, Annalise Mark	Centre for Human Machine Interaction[189]	Bookhouse[190]
Rao, Ramana	Xerox PARC, Inxight	
Rekimoto, Jun[191]	Sony	Information Cube
Rose, Daniel[192]	Apple	Piles, AIR, SCALIR
Salton, Gerard [193]	Cornell University	Text
Shieber, Stuart M.[194]	Harvard	
Shneiderman, Ben[195]	University of Maryland	
Snowdon, Dave[196]	Nottingham University	VR Vibe
Spoerri, Anselm[197]	AT&T	Info Crystal
Stasko, John	Georgia Tech[198]	
Strong, Gary[199]	NSF, Arlington	
Veerasamy, Aravindan[200]		Tkinq
Walker, Graham[201]	BT Labs	
Wickens, Chris[202]	University of Illinois, Urbana-Champaign	
Williamson, Chris[203]		Dynamic Home Finder[204]
Wittenburg, Kent	Bellcore	
Zhang, Jiajie[205]	Ohio State	DARE, TOFIR

Appendix 3. Major Projects in Information Visualisation
mostly additional to those discussed by Young (1996).

Europe
European Community Joint Research Centre, Ispra (JRC)
Institute for Systems, Informatics and Safety (ISIS)
Advanced Techniques for Information Analysis
Data Visualization Group[206] (DVG)

European Computer Industry Research Centre, Munich (ECRC)[207]
Combination of Bull, ICL and Siemens
Advanced Information Management Systems
Distributed Computing
User Interaction and Visualisation Group[208]

Canada
National Research Council, Ottawa[209]
Institute for Information Technology (IIT)
Al Hladny hladny@iit.nrc.ca
Tel. 613-993-3320
Human Computer Interaction
Integrated Reasoning
Interaction with Modelled Environments
Interactive Information
Seamless Personal Information
Visual Information Technology

Germany
Fraunhofer Gesellschaft
Institut für Graphische Datenverarbeitung,[210] Darmstadt (IGD)
Document Computing
Multimedia Electronic Documents (MEDoc)
Intelligent Online Services
Multimedia Extension (MME)
Mobile Information Visualization[211]
Active Multimedia Mail (Active M3)
Location Information Services (LOCI)
Visual Computing
Augmented Reality
Virtual Table
Abteilung Visualisierung und Virtuelle Realität, Munich
Gudrun Klinker[212]
Data Visualisation
Professional Television Weather Presentation (TriVis)

Gesellschaft für Mathematik und Datenverarbeitung (GMD)
(IPSI)

Co-operative Retrieval Interface
based on Natural Language Acts (CORINNA)[213]

Japan
Nara Institute of Science and Technology (NAIST)
Image Processing Lab[214]
- Image Recognition
- Image Sensing
- Information Archaeology
  - Restoration of Relics using VR

Sony Computer Science Laboratory, Tokyo
- Jan Rekimoto[215]
- Katashi Nagao and Jun Rekimoto, Agent Augmented Reality: A Software Agent Meets the Real World[216]
- Trans-Vision Collaboration Augmented Reality Testbed[217]
- Augmented Interaction
  - Navicam
  - Computer Augmented Bookshelf[218]
- Virtual Society Information Booth[219]

University of Electro-Communications, Chofu, Tokyo
School of Information Systems
- Information Visualization Lab[220]
- Hideki Koike
  - Bottom Up Project Visualization
  - Enhanced Desk
  - Fractal Views[221]
  - Fractal Approaches to Visualizing Hugh Hierarchies[222]
  - Vogue

University of Tokyo
- Department of Information and Communication Engineering
  - Harashima and Kaneko Laboratory[223]
  - Professor Hiroshi Harashima and Masahide Kanedo
  - Takeshi Naemura Grad. Student
    - Cyber Mirage Virtual Mall with Photo-realistic Product Display
    - Integrated 3-D Picture Communication (3DTV)
    - Interactive Kansei, Face Impression Analysis
    - Intelligent Hyper Media Processing
    - Multi-Modal Advanced Human-Like Agent
    - Information Filter
- Department of Mechano-Informatics
- Hirose Lab[224]
  - Professor Michitaka Hirose

Haptic Display
Image Based Rendering
Immersive Multiscreen Display

Portugal
University of Lisbon
Virtual Reality Lab[225]
- Scientific Visualization
- Sensory Ecosystems
- Spatial Information Systems

United Kingdom
Cambridge University[226]
Rainbow Graphics Group[227]
- Active Badges
- Animated Paper Objects
- Autostereoscopic Display
- Mobile Computing
- Multiresolution Terrain Modeling
- Net White Board
- Video User Interfaces

Loughborough University
Telecommunications and Computer Human Interaction Research Centre (LUTCHI)[228]
- Advanced Decision Environment for Process Tools (ADEPT)
- Agent Based Systems
- Development of a European Service for Information on Research and Education (DESIRE)
- Digital Audio Broadcasting and GSM (DAB)
- Focussed Investigation of Document Delivery Option (FIDDO)
- Intelligent User Interfaces
- Multi-Layered Knowledge Based Interfaces for Professional Users (MULTIK)
- Multimedia Environment for Mobiles (MEMO)
- Resource Organisation and Discovery in Subject Based Services (ROADS)

Manchester Computing Centre[229]
- Infocities
- G-MING Applications
- Janus Visualisation Gateway Project
- Knowledge Based Interface for National Data Sets (KINDS)
- Parallel MLn Project
- Super Journal with Joint Information Systems Committee (JISC)
- Manchester Visualization Centre[230]

University of Huddersfield
- HCI Research Centre[231]

Xerox Europe, Cambridge

Context Based Information Systems (CBIS)[232]

United States

Georgia Institute of Technology (Georgia Tech)

Graphics Visualization and Usability Center[233]

Virtual Environments

Information Mural[234]

School of Civil and Environmental Engineering

Interactive Visualizer Project[235] (IV)

Scientific Visualization Lab[236]

Information Visualization

Quiang Alex Zhao[237]

IBM

Visualization Space: Natural Interface[238]

Marc Lucente[239]

Visualization Data Explorer[240]

L3 Interactive Inc., Santa Monica

Net Cubes[241]

Lucent Technologies

Visual Insights[242]

Stephen K. Eick eick@research.bell-labs.com

Live Web Stationery[243]

Massachussets Institute of Technology (MIT)

Visible Language Workshop[244]

Founded by Muriel Cooper[245]

Student: David Small[246]

NASA, Ames

Scientific Visualization[247]

MITRE[248]

Collaborative Virtual Workspace

Data Mining

Information Warfare

Nahum Gershon

Orbit Interaction[249]

Palo Alto

Jim Leftwich

Infospace: A Conceptual Method for Interacting with Information in a 3-D Virtual Environment

Pacific Northwest National Laboratory,[250] Richland, Washington
- Auditory Display of Information
- Automated Metadata Support for Heterogeneous Information Systems
  - James C. Brown
- Spatial Paradigm for Information Retrieval and Explanation (SPIRE)
  - cf. Themescape[251]
  - (Irene) Renie McVeety
- Starlight
  - Text Data Visualisation Techniques
  - John Risch

Rutgers University
- Center for Computer Aids for Industrial Productivity[252] (CAIP)
- Grigore Burdea, Director
- Multimedia Information System Laboratory
  - Adaptive Voice
  - Multimodal User Interaction

Sandia National Laboratories, Albuquerque, New Mexico; Livermore, California
- Enterprise Engineering Viewing Environment[253] (EVE)
- Laser Engineered Net Shaping (LENS)
- Synthetic Environement Lab[254] (SEL)
  - Data Analysis
  - Data Fusion
  - Manufacturing
  - Medical
  - Modelling
  - Simulation
- Advanced Data Visualization and Exploration
  - EIGEN-VR

Silicon Graphics Incorporated, Mountain View (SGI)
- File System Navigator[255] (FSN)
- Visual and Analytical Data Mining[256]
  - Ronny Kohavi

University of Illinois, Chicago (UIC)
- Electronic Visualization Laboratory[257] (EVL)
- + Interactive Computing Environements Lab (ICEL)=NICE
- 4D Math
- Cave Applications[258]
  - Caterpillar: Distributed Virtual Reality[259]
- CAVE to CAVE communications
- Information Visualization, Pablo Project[260]
- Biomedical Visualization[261]

University of Illinois, Urbana Champaign (UIUC)
National Center for Supercomputing Applications (NCSA)

- Digital Information System Overview[262]
- Electronic Visualization Lab
- CAVE Applications [263]
    - Distributed Virtual Reality[264]
- Visualization and Virtual Environments[265]
    - Information Technology[266]
- Virtual Environments Group[267] (VEG)
    - Cave Automatic Virtual Environments (CAVE)
    - Infinity Wall (I-Wall)
    - ImmersaDesk (I-Desk)
    - Renaissance Experimental Lab (REL)
- Virtual and Interactive Computing Environments[268] (VICE)
- Beckman Institute Visualization Facility[269]
    - Virtual Reality Lab
    - World Wide Laboratory
        - Laser Scanning Cofocal Microscopes (LSCM)
        - Magnetic Resonance Imaging (MRI)
            - Chickscope[270]
        - Scanning Tunneling Microscope (STM)
        - Transmission Electron Microscope (TEM)

University of Pittsburgh
Department of Information Science and Telecommunications, Pittsburgh

- Michael Spring
- Multilevel Navigation of a Document Space[271]
    - Docuverse
    - Landmarks
        - Mural
        - Tilebar
    - Webview

University of Texas-Pan American[272]

- Document Explorer
- Information Navigator
- Semantic Space View

Xerox Parc

- Cone Tree
- Document Lens
- Information Visualiser
- Perspective Wall
- Table Lens[273]

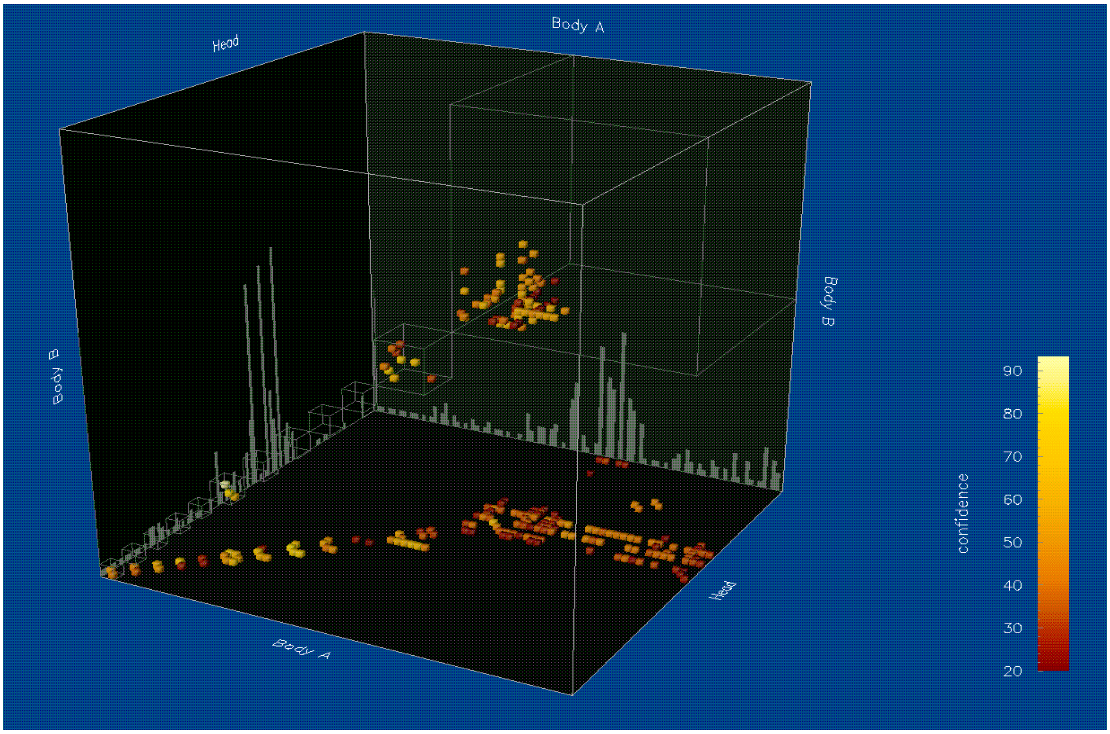

Figure 13. Illustration relating to IBM's (Almaden Laboratories) 3-D Visualization of Three Item Rules.[274]

Notes

[1] See Michael Kesterton, "Social Studies," *Globe and Mail*, Toronto, 19 February 1998, p. A26.

[2] See the author's "Frontiers in Conceptual Navigation," *Knowledge Organization*, Würzburg, vol. 24, 1998, n. 4, pp. 225-245. For another approach to these issues see Don Foresta, Alain Mergier, Bernhard Serexhe, *The New Space in Communication, the Interface with Culture and Artistic Creativity*, Council of Europe: Strasbourg, 1995

[3] Ben Shneiderman, *Designing the User Interface. Strategies for Effective Human Computer Interaction*, Reading Ma.: Addison Wesley, 1997 (first edition 1987) 3rd ed. 1997. For a standard introduction to some of the more philosophical questions attending interface design see the three books by Edward Tufte, *Visual Display of Quantitative Information*, Cheshire: Graphics Press, 1982; *Envisioning Information*, Cheshire: Graphics Press, 1990 and *Visual Explanations*, Cheshire: Graphics Press, 1997.

[4] Steven Johnson, *Interface Culture: How New Technology Transforms the Way We Create and Communicate*, San Francisco: Harper, 1998. A book by Richard Saul Wurman, *Information Architects*, New York: Graphis Inc., 1997 provides a stimulating survey of some popular techniques but offers little insight into developments at the research level.

[5] E.g. IEEE, Technical Committee on Computer Graphics (TCCG), which publishes

Transactions on Visualisation and Computer Graphics (TVCG).
See: http://www.cs.sunysb.edu/~tvcg/.

[6] Annual or Bi-Annual Conferences

Association for Computing Machinery	(ACM)
Computer Human Interface	(CHI)
	(INTERCHI)

Visualization 1998
Research Triangle Park, 18-23 October 1998
Includes IEEE Information Visualization 19-20 October 1998

EC ESPRIT Programme
Foundations of Visualisation and Multi-Modal Interfaces

1) Comprehensive Human Animation Resource Model	(CHARM)
2) Foundations of Advanced Three Dimensional Information Visualisation	(FADIVA)
3) Framework for Immersive Virtual Environments	(FIVE)
4) Reconstruction of Reconstruction of Reality for Image Sequences	(REALISE)

Visual Information Retrieval Interfaces	(VIRI)[6]
Workshop on Advanced Visual Interfaces	(AVI)

Aquila 24-27 May	1998
Gubbio	1996
Bari	1994
Roma	1992

See: http://informatik.uni-trier.de/~ley/db/conf/avi/index.html

Foundations of Advanced Three Dimensional Information Visualization Applications (FADIVA)

Glasgow	1996

Graph Drawing
See: http://gd98.cs.mcgill.ca

Montreal	1998
Rome	1997
Berkeley	1996
Passau	1995
Princeton	1994
Paris	1993

Other Significant Past Conferences in the Field:

1993
IEEE Symposium on Visual Languages

1994
InfoVis Symposium on User Interface and Technology

Related to the field of information visualization is the emerging field of diagrammatic reasoning:

See: http://www.hcrc.ed.ac.uk/gal/Diagrams/research.html

[7] See: http://www.geog.ucl.ac.uk/casa/martin/atlas/atlas.html

[8] Durham University, *Computer Science Technical Report 12/96*.

See: http://www.dur.ac.uk/~dcs3py/pages/work/Documents/lit-survey/IV-Survey/index.html

[9] See: http://rvprl.cs.uml.edu/shootout/viz/vizsem/3dinfoviz.htm

[10] See: http://www-graphics.stanford.edu/courses/cs348c-96-fall/infovis1/slides/walk005.html

[11] See: http://www-graphics.stanford.edu/courses/cs348c-96-fall/scivis/slides/

Mark Levoy provides a summary of two taxonomies based on visual metaphors. The first is by Jacques Bertin, *Sémiologie graphique: les diagrammes, les réseaux, les cartes*, avec la collaboration de Marc Barbut [et al.], Paris, Mouton, [1973, c1967]. Jacques Bertin, *Semiology of graphics*, translated by William J. Berg, Madison, Wis. : University of Wisconsin Press, 1983. This system is based on:

Imposition

- Diagrams	x	-Arrangement
- Networks		-Rectilinear
- Maps		-Circular
- Symbols		-Orthogonal
		- Polar

Retinal Variables

- Size	x	- Association
- Value		- Selection
-Texture		- Order
- Colour		- Quantity
- Orientation		
- Shape		

The second taxonomy is from Peter R. Keller and Mary M. Keller, *Visual cues : practical data visualization*, Los Alamitos, CA : IEEE Computer Society Press ; Piscataway, NJ : IEEE Press, c1993. This system is based on:

Actions	x	**Data**
Identify		Scalar
Locate		Nominal
Distinguish		Direction
Categorise		Shape
Cluster		Position
Rank		Region

Compare Structure
Associate
Correlate

Mark Levoy also distinguishes four taxonomies by data type:
- number of independent variables (domain)
- number of independent variables (range)
- discrete vs. continuous domain
- binary vs. multivalued vs. continuous range.

His additonal bibliography includes:

1977 John Wilder Tukey, *Exploratory data analysis*, Reading, Mass. : Addison-Wesley Pub. Co.

1992 Harry Robin, *The scientific image : from cave to computer*, historical foreword by Daniel J. Kevles, New York : H.N. Abrams.

1995 *Computer visualization : graphics techniques for scientific and engineering analysis*, edited by Richard S. Gallagher, Boca Raton : CRC Press.

A standard introduction to problems of visualisation is offered by the work of Edward Tufte,

[12] See: http://isx.com/~hci
http://web.cs.bgsu.edu/hcivil
http://www.logikos.com/sef.htm
Protocols
Interface Definition Language (IDL)
See: http://www.cs.umbc.edu/~thurston/corbidl.htm
Dynamic Invocation Interface (DII)
Enhanced Man Machine for Videotex and Multimedia (VEMMI)
See: http://www.mctel.fr

[13] There is of course an HCI virtual library
See: http://usableweb.com/hcivl/hciindex.html
Hans de Graaf,[13] (Technical University, Delft) has a valuable index
See: http://is.twi.tudelft.nl/hci
Isabel Cruz has made a useful collection of reports on Human Computer Interaction at
See: http://www.cs.brown.edu/people/ifc/hci/finalind.html.
See also: Human Computer Interface Virtual Library (HCI)
See: http://web.cs.bgsu.edu/hcivl/misc.html
http://www.nolan.com/~pnolan/resource/info.html
http://is.twi.tudelft.nl/hci/sources.html
Banxia Decision Explorer
See: http://www.banxia.co.uk/banxia
Document Visualization
See: http://www.psysch.uiuc.edu/docs/psych290/vincow_feb03.html
Information Visualisation Resources

See: http://www.cs.man.ac.uk/~ngg/infovis_people.html
Cf. http://graphics.stanford.edu/courses/cs348c-96fall/resources.html
Input Technologies
See: http://www.dgp.toronto.edu/people/BillBuxton/InputSources.html
Three D imensional (3-D) User Interface Kit
See: http://www.cs.brown.edu/research/graphics/research/3d_toolkit/3d_toolkit.html
Visual Information Architecture (VIA)
See: http://design-paradigms.www.media.mit.edu/projects/design-paradigms/improver-paradigms/via.html
Visualisation and Intelligent Interfaces Group
See: http://almond.srv.cs.cmu/edu/afs/cs/project/sage/mosaic/samples/sage/3d.html
Patrick J. Lynch, Annotated Bibliography of Graphical Design for the User Interface
See: http://www.uky.edu/~xlin/VIRIreadings.html
Visual Design for the User Interface
See: http://info.med.yale.edu/caim/publications/papers/guip1.html

[14] Network Centric User Interfaces (NUI)
Tom R. Halfhill, "Good-Bye, GUI, Hello NUI," *Byte*, Lexington, vol. 22, no. 7, July 1997, pp. 60-72.
See: thalfhill@bix.com
Apple
See: http://www.apple.com/
Mac OS 8
Rhapsody
IBM
See: http://www.internet.ibm.com/computers/networkstation/
Network Station
OS2/Warp 4
Bluebird
Lotus
See: http://kona.lotus.com
Kona Desktop
Microsoft
See: http://www.microsoft.com/backoffice/sbc_summary.htm#top
Memphis/Active Desktop
Netscape
See: http://www.netscape.com/comprod/tech_preview/idex.html
Netscape
Oracle/NCI
See: http://www.nc.com
NC Desktop
Santa Cruz Operation
See: http://tarantella.sco.com/
Tarantella Web Top
Sun/Java Soft
See: http://www.javasoft.com
Hot Java Views

TriTeal

See: http://www.softnc.triteal.com/

SoftNC

Ulysses Telemedia

See: http://www.ulysses.net/

VCOS

cf. http://www.softlab.ece.ntua.gr/~brensham/Hci/hci.htm

[15] Massachussets Institute of Technology, (1995), *Media Laboratory. Projects. February 1995*, Cambridge, Mass.: MIT, 6.

[16] A more interesting application is in the context of Collaborative Integrated Communications for Construction (CICC) available electronically

See: http://www.hhdc.bicc.com/people/dleevers/papers/cycleof.htm, which envisages a cycle of cognition in which the landscape is but one of six elements, namely, map, landscape, room, table, theatre, home. The author of this system David Leevers works with Heiner Benking through ASIS.

See: http://www.hhdc.bicc.com/people/dleevers/default.htm

For an excellent summary of some of the major systems presently available see Peter Young (1997), Three Dimensional Information Visualisation available electronically.

See: http://rvprl.cs.uml.edu/shootout/viz/vizsem/3dinfoviz.htm.

[17] See: Rao, Ramana, Pedersen, Jan O., Hearst, Marti A., Mackinlay, Jock D., Card, Stuart K., Masinter, Larry, Halvorsen, Per-Kristian, Robertson, George C., (1995), Rich Interaction in the Digital Library, *Communications of the ACM*, New York, April, *38 (4)*, 29-39. Card, Stuart (1996), Visualizing Retrieved Information, *IEEE Computer Graphics and Applications*.

[18] Kling, Ulrich (1994), "Neue Werkzeuge zur Erstellung und Präsentation von Lern und Unterrichtsmaterialien [New Tools for the Production and Presentation of Learning and Instructional Materials]," *Learntec 93. Europäischer Kongress für Bildungstechnologie und betriebliche Bildung*, ed. Beck, Uwe, Sommer, Winfried, Berlin: Springer Verlag, 335-360.

See: http://www-cui.darmstadt.gmd.de/visit/Activities/Lyberworld.

The GMD also organizes research on Foundations of Advanced Three Dimensional Information Visualization Applications (FADIVA) and Visual Information Retrieval Interfaces (VIRI).

See: http://www-cui.darmstadt.gmd.de/visit/Activities/Viri/visual.html.

[19] Ibid., 336-340. Cf. Streitz, N., Hannemann, J., Lemke, J. et al., (1992), SEPIA: A Cooperative Hypermedia Authoring Environment, *Proceedings of the ACM Conference on Hypertext, ECHT '92*, Milan, 11-22.

[20] See: http://viu.eng.rpi.edu/IBMS.html

[21] See: http://multimedia.pnl.gov:2080/showcase/

[22] See: http://multimedia.pnl.gov/2080/showcase/pachelbel.cgi?it_content/spire.node

[23] See: http://www.pnl.gov/news/1995/news95-07.htm

[24] See: http://www.cs.cmu.edu/Groups/sage/sage.html

[25] See: http://www.maya.com/visage

[26] See: http://www.cs.cmu.edu/Groups/sage/sage.html

[27] See: http://www.cs.sandia.gov/SEL/main.html

[28] See: http://www.cs.sandia.gov/VIS/science.html

[29] See: http://www.sandia.gov/eve/eve_toc.html

[30] He also refers to stylus devices: see digitizing tablets, lightpens, boards, desks and pads, touch screens and force feedback ("haptic") devices).

[31] See: http://www.dgp.toronto.edu/people/BillBuxton/InputSources.html. A less comprehensive list is provided by Rita Schlosser and Steve Kelly

See: http://ils.unc.edu/alternative/alternative.html who include glove data-input devices (VPL Data Glove, Exos Dextrous Hand Master, Mattel PowerGlove, Other Types of Gloves) and eye-computer interaction and access issues. It should be noted that Alias/Wavefront is working on new three-dimensional input devices.

[32] See: http://207.82.250.251/cgi-binstart

[33] See: http://www.dragonsys.com/home.html

cf. http://www.gmsltd.com/voiceov.htm

[34] See Geoffrey Rowan, "Computers that recognize your smile", *Globe and Mail*, Toronto, 24 November 1997, p. B3

[35] See: http://delite.darmstadt.gmd.de/delite/Projects/Corinna

[36] This includes Bolt, Beranek and Newman (BBN), Carnegie Mellon University (CMU), the Massachusetts Institute of Technology (MIT) and the former Stanford Research Institute (SRI).

[37] See: http://multimedia.pnl.gov:2080/showcase/

[38] See: http://multimedia.pnl.gov:2080/showcase/pachelbel.cgi?it_content/auditory_display.node

[39] See: http://www.al.wpafb.af.mil/cfb/biocomm.htm.

[40] See: http://www.sarcos.com/Jacobsen.html

[41] See: http://www.hitl.washington.edu/scivw/EVE/I.C.ForceTactile.html

[42] See Grigore Burdea, *Virtual Reality and Force Feedback*, New York: John Wiley & Sons, 1996. Cf. Grigore Burdea, Philippe Coiffet, *Virtual Reality Technology*, New York: John Wiley & Sons, 1994.

[43] This includes data input devices.

[44] These include IBM, Apple, Netscape, Oracle, Sun, Nokia, Hitachi, Fujitsu, Mitsubishi and Toshiba. Cf. ICO Global Communications at http://www.ico.com

[45] See: http://www.igd.ghg.de/www/zgdv-mmvis/miv-projects_e.html#basic

[46] See: http://www.ubiq.com/hypertext/weiser/IbiHome.html

[47] Adaptive and User Modelling

Adaptive and Intelligent Systems Applications

See: http://www.kareltek.fi/opp/projects/index.html

Adaptive Behavior Journal

Adaptive Environments

See: http://www.adapt.env.org

Adaptive Networks Laboratory (ANW)

See: http://www-anw.cs.umass.edu

Andrew G. Barto, Richard S. Sutton, Reinforcement Learning

User Modeling Conference Chia Laguna

See: http://www.crs4.it/UM97/topics.index.html

Knowledge Systems Laboratory Stanford

Adaptive Intelligent Systems

See: http://www-ksl.stanford.edu/projects/BBI

[48] See: http://www.lk.cs.ucla.edu
[49] See: http://www.virtualvision.com
[50] See, for example, the work of Gregg Vanderheiden, Trace Center, Madison, Wisconsin.
See: http://trace.wisc.edu
[51] Rita Schlosser and Steve Kelly at http://ils.unc.edu/alternative/alternative.html have made a list which includes: Gaze Tracking, Human-Computer Interaction and the Visually Impaired, Modelling and Mark Up Languages in Visual Aid.
[52] Internationale Stiftung Neurobionik, Nordstadt Krankenhaus, Hannover. The director of the project is Professor Dr. Madjid Samii.
[53] Fraunhofer Institut für Biomedizinische Technik (IBMT), D-66386, St. Ingbert
[54] Universität Tübingen, Reutlingen, Naturwisschaftlich-Medizinisches Institut (NMI)
[55] See: http://www3.osk.3web.ne.jp/~technosj/mctosE.htm
Cf. Michael Kesterton, "All in the mind?", *Globe and Mail*, Toronto, A14, 6 January 1998.
[56] See: Frank Beacham, "Mental telepathy makes headway in cyberspace," *Now*, Toronto, 13-19 July 1997, pp. 20-21.
[57] See: http://www.sciam.com/1096issue/1096lusted.html
[58] See: http://www.af.mil/news/airman/0296/look.htm. Other members of his team are Chris Gowan and David Pole. The section is headed by Dr. Don Monk. There appears to be related work at the Crew Systems Ergonomics Information Analysis Center (CSERIAC)
See: http://cseriac.udri.udayton.edu.
[59] See: http://www.harpercollins.co.uk/voyager/features/004/fut4.htm
[60] See: http://www.premier-research.com/6chris_gallen.htm
[61] I.e. Consiglio Nazionale delle Ricerche.
[62] See: http://zeus.gmd.de/projects/hips.htm
[63] See: http://www.mic.atr.co.jp/~rieko/MetaMuseum.html
[64] See: http://gn.www.media.mit.edu/groups/gn/projects/vlaptop/index.html
[65] See: http://www.cs.columbia.edu/~feiner
[66] Related projects at Columbia University include Augmented Reality for Construction (ARC), Columbia Object-Oriented Testbed for Exploring Research in Interactive Environments (COTERIE), Knowledge Based Virtual Presentation Systems (IMPROVISE), Knowledge Based Augmented Reality for Maintenance Assistance (KARMA)
See: http://www.cs/columbia.edu/graphics/projects/karma/karma.html and Windows on the World (formerly called Worlds within Worlds).
[67] See: http://www.cs.columbia.edu/graphics/projects/archAnatomy/architecturalAnatomy.html
[68] See: http://www.cc.columbia.edu/cu/gsapp/BT/RESEARCH/LOW/Models.html
[69] See: http://www.igd.fhg.de/www/igd-a4/index.html. The Institute's division on visualisation and virtual reality and (Abteilung Visualisierung und Virtuelle Realität) works directly with the European Computer Research Centre (ECRC, Munich). Cf. the Data Visualization work of Gudrun Klinker
See: http://www.ecrc.de/staff/gudrun.
[70] See: http://www.csl.sony.co.jp/person/rekimoto/navi.html

[71] See also Katashi Nagao and Jun Rekimoto, "Agent Augmented Reality: A Software Agent Meets the Real World"
See: http://www.csl.sony.co.jp/person/nagao/icmas96/outline.html;
Trans-Vision Collaboration Augmented Reality Testbed
See: http://www.csl.sony.co.jp/person/rekimoto/transvision.html
Virtual Society Information Booth
See: http://www.csl.sony.co.jp/project/VS/index.html and
Homepage of Jun Rekimoto
See: http://www.csl.sony.co.jp/projects/ar/ref.html

[72] Named after a type of old-fashioned Japanese drama.

[73] See: http://dynamicdiagrams.com/siteviews.htm

[74] See: http://www.almaden.ibm.com/vis/vis.lab.html

[75] The Uffizi already has available more complex versions of 30-40 MB per room. Indeed, the Uffizi is scanning in their entire collection of 1300 paintings at approximately 1.4 gigabytes per square meter. Assuming that the average painting is slightly larger than a square meter this means that their collection will require 2.6 terabytes. The National Gallery in Washington is scanning images at a much lower resolution of c.30 MB per painting, but with a much larger collection of 105,000 images this will still result in some 3.15 terabytes. While it is frequently assumed that only experts will want images at such high resolutions, today's desktop PCs are not yet equipped to deal with millions of paintings on-line.

[76] *IMAX is exploring the possibility of delivering their images on-line*. This will require approximately 80 GB/second, which seems astronomical at the moment but in light of recent demonstrations at the terabyte level is rapidly becoming feasible.

[77] Using GOTO technology.

[78] Once again there are problems of terminology. While *virtual museum* typically means an electronic reconstruction of the physical building, *virtual library* often means a bibliography on given subjects while *digital library* is frequently used for electronic versions of contents of books.

[79] As Michael Ester (formerly Getty Art History Information Program, now Getty Information Institute) has shown, books involve reflected light and allow the eye to see up to about 3,500 lines per inch. Computer screens, which shoot light directly into the eye, activate a different combination of rods and cones and only allow one to see about 2,000 lines per inch. This helps explain why proof-reading is so much more difficult on screen than it is on paper.

[80] Sir Ernst H. Gombrich, "The Mirror and the Map, Theories of Pictorial Representation" in *Philosophical Transactions of the Royal Society of London*, London, vol. 270, no. 903, 1975, pp. 119-149.

[81] *Archeologia, percorsi virtuali nelle civilta scomparse*, Milan: Mondadori Editore, 1996. This book has since been translated into French and English.

[82] See: http://viswiz.gmd.de/VMSD/PAGES.en/index.html. Working in conjunction with Stanford University, the GMD has also been working on a Responsive Workbench, which effectively transforms a traditional workbench surface into the equivalent of a monitor or computer screen showing images in virtual reality which can be viewed with the aid of stereoscopic glasses and manipulated interactively at a distance. Applications

of such a workbench include TeleTeaching and Virtual Meeting This bears comparison with the Virtual Workbench:

See: http://beast.cbmv.jhu.edu:8000/projects/workbench/workbench.shtml

and Brainbench

See: http://beast.cbmv.jhu.edu:8000/projects/brainbench/brainbench.shtml

being developed in the Virtual Environments Program at the Australian National University (Canberra) and the Virtual Table being produced by the Fraunhofer Gesellschaft (Darmstadt).

[83] This is being developed in the context of the GMD's VISIT project. Other projects of the GMD include the Digital Media Lab's (DML) Fluid Dynamics Visualisation in 3D (FluVis).

[84] See: http://sgwww.epfl.ch/BERGER.

[85] See: http://mediamatic.nl/Magazine/8*2Lovinck-Legrady.html.

[86] See: http://www.cdromshop.com/cdshop/desc/p.735163027518.html.

[87] See: http://shea1.mit.edu.

[88] The key figures in this Research and Development Group are Prof. Manfred Eisenbeis, Annette Huennekens and Eric Kluitenberg. See: vm@khm.de

[89] I am grateful to my colleague Professore Ivan Grossi for this information.

See: http://mosaic.cineca.it

[90] See: http://hydra.perseus.tufts.edu

[91] See: http://www.gfai.de/projekte/index.htm

[92] Since the term *virtual* is used in so many ways, the French have tended to adopt Malraux's phrase and refer to all virtual museums as *imaginary museums*.

[93] Among those active in the realm of metadata are the following:

International Council of Scientific Unions,

- Committee on Data for Science and Technology

  See: http://www.cisti.nrc.ca/programs/codata/

- United Nations Environment Programme (UNEP)

  Towards the design for a Meta-Database for the Harmonization of Environmental Measurement," *Report of the Expert Group Meeting, July 26-27, 1990*, Nairobi: UNEP, 1991, (GEMS Report Series no. 8).

  Harmonization of Environmental Measurement Information System (HEMIS)

  Cf. Heiner Benking, Ulrich Kampffmeyer, "Access and Assimilation: Pivotal Environmental Information Challenges, *GeoJournal*, Dordrecht, 26.3/1992, pp.323-334.

- American Institute of Physics

  cf. Heiner Benking and Ulrich Kampffmeyer, "Harmonization of Environmental Meta-Information with a Thesaurus Based Multi-Lingual and Multi-Medial Information System," *Earth and Space Science Information Systems*, ed. Arthur Zygielbaum, New York: American Institute of Physics, 1992, pp. 688-695. (AIP Conference Proceedings 283).

- Environmental Protection Agency (EPA) Scientific Metadata Standards Project

  See: http://www.lbl.gov/~olken/epa.html#Related.WWW

  Re: Metadata registries

  See: http://www.lbl.gov/~olken/EPA/Workshop/recreadings.html

  For an attempt at a metadata taxonomy

See: http://www.lbl.gov/~olken/EPA/Workshop/taxonomy.html

[94] A detailed survey of this important field will be the subject of a separate paper for the opening keynote of *Euphorie Digital? Aspekte der Wissensvermittlung in Kunst, Kultur und Technologie*, Heinz Nixdorf Museums Forum, Paderborn, September 1998.

[95] Hypertext Markup Language (HTML), as an interim solution, marked a departure from this method in that it conflated content with presentation.

[96] Voice activation may be attractive at times but will frequently be impractical. Imagine the reading room of a library where everyone is speaking, or even a museum where everyone is speaking to their computers.

[97] The Getty Research Institute's Union List of Artists Names (ULAN) would be another example, although with only 100,000 names as opposed to the 328,000 of the AKL, the term "union" promises more than it delivers.

[98] See, for instance, the methods being developed by Lucent in their Live Web Stationery.

See: http://medusa.multimedia.bell-labs.com/LWS/.

[99] Libraries are relatively simple structures. In the case of more complex systems such as the London Underground it is useful to move progressively from a two-dimensional schematic simplification of the routes to a realistic three-dimensional rendering of the complete system, station by station. In the context of telecommunications the so-called physical world becomes one of seven layers in the model of the International Standards Organisation (ISO). In such cases it is useful not only to treat each of the seven layers separately but also introduce visual layers to distinguish the granularity of diffferent views. In looking at the physical network, for example, we might begin with a global view showing only the main nodes for ATM switches. (Preliminary models for visualising the MBone already exist (Munzner, Tamara, Hoffman, Eric, Claffy, K., Fenner, Bill, (1996), Visualizing the Global Topology of the MBone, *Proceeding of the 1996 IEEE Symposium on Information Visualization, San Francisco, October 28-29*, 85-92 available electronically

See: http://www-graphics.stanford.edu/papers/bone). A next layer might show lesser switches and so on such that we can move up and down a hierarchy of detail, sometimes zooming in to see the configuration of an individual PC, at other times looking only at the major station points. This is actually only an extension of the spectrum linking Area Management/ Facilities Management (AM/FM) with Geographical Information Systems (GIS) mentioned earlier.

[100] These combinations were and remain successful because they were guided by culture and taste. Combinations per se do not guarantee interesting results. If taste and sensibility are lacking the results are merely hybrid versions of kitsch. So the technology must not be seen as an answer in itself. It offers a magnificent tool, which needs to be used in combination with awareness of the uniqueness and value of local traditions.

[101] An exception is a university textbook, *Atlas of Western Art History*, ed. John Steer, Anthony White, New York: Parchment Books, 1994, pp. 54-55.

[102] This problem is somewhat more complex than it at first appears. Many of the great temples are in ruins. There are conflicting interpretations about their exact dimensions and appearances. Hence in this case interpretations about various ruins is more closely linked to our "knowledge" thereof than in the case of historical buildings which are still intact.

[103] For a serious discussion of how the advent of printing changed the criteria for knowledge see: Michael Giesecke, *Der Buchdruck in der frühen Neuzeit. Eine historische Fallstudie über die Durchsetzung neuer Informations- und Kommunikationstechnologien*, (Frankfurt am Main: Suhrkamp, 1991).

[104] J. Perrault, "Categories and Relators", *International Classification*, Frankfurt, vol. 21, no. 4, 1994, pp. 189-198, especially p. 195. The original list by Professor Nancy Williamson (Faculty of Information Studies, University of Toronto) lists these in a different order under the heading:

Types of Associative Relationships

1. Whole-part
2. Field of study and object(s) studied
3. Process and agent or instrument of the process
4. Occupation and person in that occupation
5. Action and product of action
6. Action and its patient
7. Concepts and their properties
8. Concepts related to their origins
9. Concepts linked by causal dependence
10. A thing or action and its counter-agent
11. An action and a property associated with it
12. A concept and its opposite.

[105] Anthony J. N. Judge, "Envisaging the Art of Navigating conceptual Complexity," *International Classification*, Frankfurt, vol. 22, n. 1, 1995, pp. 2-9. The same author was responsible for one of the very early publications on this theme, “Knowledge Representation in a Computer Supported Environment,” *International Classification*, Frankfurt, vol. 4, no. 2, 1977, pp. 76-80. The pioneering work of Anthony Judge in the context of the Union Internationale des Associations is also available on-line:

See: http://www.uia.org

This includes:

Coherent Organization of a Navigable Problem-Solution-Learning Space
See: http://www.uia.org/uiadocs/ithree2.htm

Metaphors as Transdisciplinary Vehicles for the Future
See: http://www.uia.org/uiadocs/transveh.htm

Sacralization of Hyperlink Geometry
See: http://www.uia.org/uiadocs/hypgeos.htm

Representation, Comprehension and Communication of Sets: The Role of Number
See: http://www.uia.org/knowledg/numb0.htm

The Future of Comprehension
See: http://www.org/uiadocs/compbasc.htm

Dimensions of Comprehension Diversity
See: http://www.uia.org/uiadocs/compapl.htm

Using Virtual Reality for Visualization
See: http://www.uia.org/uiademo/vrml/vrmldemo.htm

The Territory Construed as a Map
See: http://www.uia.org/uiadocs/termap.htm

[106] Pioneering in this field has been Eugen Wüster, *Internationale Sprachnormierung in der Technik*, Bouvier: Bonn, 1966. He distinguishes between generic (logical), partitive (ontological), complementary (oppositions) and functional (syntactic) relations. For other studies see Wolfgang Dahlberg, *Wissenstrukturen und Ordnungsmuster*, Frankfurt: Indexs Verlag, 1980 and *Analogie in der Wissensrepräsentation. Case-Based Reasoning und räumliche Modelle*, ed. Hans Czap, P. Jaenecke und P. Ohly, Frankfurt: Indeks Verlage, 1996.

[107] Any attempt at ontological structuring will inevitably inspire critics to claim that a slightly different arrangement would have been closer to the true hierarchy. While such debates have their value, it is important to recognize that even if there is no complete agreement about a final configuration, the conflicting versions can still contribute to new insights, by challenging us to look at trends from a more universal level.

[108] See: http://www.uia.org/webints/aaintmat.htm.

[109] See: Benking, Heiner, (1997), "Understanding and Sharing in a Cognitive Panorama." *Culture of Peace and Intersymp 97. 9th International Conference on Systems Research, Informatics and Cybernetics, August 18-23*, Baden-Baden, available electronically

See: http://www3.informatik.uni-erlangen.de:1200/Staff/graham/benking/index.html.
http://newciv.org/cob/members/benking/

Other articles by the same author include:

Benking, Heiner, (1992), "Bridges and a Master Plan for Islands of Data in a Labyrinth of Environmental and Economic Information," *Materials and Environment. Databases and Definition Problems: Workshop M. and System Presentation. 13th ICSU-CODATA Conference in collaboration with the ICSU-Panel on World Data Centers, Beijing, October 1992*.

Benking, Heiner, "Design Considerations for Spatial Metaphors- Reflections on the Evolution of Viewpoint Transportation Systems," Workshop at the European Conference on Hypermedia Technology (ECHT 94), *Spatial User Interface Metaphors in Hypermedia Systems*, September 1994, Edinburgh, 1994.

See: http://www.lcc.gatech.edu/~dieberger/ECHT94.WS.Benking.html

Benking, Heiner, (1998), "Sharing and Changing Realities with Extra Degrees of Freedom of Movement," *Computation for Metaphors, Analogies and Agents*, Aizu-Wakamatsu City, April 1998, University of Aizu (in press):

See: http://www.ceptualinstitute.com/genre/benking/landscape.htm

Cf. also the forthcoming Benking, Heiner and Rose, J. N., "The House of Horizons and Perspectives," ISSS Conference in cooperation with the International Society of Interdisciplinary Studies, Atlanta, 19-24 July 1998.

Benking identifies six elements as part of his Panorama of Understanding, knowing and not knowing: bridges (*Brücke*), forest and ground (*Wald und Flur*), unknown territory (*terra incognita*), maps, filters and brokers; multimedia bridges and integration; viewable ensemble of the world of the senses (*Anschauliches Sinnweltenensemble*).

[110] If we look, for instance, at classifications of the Middle Ages there were no categories for science (as we now know it) or psychology. What we call *science* was typically (*natural) philosophy* or was included under the rubric of the *quadrivium* (arithmetic, geometry, music and astronomy). Psychology was often in literature such as the *Roman de la Rose*.

[111] See: http://www.hitl.washington.edu/.

[112] See: http://viu.eng.rpi.edu/overview2.html and http://viu.eng.rpi.edu/IBMS.html.

[113] Martin, Steve, Clarke, Steve, Lehaney, Brian, (1996), "Problem Situation Resolution, and Technical, Practical and Emancipatory Aspects of Problem Structuring Methods," *PARM '96, Practical Aspects of Knowledge Management, First International Conference, Basel, 30-31 October 1996*, 179-186. I am grateful to Heiner Benking for this reference.

[114] Cf. Hans Robert Jauss, *Ästhetische Erfahrung und literarische Hermeneutik*, Munich: W. Fink, 1977.

[115] See Rensselaer W. Lee, *Ut pictura poesis. The Humanistic Theory of Painting*, New York: W. W. Norman and Co., 1967.

[116] Sir Ernst Gombrich, "The What and the How. Perspective Representation and the Phenomenal World," Logic and Art. Essays in Honor of Nelson Goodman, ed. R. Rudner and I. Scheffler, New York: Bobbs Merrill, 1972, pp. 129-149.

[117] Sir Ernst Gombrich, "The Visual Image: Its Place in Communication," *The Image and The Eye*, London: Phaidon, 1982, pp. 137-161.

[118] See: http://www.cs.sandia.gov/SEL/Applications/saturn.html

[119] Brygg Ullmer discusses Cellular Universe Multiscale Spatial Architecture (CUMSA) Cellular Spatial and Entity Class in *Multiscale Spatial Architectures for Complex Information Spaces*

See: http://ullmer.www.media.mit.edu/people/ullmer/papers/multiscale/node7.html.

[120] For a further discussion of these problems see Veltman, Kim H., (1997), "Why Culture is Important [in a World of New Technologies]," *28th Annual Conference: International Institute of Communications Conference, October 1997*, London: International Institute of Communications, 1997, 1-10.

[121] Anthony J. N. Judge, "Systems of Categories Distinguishing Cultural Biases with notes on facilitation in a multi-cultural environment", Brussels: Union of International Associations, n.d. [c.1992]. See also an important article by the same author on "Distinguishing Levels of Declarations of Principles," available on line:

See: http://www.ceptualinstitute.com/genre/judge/level20.htm

[122] Magoreh Maruyama, "Mindscapes, Social Patterns and Future Development of Scientific Types," *Cybernetica*, 1980, 23, 1, pp. 5-25.

[123] Geert Hofstede, *Culture's Consequences: International Differences in Work Related Matters*, London: Sage, 1984.

[124] Kinhide Mushakoji, *Scientific Revolution and Interparadigmatic Dialogue*, Tokyo: United Nations University, GPID Project, 1978.

[125] Will McWhinney, *Paths of Change: Strategic Choices for Organizations and Society*, London: Sage, 1991.

[126] S. Pepper, *World Hypotheses: A Study in Evidence*, Berkeley: University of California Press, 1942.

[127] Mary Douglas, *Natural Symbols: Explorations in Cosmology*, London: Pelikan, 1973

[128] Howard Gardner, *Frames of Mind: The Theory of Multiple Intelligences*, London: Heinemann, 1984

[129] W.T. Jones, *The Romantic Syndrome: Toward a New Method in Cultural Anthropology and the History of Ideas*, The Hague: Martinus Nijhoff, 1961.

[130] Emmanuel Todd, *La Troisième Planète: structures familiales et systèmes idéologiques*, Paris, 1983.

[131] See: http://www-cui.darmstadt.gmd.de/visit/People/hemmje/Activities/Virgilio/
Cf. http://graphics.lcs.mit.edu/~becca/vie/prop.html
[132] See: http://www.cs.umd.edu/users/north/infoviz.html
This is being replaced by On-Line Library of Information Visualization Environments (OLIVE)
See: http://www.otal.umd.edu/Olive/
which distinguishes between eight kinds of interfaces, namely, temporal, 1D, 2D, 3D, MultiD, Tree, Network, and Workspace.
A similar list entitled Visual Information Interfaces was is available at the VIRI sight maintained by the GMD:
See: http://www-cui.darmstadt.gmd.de/visit/People/hemmje/Viri/visual.html
[133] See: http://www.cs.chalmers.se/~ahlberg/
Cf. ahlberg@cs.chalmers.se
[134] See: http://www.mtm.kuleuven.ac.be/~hca/index.index.eng.html
[135] See: http://www.ibm.com/ibm/hci/guidelines/design/realthings/ch4cl.html
[136] See: http://www-cse.ucsd.edu/~rik
[137] See: http://www.crg.cs.nott.ac.uk/people/Steve.Benford
[138] See: http://www.parc.xerox.com/istl/members/bier/
[139] See: http://www.parc.xerox.com/istl/projects/MagicLenses/
[140] See: http://www.biochem.abdn.ac.uk/~john/john.html
cf. http://www.biochem.abdn.uk/~john/vlq/vlq.html
[141] See: http://science.nas.nasa.gov/~bryson/home.html
[142] See: http://www.cwi.nl/~dcab
[143] See: http://www.dgp.toronto.edu/people/BillBuxton/billbuxton.html
[144] See: http://www.computer.org:80/pubs/cg%26a/report/g20063.htm
[145] See: http://www.dis.uniroma1.it/AVI96/tchome.html
[146] See: http://www.ubs.com/webclub/ubilab/staff/e_chalmers.htm
Matthew.Chalmers@ubs.com
Tel. 41 1236 7504
[147] See: http://www.ubs.com/cgi-bin/framer.pl?/webclub/ubilab/e-index.htm/Projects/hci.html
[148] See: http://www.cs.unm.edu/~jon/dotplot/index.html
[149] See: http://soglio.colorado.com
[150] See: ftp.comp.lanc.ac.uk/pub/reports/1994/CSCW.13.94.ps.2
[151] See: Crouch, D., & Korfhage, R. R. (1990). “The Use of Visual Representations in Information Retrieval Applications”. In T. Ichikawa, E. Jungert, & R. R. Korfhage, (Eds.), *Visual Languages and Applications*, New York, Plenum Press, 305-326.
Donald B. Crouch, “The visual display of information in an information retrieval environment,”
in: *SIGIR '86. Proceedings of 1986 ACM conference on Research and development in information retrieval*, pp. 58-67.
[152] See: http://www.cs.brown.edu/people/ifc
[153] See: http://www.lcc.gatech.edu/~dieberger/CSDL4_abstract.html
cf. andreas.dieberger@acm.org
[154] See: http://www.lcc.gatech.edu/~dieberger/Proj_Vortex.html
[155] See: http://www.soc.staffs.ac.uk/~cmtajd/online.html

cf. http://www.soc.staffs.ac.uk/~cmtajd/papers/version-PSE97

156 See: http://panda.iss.nus.sg://8000/kids/fair/

157 See: http://www.cc.gatech.edu/gvu/people/Faculty/James.D.Foley.htm
cf. james.foley@gvu.gatech.edu

158 See: http://fox.cs.vt.edu

159 See: http://www.cs.panam.edu/info_vis/info_nav.html

160 See: http://www.cs.brown.edu/people/ag/home.html

161 See: http://www.cs.rpi.edu/~glinert

162 See: http://www.csd.abdn.ac.uk/~pgray

163 See: http://www.dcs.gla.ac.uk/personal/personal/pdg

164 See: http://www.ics.uci.edu/~grudin

165 See: http://www.sims.berkeley.edu/~hearst

166 Re: Visualization of Complex Systems,
See: http://www.cs.bham.ac.uk/~nsd/Research/Papers/HCI/hci95.html
Re: Hyperspace: Web Browsing with Visualisation
See: http://www.cs.bham.ac.uk/~amw/hyperspace/www95

167 See: http://www-cui.darmstadt.gmd.de/visit/People/hemmje

168 See: http://www.cs.unm.edu/~hollan/begin.html

169 See: http://www.crg.cs.nott.ac.uk/~rji

170 See: http://www.cs.wisc.edu/~pubs/faculty_info/ioannidis.html

171 See: http://www.eecs.tufts.edu/~jacob/

172 See: http://www.cs.cmu.edu/People/bej/

173 See: http://www.cs.umd.edu:80/projects/hcil/People/brianj/VisualizationResources/

174 See: kimoto@nttvdb.dq.isl.ntt.jp

175 See: http://www.dbs.informatik.uni-muenchen.de/dbs/projekt/visdb/visdb.html
cf. http://www.dbs.informatik.uni-muenchen.de/dbs/mitarbeiter/keim.html

176 See: http://www.darmstadt.gmd.de/~kling

177 See: http://www.pitt.edu/~korfhage/korfhage.html

178 BIRD= Browsing Interface for the Retrieval of Documents

179 See: http://www.research.microsoft.com/research//ui/djk/default.htm

180 See: http://www.uky.edu/~xlin/publication.html

181 See: http://virtual.inesc.pt/rct.30.html

182 See: http://wwwwksun2.wk.or.at:8000/0x811b0205_0x00d1119;skF50A50ED

183 See: http://www.comp.lancs.ac.uk/computing/users/jam/proj300.d/qpit.html

184 See: http://www.csri.utoronto.ca/~mendel/

185 See: http://www-graphics.stanford.edu/papers.edu/papers.webviz

186 See: http://www.cs.cmu.edu/~bam

187 See: http://asnst5@lis.pitt.edu

188 See: http://www.cs.cmu.edu/~dolsen

189 See: http://www.risoe.dk/sys-mem/cmi-web.htm

190 See: Pejtersen, Annelise Mark.*The Bookhouse: Modeling User's Needs and Search Strategies, a Basis for System Design*. Roskilde, Denmark: Riso National Laboratory, 1989.

191 See: http://www.csl.sony.co.jp/person/rekimoto/cube.html

192 See: rose@apple.com

[193] See: http://cs-tr.cs.cornell.edu/TR/Search/?publisher=CORNELLCS&number=&boolean=and&author=Salton&title=&abstract=information+retrieval
[194] See: http://www.eecs.harvard.edu/~shieber
[195] See: http://www.cs.umd.edu/users/ben/index.html
[196] See: http://www.crg.cs.nott.ac.uk/people/Dave.Snowdon
cf. http://www.crg.cs.nott.ac.uk/crg/Research/pits/pits.html
[197] See: http://researchsmp2.cc.vt.edu/DB/db/conf/cikm/cikm93.html
cf. aspoerri@research.att.com
[198] See: http://www.cs.gatech.edu/gvu/people/Faculty/john.stasko
[199] See: http://www.cise.nsf.gov./iris/ISPPDhome.html
[200] See: http://www.informatik.uni-trier.de/~ley/db/indices/a-tree/v/Veerasamy:Aravindan.html
[201] See: http://www.labs.bt.com/innovate/informat/infovis/part1.htm
[202] See: cwickens@s.psych.uiuc.edu
[203] See: http://www.dq.com/
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