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Abstract

Plans for architecture go back to Antiquity. Attempts to create idealized views of ancient cities go back to the 16th century, when architects reconstructed Roman cities. From the 17th through the 19th centuries such reconstructions became linked with archaeology and history. Since 1990, especially in Italy, Germany and Japan, there have been trends to reconstruct buildings, sites and cities in digital form, partly for conservation purposes, partly to understand historical contexts. Recent trends are to link these with Geographical Information Systems (GIS) and with reconstructions of events such as the eruption of Vesuvius. Seven applications of such virtual reconstructions have evolved in parallel, namely, restoration, tourism, architecture, history, entertainment, education and games. Three waves of convergence with trends towards Universal Convergence Technologies (UCT), are bringing new synergies among these applications. They also point to a potential integration of mapping, reconstructing, recognition and embedding. Herein, lie new possibilities for new knowledge organization in the form of systematic scales and worlds of knowledge. Virtual and digital reconstructions therefore represent much more than electronic versions of the physical world. They help us to understand, why there has been an increasing interplay between software for architecture and entertainment. They open new possibilities, whereby methods of film and television such as blue rooms, can be used for education and research. They offer new strategies for organizing the knowledge of memory institutions, which in turn can serve as a renewed source of creativity.

1) Introduction

Planned cities using a grid-system go back at least to the time of Hippodamus of Miletus.[1] During the Middle Ages, Saint Augustine explored the idea of an earthly city of man and a heavenly city of God, thus shifting idealized cities explicitly to the divine world beyond the experience of everyday life. The Renaissance introduced a new chapter in this story which brought the idealized city back to earth. The Baltimore, Berlin and Urbino panels represented idealized cities as if they were local places.[2] Meanwhile, physical sites of piazzas in Venice, Ferrara, Florence, Pisa and Rome became sources for idealized spaces in stage scenery. Architects such as Filarete, Leonardo da Vinci, Bramante and Serlio offered visions of idealized sacred and secular architecture.

In the 15th and early 16th centuries, the sojourns of Brunelleschi, Donatello, Raphael, Baldassare Peruzzi and others among the ruins in Rome heralded a next important step. Their detailed studies of individual capitals, columns, and other architectural features prepared the way for what would later become classical archaeology. At the same time, their drawings introduced various idealized images, which were both reconstructions of possible past buildings and scenarios for possible future constructions. By the 1530s, Sebastiano Serlio, who inherited much of the corpus of Peruzzi, began publishing these studies. In the decades that followed, a wave of Northern artists and engravers, notably Thiry, Du Cerceau, Cock and Vredeman de Vries, began a more systematic publication of Roman ruins.[3] These ruins were much more extensive, consciously more playful and introduced a tradition of fanciful and creative combinations to produce caprices and capriccios. What began as a recording and copying of the past, was thus transformed into a new source of creativity. This tradition of Roman ruins was most active in the second half of the 16th century and continued until the mid- 17th century.[4]

The 17th, 18th and 19th centuries saw a significant expansion of horizons as explorers and archaeologists looked beyond Rome to other Greco-Roman sites (Pompeii, Herculaneum, Paestum) and then to the Near, Middle and later the Far East. High costs of printing images meant that early descriptions of sites were frequently only verbal. Only gradually were reconstructions in the form of engravings available. Some of these, such as Robert Wood's *Ruins of Palmyra* (1753),[5] became luxurious classics, which fired the imagination of both active and armchair explorers. Parallel with these developments was the rise of archaeology, which entailed reconstructions, often highly idealized, of major sites in Rome, Greece, Egypt and Babylonia.[6] While very impressive, most of these virtual reconstructions lacked specific measurements and explicit methods and were thus not reversible: one could not go from such a reconstruction to rebuild accurately an original building or monument.

By the 19th century these images were sometimes coloured. For instance, Owen Jones' *Grammar of Ornament* (1856)[7] provided a catalogue of ornamental details from cultures around the world. While purportedly a catalogue of existing motifs, it effectively became a starting point for novel, creative expressions. By the late 19th century, attempts to record details and sites in the form of drawings, and engravings, were complemented by black and white photographs. In the 20th century, these were slowly replaced by coloured photographs and techniques from photogrammetry.

Parallel with these trends towards ever more accurate documentation of archaeological remains, were more fanciful reconstructions by artists such as Eugene Delacroix in his visit to Spain and North Africa (1832)[8] and David Roberts' *Sketches in the Holy Land and Syria*

(1842-1849).[9] These shifted the fascination with Greco-Roman traditions to include more exotic vistas of the Near and Middle East in what is now called Orientalism.[10] While very attractive, these images often belonged to what would today be called artists' impressions. They combined records of physical buildings and ruins with imaginary views of how these might once have looked. They also frequently used an Eastern backdrop to explore possibilities, romantic visions or make political and or moral critiques of society at home (cf. Voltaire and Montesquieu). What were supposedly the equivalents of reporters' accounts from abroad, thus became also reports of journeys into the worlds of imagination and phantasy, glimpses into possible worlds and utopias.

Meanwhile, the relationship of regular architects to their constructions changed also. For instance, the French architect, Ledoux, constructed buildings; then published idealized versions of these existing buildings in his books, which frequently simplified the contours of the original physical monument.[11] Plans to build did not necessarily mean that buildings were completed. In the 20th century, even famous architects such as Corbusier and Frank Lloyd Wright produced various plans that remained visual ideas rather than finished physical structures. Examples such as Gaudi's *Sagrada Familia* continued the tradition of mediaeval cathedrals, whereby plans for a building continued to evolve beyond the lifetime of a given builder. In the 1930s, the Bauhaus School explored motifs in nature as modules and building blocks that could serve as design elements in architecture. At its worst this led to massive apartment flats and suburbs that resembled the mass/production of factories. At its best this led to new creative methods and forms, which are being taken up anew in electronic form by Oliver Bimber[12] and others.

One might expect that the rise of commercial computers in the second half of the 20th century would mean that traditional analogue activities were gradually translated into digital form. To some extent this is the case. But the possibilities of cross-media and potentially cross-sensory translation in a digital context, mean that the advent of digital techniques is having more far reaching effects. We begin with a short survey of changes in visualization software, examine the role of previsualization; consider seven domains where visual and augmented reconstructions are becoming important; then outline three waves of convergence culminating with a trend towards Universal Convergence Technologies. We explore show how these developments have implications for new approaches to knowledge organization, which can also stimulate future creativity.

## 2) Visualization Software

Early visions of the Internet by Paul Otlet (1934)[13] and David Sarnoff (1964)[14] foresaw the integration of visual materials within a global network. Ivan Sutherland, whose ideas for his Sketchpad (1963)[15] go back to 1960[16] was one of the first to makes practical progress in this direction. Sutherland and his colleague went on to found Evans and Sutherland, which became one of the leading scientific visualization firms with a focus on the military. In 2006, Evans and Sutherland sold its visualisation and simulation business to Rockwell Collins and acquired Spitz Planetarium Business.[17] Hence, Evans and Sutherland, which was military, is now in the entertainment business and working with Goto Inc.[18]

This shift from the military to entertainment is one example of a larger trend. The field of visualization has traditionally had two separate poles. One was entertainment (film and television). The other was construction (engineering and architecture). These are becoming intertwined. The analogue roots of the entertainment pole go back to the 19th century with

companies such as Carl Zeiss (1949) and continue in the 20th century with Goto Inc. (1926)[19], Barco (1934), Walt Disney (1934), Spitz Inc. (1945) and IMAX (1967). Steps towards digital production began with Robert Abel and Associates (1971) and Industrial Light and Magic (1975). The 1980s saw a profound shift towards digital production with the advent of eight key firms: Alias, Wavefront Technologies, BUF, Pixar, Softimage, Side Effects, Avid and Rhythm and Hues.

In the realms of architecture and engineering, the 1980s also saw the rise of four key firms, two in Europe, CATIA and Archicad and two in the United States, AutoDesk and Microstation (Appendix 1). Since then there have been two important changes. One entails shifts in ownership. Softimage was sold to Microsoft and then to Avid. Pixar was sold to Disney. Alias and Wavefront became part of SGI and were then sold to Autodesk. As a result, a number of tools traditionally linked with film and television production became linked with engineering and architecture. A second change has been the increasing interplay of Architecture, Engineering, Construction (AEC) and Facilities Management (FM) with Geographical Information Systems (GIS) and Geo-Positioning Systems (GPS). Facilities Management has been extended to Forest Mapping Management (FMM).[20] This integration of interests has made possible a revolutionary integration of scales that was prefigured by the movie, *Powers of 10* (1977)[21]; captured by the slogan: "from outer space to right in your face" and has now become commonplace through Google Maps, Microsoft Virtual Earth, Microsoft Live Local and Google Street Level. All of these are part of a larger strategy by Al Gore, which foresee sees a Digital Earth[22] with a 1:1 replica of the entire physical world.

3) Previsualization

These new digital tools are changing the role of architectural and environmental images. Ever since the Code of Hammurabi (1750 B/C.) there have been concerns that architects deliver what they promise. Architects' plans (2D ground plans, elevations and 3D views (cf. *scaenographia*) have been around for over two thousand years in order to give future owners an idea of the building that they have contracted to have built. This concern with individual buildings led to the fields of Facilities Management (FM) and Town Planning, whereby the reconstruction of individual houses and buildings led to the reconstruction of entire cities. The past decades have seen shifts in these models of cities, of which Paul Torrens has outlined four stages (figure 1).

1. 3D CAD (computer aided design) models of cities
2. Static 3D GIS (geographic information systems) models of cities
3. Navigable 3D GIS models of cities
4. 3D urban simulation model [23]

Figure 1. Four Kinds of Digital Cities

### 3.1 Environmental Impact

In the 1990s, these plans for architectural projects took a new turn: not just to show customers what the results would be like, but also to warn persons of possible negative environmental effects of a proposed project. Ottawa is the capital of Canada. The cityscape is dominated by the 19th century Houses of Parliament and a other historical buildings. There were plans to build a skyscraper in the city centre. John Danahy,[24] a professor of Landscape architecture (Toronto), created a model that revealed how a skyscraper would destroy the traditional

cityscape of Ottawa. This was shown to politicians and citizens. As a result, the plan for a skyscraper was abandoned. There have been a number of such projects, to the extent that software such as Archicad now includes examples of environmental impact in their demos.[25] Major architects such as Jean Nouvel use the same technique to demonstrate how their designs will enhance rather than endanger the visual landscape.

In the course of the past decade, there has been a remarkable rise in cyber cities[26] and digital cities, which have become "one of the important branches and regional layers of digital earth."[27] Plans for a Digital Earth or a Virtual Earth, which provides a 1:1 digital copy of the entire earth have advanced from visionary ideas to a concrete program.[28] Digital models have become simulations, frequently involving agents, multi-agent systems and even interactions among humans and computational agents.[29]

### 3.2 Emergency Scenarios

In the past decade, the dangers of terrorism have led also to increasing efforts to create complex models of cities, which can simulate possible dangers. This stimulated the growth of specialized departments such as the Urban Simulation Team at UCLA.[30] In the United States, Senior members of Homeland Security now see the gaming industry as a key to such simulations.[31] Simulation and Gaming are now major sources of funding.

One effect of these developments is that companies now see homeland security as yet another example in their wide spectrum of offerings. For instance, the Austrian firm, Viewtec, caters to: "Defense Industry, Homeland Security, Oil & Gas Industry, Insurance Industry, Flight Simulation & Training, Television Broadcasting & MultiMedia, Travel & Tourism, Civil Engineering, Urban Planning, Architecture & Real Estate, Imagery & Geodata Industry".[32] The good news is that these simulations are ever more realistic. The problematic news is that the US Military is now a major investor in networked games and simulations. These simulations typically use battle scenes in Iraq both for training prior to combat and for treatment of Post Traumatic Stress Disorder (PTSD). The bad news is that for the players, distinctions between game and real-life are diminished or removed. The tragic news is that some of the simulations have effectively prefigured in a virtual world, what later happened in the physical world.[33] We become not only what we dream but also what we fear most.

## 4. Virtual and Augmented Reality

Aside from everyday Architecture, Engineering and Construction (AEC) and the military, a whole range of applications has been predicted. In 2000, Diana Walzak, was asked to foresee developments in education for the year 2020. Her vision includes: "Tangitrek. With a force feedback exoskeleton, motion base, gimbaled harness and autostereoscopic display, a student can go anywhere and do anything."[34] This includes being able to navigate amongst virtual atoms in chemistry; touch simulated dinosaur eggs in biology and, as part of history, the student "flies over the Acropolis as it may have looked in ancient times. She can converse with synthetic townspeople about their era."[35] Striking in this vision is the emphasis on technological bravura in the absence of critical methods to understand the images the processes being shown. Some would claim that Europe is more sensitive to these problems of method. In any case, around the world, there is a wide range of actual applications, which are already being used today in at least seven domains. These include restoration, tourism, architecture, history, entertainment, education and games. (Figure 2).

1. Restoration
2. Tourism
    Virtual Visits to Endangered and Remote Sites
    Politically Censored Images
    Contextualization
    Virtual Spaces of Paintings
3. Architecture
4. History
5. Entertainment
6. Education
7. Games and Creativity

Figure 2. Seven Applications for Virtual and Augmented Reality:

### 4.1 Restoration

Technology has long played a role in restoration through techniques such as X-Radiography (x-rays) and dendrochronology. More recently these have been complemented by Infra-Red (IR) Reflectography, Infra-Red (IR) Photography in Pseudo Colours, Ultra Violet (UV) Fluorescence and High Definition Images in Visible Light.[36]

In 1982, Marc Rioux[37] and his team began publication on what would become the NRC Laser Camera, images from which were used to create three-dimensional facsimiles of a unique, transparent Inuit sculpture of a head at the Canadian Museum of Civilization (Ottawa). This was one of the earliest cases where new technologies were used to study possible interventions in a unique cultural object.

In 1990, Massimo Chimenti and Luca Menci (Arezzo) created one of the first digital reconstructions of 11,000 houses of Renaissance Florence using Autodesk (1990). They went on to use digital facsimiles in 2D and 3D to explore virtual interventions in an historical artefact. The restoration of the frescoes by Piero della Francesca in Arezzo, with the technical aid of Chimenti and Menci, was one of the earliest examples of this principle applied to a major work of art.[38] The restoration of the *Last Supper* by Pinin Brambilla Barcillon took these methods further. Methodologically, this is of the greatest importance because it means conservators and restorers can explore potential effects of alternative interventions in a virtual environment before introducing irreversible effects on the original. The Japanese firm, Hitachi has used similar principles in exploring values for the original colours of Hokusai's woodcuts and in restoring one of the famous ceilings of Kyosai.[39] The past 50 year have seen the beginnings of Conservation Networks (CCI, Getty, C2RMF). Needed are global networks in this domain, whereby some of the interventions on individual works become a layer of knowledge accessed via memory institutions.

### 4.2. Tourism

In the past decades, there has been an enormous rise in virtual reconstructions of archaeological and historical sites. Some critics remain very sceptical as to the value of such reconstructions arguing that they can never replace the original. This scepticism is understandable. On the other hand, it is worth recalling that in earlier times potential explorers and visitors had only oral accounts. From the 16th through the 18th centuries explorers, visitors, gentlemen on the grand tour, and proto-tourists, were limited to woodcuts, engravings, and lithographs. The 19th century brought black and white photographs. The 20th

century brought colour photographs, videos, which are now being complemented by virtual and augmented reality. Once we accept that these reconstructions are effectively a new kind of travel brochure on steroids, their contribution is clear. As orientations in helping to prepare us for what we will see *in situ,* these new tools offer a significant stage forward.

The deeper value of virtual reconstructions lies elsewhere. Many sites are so delicate that they are closed to the public and even to most researchers. The famous caves at Lascaux are one obvious example. One alternative is to build replicas as 1:1 scale models. There is one such replica in the Dordogne near the original caves and another in Saint-Germain-en-Laye, near Paris, at the Musée d'archéologie nationale.[40] While very useful, such replicas constrain visitors to go to these specific sites for the experience. Virtual reality reconstructions, such as that of Benjamin J. Britton,[41] allow potential visitors to have this experience anywhere in the world, where there is the appropriate equipment.

It may not be "the real thing", but it is far superior to the prospect of never seeing the original. This principle extends to many other important sites such as the Tomb of Nefertari and the Palazzo Sciarro reconstructed by Infobyte.[42] This principle extends also to many cases where the original is theoretically open for view. There are thousands of aboriginal caves in Australia. There are over 30,000 painted caves in Africa. Even a professional fully dedicated to cave markings, drawings and paintings, would have difficulty visiting all these caves in a lifetime. If there were reconstructions of all these caves and efficient search tools, then scholars, amateurs and the general public alike could have a chance to explore many parts of the world beyond their travel budgets and time constraints. Meanwhile, an estimated 50-95% of museums and collections are carefully stored in museum vaults and storehouses and not on display. If these materials were scanned, these too could be made available virtually for study and leisure. Hence, while virtual reconstructions ultimately cannot replace the full experience of seeing the original; they can make fundamental contributions in increasing the sample of materials on which we base our studies.

The earliest reconstructions focussed simply on a physical object, cave, monument or building. They were effectively static facsimiles. In the 1990s, further elements were added. The pioneering work of Marilyn Aronberg Lavin, linked reconstructions with their narrative sequences.[43] The reconstruction of the Tomb of Nefertari (1995) by Infobyte contained translations of the hieroglyphs on the wall of the tomb, which could be read out loud by an actor or silently by a user. The reconstruction of the Cappella degli Scrovegni [44](2002) went considerably further adding other interactive possibilities such as focussing on individual scenes, following their narrative sequence. A reconstruction of the Interior of the Winter Counsel Chamber Earthlodge at the Ocmulgee National Monument, Macon, Georgia (1998), allows us to imagine what Indian ceremonies that are no longer extant may have been like.[45] A project by Antonella Guidazzoli (CINECA) has reconstructed the Cathedral of Parma (2007)[46] and uses this reconstruction as a context for re-enacting mediaeval processions and other sacred events. A project by Malvina Borgherini (Venice) is linking the cycle of frescoes in the Palazzo della Ragione (Padua), with astronomical and astrological cycles and mediaeval clock-making, thus allowing us to understand connections, which we could not see simply by looking at the originals.[47] Such examples are of interest to tourists and researchers alike (cf. § 4.4 and 4.6 below).

Visiting endangered, remote and non-extant sites is probably the most obvious set of applications of virtual and augmented reality for tourism. A second set of applications entails the domain of contextualization. Complex works of art are often made in one location and

then become dispersed in separate collections. If we go the Louvre, for instance, we find a predella by Gentile da Fabriano showing the *Presentation in the Temple* (1423). This was originally part of an altar now in the Uffizi showing *the Adoration of the Magi*. The Louvre is not likely to give their predella back. Reconstructions can show their connections. Carpaccio's *Two Court Ladies* (Venice, Museo Correr, c.1490) is well known. Far away is Carpaccio's *Hunting on the Lagoon* (Los Angeles, Getty Museum). Scholars have suggested that they were originally one painting.[48] In such cases, a virtual reconstruction available at both locations can help viewers understand the original work. More detailed reconstructions can also explain the points of controversy in different interpretations concerning the same work.

This quest for contextualization goes beyond re-assembling complex works of art, pieces of which have landed in various galleries. It applies also to understanding the sources, related paintings and drawings of a given work: e.g. being able to compare the three quite different versions of Paolo Uccello's *Battle of San Romano* in the Uffizi, Louvre and National Gallery, London, respectively. A tourist visiting the beach at Etretat in Normandie might well be unaware that this was a recurrent scene in Monet's paintings. How many visitors to the museum in North Carolina who look at Monet's *Sunset at Etretat* realize that there are similar paintings in Cleveland and Nancy? Needed are contextualizers that show us these connections.

The extent to which this approach might be useful is seen if we turn to another Monet painting, which almost every art student has encountered: the *Japanese Bridge at Giverny*. Monet lived at Giverny, West of Paris, from 1883 until his death in 1926. In 1890 he bought the property, built extensive gardens including a Japanese bridge, which crossed an adjacent pond. By 1895, he had begun painting this pond and bridge. The titles varied: *The Water Lily Pond*; *Le pont dans le jardin de Monet*; *Le Bassin aux nymphéas* ; *Japanese Bridge at Giverny*, but the basic theme remained the same. In the course of 31 years he painted at least 26 versions of this theme. Over seventy books have been written on Monet. Many contain some examples. Strikingly, as of 2000, not one of the major monographs of Monet contained the entire series. This is all the more significant, because it is only when we see them in context that we realize how Monet's impressionist version of realism gradually transformed into an almost abstract modern art. Contrary to what we read in general histories of art, this case shows that one important source for the rise of modern art lay in a profounder study of nature rather than a simple rejection of naturalism. Such comparisons are already possible on today's Internet. A high speed infrastructure would allow us to do the same with high level images of the same.

A third application pertains to recreating the spaces of paintings. Art historians (e.g. Carter, 1953)[49] explored this principle in their efforts to reconstruct the perspectival space of paintings such as the Piero della Francesca's *Flagellation* (Urbino, Galleria Delle Marche). This idea was taken up by Andrei Tarkovsky, in his film, *Solaris* (1972), where the protagonist at one point floats in front Brueghel's *Hunters in the Snow* (Kunsthistorisches Museum, Venice, 1585), and then floats into the space of the painting itself.[50] In 1994, Infobyte used this technique in the virtual reality reconstruction of the Basilica of San Francesco in Assisi, to show how one could fly through Giotto's depicted spaces. They used the same technique in their reconstruction of the *Stanze* (1995) of Raphael in the Vatican to show how one could enter the depicted spaces of the *Incendio nel Borgo* and the *School of Athens* and interact with avatars of the painted figures. DePinxi developed this approach in their *World of Rousseau* (2004) shown at Laval Virtual[51], wherein a series of Rousseau's

painted spaces were combined in a virtual interactive game. These potentials have also led to playful applications, whereby contemporary individuals are inserted into seventeenth century paintings by Jan Steen.[52]

A fourth application of virtual reconstructions is unexpected: providing public access to images, which are forbidden and censored because they reflect politically incorrect or politically unpopular themes. A case in point is a group of modern artists in Uruguay who were banned from physical museums, because they did not reflect the tastes of the ruling political party. After a number of years attempting to find acceptance, the artists constructed a *Museo Virtual de Artes El Pais* (MUVA),[53] which has brought their work to the attention of viewers worldwide. Such "reconstructions" are so convincing that they pose new problems of method. Unless we develop very clear rules for presentation of such non-physical museums, there will be no way of knowing at a future date, which museums were born-virtual and which were virtual surrogates of physical originals – which will pose major difficulties for future historians. The early practitioners were so intent on creating images that could pass for real, that we have not really thought enough about the need to be able to distinguish between born-physical and born-virtual.

### 4.3 Architecture

Mainstream architectural applications were considered earlier (§ 2-3). Virtual reconstructions can help us to understand aspects of buildings which are no longer extant. For instance, in the case of the Theatre of Pericles at Athens, a project at Warwick has created a virtual reconstruction, which permits us to see to what extent the stage was visible from different viewpoints.[54] Virtual reconstructions are of particular interest in problematic cases where a building has been damaged or destroyed. In 1945, the Frauenkirche in Dresden was bombed. All that remained was a pile of stones. During the early 1990s students of the Technische Hochschule (Dresden) collected all the remains, numbered them and entered virtual surrogates in digital form. These were then reorganized. The result was a virtual reality reconstruction of the original church, which was a highlight of CEBIT (Hanover, 1994). This virtual reconstruction was subsequently used to rebuild the physical church at its original location.

Infobyte had made a reconstruction of the church of San Francesco at Assisi (1994). After the earthquake in 1997, they made a second, more detailed reconstruction, to aid in the physical restoration of the original monument, working in collaboration with both the Franciscan friars and the Consiglio Nazionale delle Ricerche (CNR).[55] With nearly two million fragments, one observer described this as the biggest jigsaw puzzle that ever was. Sceptics have said that it will never work. Optimists will note that the new technologies are allowing us at least to attempt levels of restoration, which would have been unthinkable even a century ago.

### 4.4. History

All this is fine and well if the extant remains are sufficiently intact and/or if historical documentation is available. In some cases, both are lacking or the evidence is such that it is open to multiple interpretations. This applies to reconstructions ranging from single churches, through sites to cities.

## Churches

One of the earliest objects of detailed study in this field was the Abbey at Cluny. In the decade from 1991-2000 there were at least six significant reconstructions (Figure 3). These varied tremendously in their interpretations. It is striking that three are no longer available at their original addresses. Lacking thus far is a detailed documentation of sources used, assumptions made and methods used, which will enable future students to weigh the relative value of these reconstructions. This desideratum applies to the hundreds of reconstructions of churches now online. Not surprisingly in a new field, there is a flurry of initial enthusiasm, which is only gradually tampered by clear rules of method. In the next decades, there is a need to define a basic set of rules and methods for the emerging field of digital reconstructions. As in the case of restorations, reconstructions need to become a layer in our access to knowledge in memory institutions.[56]

1991 INA (Institut National de lÁudiovisuel) and IBM
1993 IBM and ENSAM (Centre d'Enseignement et de Recherche, Cluny)
1999 Walder & Trüeb Engineering AG (RZW)
1999 Manfred Koop, Technische Universität, Darmstadt
2000 Wolfgang Kerscher, Technische Universität, Darmstadt
2000 NÖ Landesregierung, Abteilung Kultur und Wissenschaft
Figure 3. Six Reconstructions of the Abby at Cluny.[57]

## Sites

Although the use of electronic methods in archaeology became a reality in the 1990s.[58], these problems of method extend also to archaeological and other historical sites. An excellent early example of the potentials of virtual techniques was the Virtual Xanthen Project (1995)[59] for which Monika Fleischmann[60] created a Skywriter system for virtual flyovers. The user stands on a moveable platform. Changes in position on this platform determine one's navigation with respect to the reconstruction, which can cover an entire wall in front of us.

In the case of major sites such as Pompeii, there is long tradition of reconstructions going back to famous examples such as Rochette (1825).[61] These reconstructions range from the efforts of individuals such as Victoria I (1993)[62], to university projects;[63] commercial products[64]; to formal projects sponsored by the Soprintendenza dei Beni Culturali.[65] Each of these parties typically refers to their own work. Lacking thus far is a systematic survey of work done by different parties and a set of criteria to weigh their relative contributions. Meanwhile, some of the most impressive reconstructions of ancient cities are being produced outside Europe, namely, of the city of Kyoto in Japan and the Forbidden City in Beijing. Organizations such as the Virtual Heritage Network are bringing together some of the major contributions worldwide.[66]

One significant development of the last years has been an extension of concerns beyond simple archaeological reconstruction. Researchers at CINECA in an EU project have simulated the eruption of Vesuvius[67] in the context of larger concerns about natural disasters and emergencies. As a result, geo-physicists, seismic experts, computer scientists, archaeologists and historians are now working together. Study of an event long past thus becomes much more than an historical curiosity: it prepares us for future volcanic eruptions around the world. Some researchers believe that virtual reconstructions can be used to test hypotheses regarding social and economic life in Antiquity.

Cities

These developments are found also in the case of digital cities such as Rome. Again there are research efforts (CNR); university efforts such as those of the Centre Interdisciplinaire de réalité virtuelle (CIREVE, Caen)[68] or the Cultural Virtual Reality Lab (UCLA).[69] There have also been commercial efforts, such as the reconstruction of Rome by the Taisei Corporation (1995).[70] In the case of Rome, certain key sites such as the Forum of Trajan and especially the Basilica Ulpia have been a source of numerous interpretations.[71] While European, notably Italian versions, tend to downplay dramatic effects, American and also Japanese reconstructions often have a Hollywood-like effect of being almost too perfect in their sparking colours and bright skies.

In a class on its own, is Professor Francesca Bocchi's long-term project of a Nuovo Museo Elettronico (NUME),[72] which offers multiple reconstructions of the city of Bologna over a millennium from the year 1000 to the present. NUME is much more than a simple reconstruction of an historical city. Its visual presentations are based on close study of historical manuscripts, maps and other sources. The project, now over 7 terabytes was, until recently, hampered by its only being fully accessible on the CINECA premises. New algorithms are making subsets of this massive database accessible on-line using everyday personal computers.[73]

4.5. Entertainment

One of the important features of digital reconstructions is that they can be translated to different scales and thus be adapted for single users, classrooms or large audiences in movie and other theatres. For instance, Infobyte's reconstruction of Saint Peters Basilica, which was originally produced for individual viewers using an SGI Onyx machine, a monitor and stereo glasses, was adapted by Goto Inc to be shown on their special kind of planetarium, aptly called a Virtuarium.[74] Hence, by 1996, Japanese tourists could visit a virtual Saint Peters in Tokyo. In 1967, the IMAX format introduced a new level of optical quality. A recent ability to adapt formats means that films such as the *Journey into Amazing Caves* is now available on IMAX screens, on DVDs for home use and on Mobile cell-phones.[75]

In Japan, NHK has the most advanced imaging with their Hi Vision projects. NHK is already working on a future version with a display of 8K x 4K.[76] This proprietary system remains very expensive. Meanwhile, in 2006, Sony changed the world of regular cinema through the introduction of a 4K[77] projector, which shows images at 4000 x 2000 pixels, i.e. more than twice the resolution of current high definition efforts in the United States. The introduction of this 4K projector co-incided with the emergence of a new network linking Tokyo, Beijing, Moscow, Helsinki, Hamburg, Amsterdam and Paris, operating at 10 GB and scheduled to expand to 20 GB within a year, by which time it will also connect with the Canadian CAnet. This is significant because it means the rise of a global digital network in the Northern hemisphere that potentially bypasses Hollywood.

This advance in projection quality is having repercussions for the whole of digital film production. In 1904, there was a film called *Paris Je T'Aime* (1904). In 2006, a new version of *Paris Je T'Aime* became "the first feature film fully scanned in 6K and mastered in 4K in Europe (as opposed to the normal 2K). Encoding the image took about 24 hours per reel (at Laboratoires Éclair)."[78] When it was ready in September 2006, a French company called Smartjog[79] sent online digital copies to 12 movie theatres in the United States. As their

website modestly reported, as of August 2006: "the company transmits either by satellite or Internet about 1 Terabyte per 24 hours."[80]

Meanwhile there are trends towards 3-D television and cinema.[81] In isolation, these developments are significant. To understand their full import, it is important to recall parallel developments. In 1950, Arthur Widmer (Warner Bros. and formerly Kodak), began developing bluescreen techniques, known as chroma key in television. In the course of a half century this technique has evolved dramatically. Since 2000 :

> several movies were made using this technique, including *Immortel: Ad Vitam*; *Sky Captain and the World of Tomorrow*; *Casshern*; *Star Wars Episode III*; *I, Robot*; and *Sin City*. Performances from different takes can even be composited together, which allows actors to be filmed separately and then placed together in the same scene. Blue screen allows performers to appear to be in any location without even leaving the studio. They could appear to be anywhere on Earth, or any other world that could be depicted.[82]

The initial notion of a blue-screen covering one wall has also been extended to include the four walls, floor and ceiling to create blue rooms. By 1995, IBM and the BBC, using reconstructions from Pompeii, demonstrated how blue rooms could be used to place a reporter into [a reconstruction of] an ancient room. They called it virtual television studios.[83] The same principle using the same topic, Pompeii, and more specifically, the Casa del Centenario has since the been the subject of further developments, through a cooperation between CINECA (Bologna) and RAI (Milan).[84] The subsequent Whyre Project,[85] demonstrated how such high level images might be adapted for portable devices such as Palm Pilots, thus potentially making high-level content available for tourism.

### 4.6. Education

In the course of the past 50 years, digital production has evolved from individual elements into a networked process that entails the entire life-cycle from creation, through, production, post-production and delivery leading to the metaphor of a factory: e.g. Digital Design Factory and Digital Production Factory. In parallel, there have been trends towards ubiquitous and mobile computing characterized as network-centric computing and ambient intelligence.[86] There have also been hundreds of projects concerning a schoolroom of tomorrow, a classroom of the future, often with names such as the magic classroom. For a time, it seemed as if the professional needs of the television world, the post-production and multimedia production worlds (e.g. Studio Azzurro) and the academic worlds (computer graphics and computer science) were in competition. There is now a growing awareness that this is not the case and that the full consequences of these parallel developments will come into focus only when they become complementary and symbiotic.

In the past students, read about historical sites in history books with black and white images. Classrooms of today and even most so-called classrooms of the future still assume a single projection wall, which can show colour slides, Powerpoints and potentially videos of these sites. A classroom of the future can have the equivalent of blue-rooms. Instead of seeing a picture of an ancient Roman site, an immersive space can place them inside the Roman Forum, the ancient city of Kyoto or the Forbidden City in Beijing. The whole class could make virtual tours with the aid of a teacher, who provides a basic orientation to these eternal monuments. Individual students can then access these databases on their own computers, both

in classrooms and at home to explore them further, while studying and preparing assignments. Online access to sites and their reconstructions is a first step. To achieve this requires that high-speed e-infrastructures extend far beyond major pipelines into schools and homes

Three other steps are necessary to make this a reality. First, we need the equivalent of a distributed knowledge repository. This requires that current projects towards a European Library and World Digital Library become part of the plan.[87] Second, we need a new kind of Virtual Reference Room, which will help users find their way into and through these enormous resources. This requires new work on knowledge organization (cf. § 6 below) and especially on ways to maintain and show different and sometimes competing methods of knowledge organization. Third, we need the equivalent of a virtual agora, where persons can share, discuss and explore collaboratively the materials available in the distributed repository. This requires more systematic use of tools such as e-mail, blogs and video-conferencing. A first attempt to outline these challenges was made in E-Culture Net with a report by Suzanne Keene and Francesca Monti.[88] This virtual agora needs to encompass the work of national research institutes and organisations such as Max Planck, and JISC.[89]

### 4.7 Games and Creativity

Further developments can be foreseen. The past 50 years have seen the advent of editing tools for most media ranging from words, and pictures, to video, and film. Until recently, only word-editing and processing, dominated by Microsoft Word, became an everyday tool. This arose from a business model, which assumed that one should make profits on tools for content and also own the content if possible. Other models loom. If we want to create services using digital content, then the best incentive is to make the tools for content creation freely available. If this sounds unrealistic it is instructive to note that in the seven years since 2000, the *Wikipedia* has created a larger encyclopaedia than all other efforts of the past 4000 years.

IGN (International Games Network)
Games Creators Network
Online Gaming Network
Entertainment Network
Figure 4. Some Examples of Games and Related Networks.[90]

Meanwhile, there is evidence that the old models are failing. Ten years ago, professional versions of software such as Alias' Maya cost $90,000. Alias went near bankrupt, was acquired by SGI, then acquired by Autodesk. In 2006, Autodesk announced that it would make all its software available free of charge to students. Open Source software is becoming a mainstream phenomenon. On the desktop, some 4% of machines use Linux. By 2010, this is scheduled to rise to 20%. Mobile phones were c. 4% Linux in 2006. This is due to rise to over 50% in 2010. In the world of supercomputing, over 70% of all operations are already in Linux.[91] Within a generation or two, it is feasible that Linux or a related open-source software will be ubiquitous and that editing tools for all media will be freely available.

Within today's Internet, a number of specialized networks are also evolving in the realms of games and entertainment (Figure 4). The quality of these so-called amateurs exceeds that of the finest professional productions at the international level only a decade ago. Herein lie great potentials. In the past decades, projects by Nadia Magnenat-Thalmann have shown how a virtual avatar of Marilyn Monroe can be used to create playful films of *Marilyn with Students* (1994), *Marilyn by the Lake* (1995) and *Marilyn at ONU* (i.e. United Nations,

1996).[92] In a world where editing tools are readily available, making such short films could become an everyday experience in the manner of home movies on UTube.

During the Renaissance, artists created their works by drawing on a common heritage of mythology, literature, imagery and symbolism. Leonardo and Michelangelo were able to create their masterpieces precisely because there was no copyright on figures such as the Virgin Mary or subjects such as the *Last Supper*. They were able to copy, cite, allude to and adapt motifs and details in arriving at new works. In the modern world, the notion of citing and quoting other works is standard in literature and is one of the basic tenets of scholarship. Curiously, it is not nearly as widespread in the visual arts, and even less so in film, and television. To promote creativity, we need new conventions about citation in all media, not copying entire works, which is as uninteresting as plagiarism, but rather copying and documenting short clips, as the equivalents of quotes.

In the context of a virtual agora, students, amateurs and professional could then create a new generation of literature, art, design and architecture. This could use the contents of e-culture, including the thousands of reconstructions of objects, monuments, sites and cities, which have already been made, as starting points for new imagery, electronic "paintings", games, videos, films and other expressions. In this way, the richness of the past can become a font for future creativity. Some of these creations will be realistic, others playful, others completely imaginary and we shall need new tools to help us distinguish between these worlds. All the world's a stage and life is but a game, are useful metaphors, but it remains important to distinguish carefully between the fictive murders in a good detective novel that entertains us and real murders that threaten us. As we create new worlds we need also to distinguish between them more clearly with new ordering systems (cf. § 6 below)..

## 5. Universal Convergence Technologies

For the past twenty years convergence has been a buzzword. We have suggested elsewhere[93] that this convergence entails at least three phases (Figure 5). Convergence one entailed multimedia or more precisely multi-sensory media. Convergence two entailed Networked Information and Communications Technologies (ICT). Phases one and two brought together the seven developments outlined above. A third phase entails a series of new advances of the past decade for which there is as yet no clear name. In the United States, they are called NBIC (Nanotechnology, Biotechnology, Information Technology and Cognitive Science) In Canada, they are called Bio-Systemics Synthesis. In Europe, they have been called CTEK (Converging Technologies for the European Knowledge Society). We have called them a shift from Information Communication Technologies (ICT) to Universal Convergence Technologies (UCT).[94]

Convergence 1: Multi-Sensory Media or Multimedia
Convergence 2: Networked Information and Communication Technologies (ICT)
Convergence 3: Networked Universal Convergence Technologies (UCT)
Figure 5. Three stages in Convergence.

The long-term consequences of this shift are infrastructures, wherein cable-television, telephony and internet are all interoperable; where there is an ability to move across media and across different senses in order to achieve sensory transduction. In the shorter term, four distinct processes are coming together: Mapping, Reconstructing, Recognition, Embedding (Figure 6).[95] The advent of GIS, GPS, and UMTS means that mapping the world has become

Mapping
Reconstructing
Recognition
Embedding
Figure 6. Four Processes which are coming together in Universal Convergence Technologies (UCT).

a seemingly everyday matter as witnessed by the rapid rise of tools such as Google Maps and navigation systems. The rise of ever more efficient and less costly software means that virtual reconstructions considered earlier are being inserted into increasingly realistic virtual environments.

Meanwhile, millions of surveillance cameras and web-cameras are gradually becoming part of the same networks. At present, recognition technologies and specifically face-recognition technologies are directed almost exclusively to recognizing thieves and terrorists. The same technologies can also be used for other purposes. They could, for instance, be used to recognize basic classes in the animal, mineral and vegetable world.

Today our digital cameras and mobile phones take pictures as a passive exercise of recording the outside world. It is easy to imagine a rather different scenario: we use the same cameras and mobile phones with cameras to take pictures of a given plant or tree. We send this to a virtual reference room. Image recognition technologies identify the plant. The virtual reference room then sends a message or an e-mail back to our camera or phone, telling us the kind of plant we have just photographed. Our camera or phone has now become an active, knowledge gathering device. The physical world is now something much more than a place for walks and travel. It now becomes a new interface for searching for everything in the natural world. Linked with taxonomies, and scientific classification systems, taking a picture of any detail of a flower or a leaf, becomes an entry point into systematic study of different kinds of species, genus, family, order, class, phylum, kingdom and domain. Picture taking now becomes an active knowledge-acquisition process.

## 6. New Knowledge Organization

Since the Renaissance there has been a veritable explosion in knowledge. In the West, the largest collections have grown from just over a thousand in the mid-15th century to collections between 10 and 30 million books (depending on definitions of what constitutes a book). In the 21st century, as digital formats become the norm, the scale of these collections is

| Year | Library | Unique Volumes |
|---|---|---|
| 1451 | Vatican | 1,160 |
| 1630 | Herzog August Bibliothek | 130,000 |
| 1837 | British Library | 235,000 |
| 1854 | “ ” | 540,000 |
| 2007 | “ ” | 13 million |
| | Library of Congress | 17 “ ” |
| | Russian State Library | 16.5 “ ” |
| | Bibliothèque Nationale | 12 “ ” |
| | Beijing: National Library | 24 “ ” |
| | Worldcat Network | 76 “ ” (representing over 1 billion Copies) |

Figure 7. Growth of the world’s largest libraries since the Renaissance.

increasing enormously. In 2001, one source estimated that the Internet was producing 7 million new pages a day. The largest electronic library networks, e.g. *Worldcat*, now entail over 80 million unique titles and over 1 billion copies of books (Figure 7).[96] Massive projects for full-text scanning of over 60 million books by the year 2020 are underway.

In the past, each wave of expansion in knowledge brought new levels of bibliographical control. At the turn of the 20th century, the vision of a world-brain (*Gehirn der Welt*),[97] led also to a Mundaneum, with a programme for systematic treatment of secondary literature and an Organization for a Universal Bibliography of Intellectual Work. It led also to an International Union of Associations (UIA) and an International Fedeation of Documentation (FID). By the mid 20th century, the British Museum Library, had a reference library of some 300 thousand books that served as an entry point into their collection of over 10 million books. In the meantime, new approaches are necessary. Significantly, Anthony Judge, a long-time head of UIA, now foresees the advent of a Union of Imaginative Associations[98] as one dimension of a tetrad that includes a Cognitive Fusion Reactor, a University of Earth and a Fusion of the Whys.[99]

Seen in terms of simple proportions, if the 20th century required 300,000 reference works for collections of over 10 million, the 21st century theoretically will need over 3 million reference works to cope with electronic collections of over 100 million – an amount no one could ever read by way of preparing to make a query or search. So the reorganization of knowledge requires multiple filters to choose the right sources seamlessly in the pre-search phase. For instance, in normal circumstances a search for an English author should begin with the Dictionary of National Biography (DNB), just as a search for a Russian author should begin with Russian national biographies. Search for weather in London does not require searching all weather reports. A key to universal access to knowledge is to refine questions such that each new query does not require searching the whole of knowledge. If the question is very precise: e.g. when was Mozart born?, then a regular biography can give us the date: 27 January, 1756.

Hence, if the physical world can become an interface for getting started in our searching, systematic access to the organized reference works, citation indexes, abstracts, reviews and catalogues of reference rooms in digital form, offers a key to solving simple queries, while adding precision to our pre-queries for more serious research, which will also require new access to systematic scales and systematic worlds of knowledge.

### Systematic Scales

The film, *Powers of Ten*,[100] cited earlier, showed the fascination of being able to zoom systematically through different scales of existence. *Google Maps*, is a preliminary attempt to show this for the entire physical world. With Universal Convergence Technologies (UCT), this shifting through scales of the physical world can be linked with corresponding conceptual scales in taxonomy, such that a simple apple can lead to all subsumptive categories of apples, including their 1200 species (taxonomy) and the parts of apples (partonomy). This principle applies equally across the animal, mineral and vegetable worlds. In the longer term, we need more than the standard classification of the present: we need to be able to follow earlier classifications systems as they evolve in order to arrive at dynamic, historical and geographical maps of classes and categories.[101]

In the man-made world, the situation is slightly different. Here there may be no "natural" classes. On the other hand, three centuries of industrial and post-industrial production have led to exhaustive parts catalogues of every object that is produced. In the past decades our energies have been focussed on making this knowledge part of the production chain within a product's life cycle. A next step will be to link these parts catalogues back to our distributed knowledge repositories (libraries, archives, museums), such that mention of a machine, leads to parts of a machine, which are then linked to dictionary definitions, encyclopaedic explanations, articles and books about that machine and/or a specific part. The same principle applies to buildings and their parts. So focusing in on a physical temple or virtual reconstruction thereof will take us to the equivalents of visual dictionaries, which provide us the detailed names of parts of temples such as columns, architraves, triglyphs, metopes, glutta etc. With these precise terms we can make detailed and precise searches pertaining to Greek and other temples.

This seemingly simple approach has profound consequences for the realm of search engines. The *Bible* tells us: ask and you shall receive. Search engines such as *Google* implicitly promise us the same. However, they assume that we know the term for which to ask. The problem is that unless we are specialists in a given field we are all like tourists in a foreign country, where we do not know the language. We may be looking for something very specific in a car, but we do not know the word for spark plugs in that language. In addition to ever faster algorithms, the future of search engines requires new methods to go from vague words in personal usage (the you know what I mean stage where, as Montaigne would say, we are all a dictionary unto ourselves), to technical terms and clusters of clearly defined terms, and ultimately to subsumptive, ordinal and determinative relations linked with that term, which then serve as accurate entry points for precise searches. Searching is like learning a new language, which gives us the vocabulary, that we need to make the next steps. Once we have the terms we need, then we can truly ask and receive. A next key step is to have intuitive 3-D displays of knowledge such as those foreseen by Spectasia.[102]

### Systematic Worlds

While systematic scales are wonderful for the physical world, knowledge is ultimately about multiple worlds: e.g. metaphysical, mental, physical (or natural world), man-made and social worlds. Today, when we search for a word such as angel in *Google,* we get 191,000,000 hits largely because materials from these five worlds are listed indiscriminately: titles of movies by that name from the man-made world; Angel Flower (*Angelonia angustifolia* or Summer Snapdragon), from the physical world, and ethereal beings, such as the Archangel Michael, from the metaphysical world.

Needed are new methods to distinguish systematically between these worlds, which are linked with questions and disciplines. The metaphysical world is linked with Why? and with the disciplines of religion and philosophy. The mental world is linked with What? and the disciplines of Language, Literature and Mathematics (or in terms of the seven liberal arts with Grammar, Arithmetic and Geometry). The physical world is linked with What? as medicine and science; with Where? as geography and When? as history (Appendix 2). In other words, our memory institutions have already organized knowledge in terms of disciplines, which provide us with a key for distinguishing between these five basic worlds.

Standing back we see that these five worlds and six questions provide a grid of 30 choices. In future, such grids can be used for pre-searches. For instance, a vague query for angel, searches

though subject headings and identifies, where angels occur. These are shown as a grid. In our hypothetical example, the user now has nine choices to narrow down their search (Appendix 3). If the user then chooses the Archangel Michael, the system asks whether they are searching in a specific medium, e.g. paintings. Questions about when (e.g. 1600-1650) and where (Rome), then allow precise answers such as: Guido Reni's *Archangel Michael* (Capuchin church of Santa Maria della Concezione, Rome, c. 1635).[103] Hence, using an electronic equivalent of the game 20 questions, we can find a specific painting without detailed knowledge of either the painter, Guido Reni, or of the particular church in Rome. Proceeding via worlds, questions and media, we thus move from a vague question about angels, which produces an unmanageable 191 million results, to a specific query about a given painting which helps us further in our studies.

The depth of research will determine the level of detail, or granularity, to which this method applied. In many cases, a simple survey of subjects linked with a standard classification will be sufficient. In other cases, mappings among multiple classification systems will be useful. In some cases, we shall wish to search the titles linked with those subjects and occasionally we need a full search of the complete contents of these titles. These needs are determined also by the level of the user. A high school student looking for a quick answer to a school essay, needs much less than a scholar writing a standard monograph. These needs are also shaped by our goal. A tourist whose goal is recreation looks for different things in London than the scholar writing a standard history of the city. Future systems will make level of education and goals a basic part of their filters, just as students in the physical world are expected to go first to their school and local libraries rather than rushing at once to the British Library or the Vatican.

### Different Ways of Knowing

As Philippe Quéau (2003) [104] has noted, knowledge is very much linked to different cultural traditions in different languages. In Italian and in French, the words for knowledge are linked with taste: *sapienza* and *savoir*, cf. English "savour". This knowledge is more in the sense of know-how, cf. German, *können* and *Kunst*. Appropriately there are many *savoirs*. The French word for certified knowledge is *connaissance*. The Hebrew word for knowledge is linked with carnal knowledge. The Sanskrit word for knowledge is linked with parturition. In German, *Wissenschaft* also exists is in the plural (*Wissenschaften*) and yet there is an underlying assumption that there is one corpus of knowledge. The English word, "knowledge", lacks the ontological dimensions of the German, is more intuitive, and yet there is a deep sense that knowledge is a singular term, such that to speak of knowledges seems contradictory, although phrases such as kinds of knowledge and ways of knowing, which amount to something similar, pose no problems.

Knowledge is integrally linked with language. In the early days of the Internet, it was generally assumed that the Internet would be predominantly English. Indeed, until 1995, the Internet was more than 90% English. The rise of the World Wide Web has transformed this. English fell to 50% (2000), to 28.9% (2007) and continues to fall. Chinese which had effectively no presence in 1995 is now the second language of the Internet with 14.7 %. Since January 2007, Spanish is the 3rd language of the Internet with 8.9%. Portuguese is the 7th language with 3.6.[105] There are now more persons with Spanish as their mother tongue than English. Despite the greater numbers of Chinese, it is unlikely that Chinese will become the *lingua franca* of the 21st century. Hence, Spanish is positioned to become the second most

important language internationally and could one day become the number one language world-wide.

In March 2007, the top ten languages of the Internet represented 82.3% of all users. So one obvious challenge lies in translating content of Internet into these ten main languages. A more subtle challenge is how these translations will manage to keep in focus the different senses of knowledge and different ways of knowing of these languages. A deeper challenge is even more elusive. South America alone has 547 languages.[106] Ethnologue[107] has recorded 6912 languages around the world. How can we create systems that reflect the richness of this linguistic diversity?

### Semantic Webs

The fashion of the day sees the next steps in logic as a key to a semantic web which, we are assured, will make possible machine-to-machine communication. This is essential to ensure that the basic container for the Internet is logically sound. However, if only logical statements were acceptable in the World Wide Web, then the quest to add content produced by humans, which is about much more than logic, would be futile. Adapting our previous matrix (Appendices 2 and 4), we see that logic focuses on cubbyhole 8. If we use logic to explain science, then we still have only 2 of the 30 cubbyholes (8 and 14), which still ignores 28/30ths of what we do as humans. If we want semantics in the human sense, then we need to make the history of human meanings (etymological dictionaries) a central dimension. Instead of building Internet databases as if they were one static system of true statements, we need dynamic systems that reveal how meanings shift temporally and geographically, e.g. how "nice" in the modern United States is not "nice" in Elizabethan England. Such shifts in individual meanings of words in a language are only the most obvious manifestation of different kinds of knowledge. In future, we need search engines that reveal how different philosophical schools or ways of knowing focus on certain areas of knowledge, while excluding others. Today's search engines focus on areas of knowledge: we also need maps of the areas and domains of ignorance, so that we can understand courses for future research.

### Relations

Our matrix of worlds and questions offers a way forward in understanding relations and underlying differences between science and art. Relations are a quintessential dimension of human activities. Every time we say that someone or something "is" we are making a relation. Science is focussed on systematic relations that are persistent and theoretically eternal and necessary,[108] e.g. subsumptive relations (meronymy, partonomy); determinative relations (e.g. law of gravity and $e=mc^2$) and ordinal relations[109] (e.g. temporal and spatial). In terms of the big picture, some disciplines belong to a specific concept or cubbyhole in the matrix: e.g. arithmetic and geometry belong to cubbyhole 8. Disciplines such as astronomy and music, which Aristotle called mixed sciences, are those which bridge two worlds, in this case, mental and physical (cubbyholes 8 and 14). With the advancement of science, a discipline that begins from a focus in one cubbyhole uses methods from another cubbyhole. For example, botany is initially cubbyhole 14 (the question what? applied to the vegetable kingdom). Since Linnaeus, botany uses methods of taxonomy, so early modern botany is a combination of cubbyhole 8 and 14. In the modern world, where botany becomes part of the bio-sciences, the range of relations increases accordingly. These efforts result in disciplines such as taxonomy, and partonomy, that focus on subsumptive relations.

A second domain of systematic relations comes from library and information science. These pragmatic methods for knowledge organization were traditionally called classification systems, and thesauri. While there are thousands of such systems, it is noteworthy that there are only six, which claim to be universal in scope.[110] In the jargon of computer science, classification systems and thesauri are now referred to in the same breath as taxonomy, as examples of ontologies. This creates more confusion than clarity, because it conflates cases, where there is a scientific quest to explain truths of nature (taxonomy), with pragmatic approaches such as the Dewey Decimal System (DDC) and the Library of Congress, which do not have such a clear scientific method.

A third domain of systematic relations is comes from a combination of religion, mythology, astronomy and botany and biology, linked with number symbolism. Hence we have three graces, seven days of the week, seven chakras, cardinal virtues, seven vices. In complex cultures such as India, these relations are multi-layered: i.e. something in the physical world, has its corresponding animal, plant, and gem in the animal, mineral and vegetable worlds, and its corresponding planet and/or star in the heavens. Some of these relations have a scientific basis. Others do not. Cynics would dismiss all such relations as leftovers from a superstitious past. Cultural historians will note that such relations serve as memory aids and structuring aids in creating microcosm-macrocosm analogies. Hence, even if they are not necessarily true in modern scientific terms, they are keys to understanding earlier attempts at science and are central to earlier visions of meaning in the universe. For the ancients they constituted a proto-semantic web in analogue form. Hence, it is important to document these relations while remaining very clear that they are of a different order than those of science and library science.

Meanwhile, there are other categories of relations, which are usually applied individually rather than systematically. The most disciplined of these is scholarship, which makes relations with individual objects, ideas and concepts. While the aim is truth, the criterion is ultimately not whether the relations are true, but rather to what extent interpretations are linked clearly with the object under discussion, whereby any claims made can be re-examined. This is scholarship's equivalent of repeatable experiments in science and explains why sources (the return *ad fontes*), is central to scholarship.

In contrast to science, which focuses on relationships in nature that (pace Heisenberg) are theoretically true without human intervention, language, literature and art focus on relations where human intervention is central to the process.[111] Language, as recorded in dictionaries entails definitions that tell us what a word "is". These definitions change temporally and geographically, may become obsolete, but remain meaningful, which is why we have etymological dictionaries. In science, only eternally true terms are meaningful. In language, all meanings that are recorded, remain potentially useful.

Literature, another of the basic human interventions, sometimes begins with cubbyhole 14, but is free to use any of the cubbyholes as its point of departure. Greatness in a work of literature is not about the extent that it describes a cubbyhole, concept or discipline, but rather in ways it suggests relations that stimulate and inspire a reader to jump between and among categories. This is equally true in art, where a painting as a canvas may seem to belong to cubbyhole 14, but as a painting its value lies in the extent to which that canvas links the viewer to cubbyhole 8 and possibly others. If the painting is about the *Last Judgment* it will link to cubbyhole 2. If it is about an historical event in the Renaissance, it will link to cubbyhole 16 and so forth.

| | |
|---|---|
| Systematic | |
| 1) Science | Systematic Subsumptive Relations (Taxonomy, Partonomy ) Determinative, Ordinal Relations |
| 2) Knowledge | Potentially Systematic Subsumptive, Determinative, Ordinal Relations (Classifications and Thesauri) |
| 3) Symbolism | Systematic Relations linking Numbers with the Physical, Metaphysical Worlds |
| Individual | |
| 4) Scholarship | Fixed Relations to Specific Objects, Concepts, Ideas |
| 5) Language, Literature, Art | Suggestive Relations Across Objects, Concepts, Cubbyholes |
| 6) Criticism, Secondary Lit. | Intuitive Relations which may or may not be true. |

Figure 8. Different Categories of Relations.

Returning for a moment to Guido Reni's painting mentioned earlier, the *Archangel Michael* (Rome, c. 1635), "tramples a Satan with the vividly recognizable features of Pope Innocent X".[112] Here any attempt to identify the pope as Satan in the sense of Innocent X = Satan would as be naïve, as it would be to insist that there is no association. Authors and artists use as one of their central tools, metaphor, which is ultimately an equation that insists it is not an equation or in Shakespeare's words: "And nothing is but what is not." This also explains why related figures of speech such as simile, analogy and allusion, other tools of non-equation, are also central to language, literature and art.

Whereas science promises to tell us the truth about what a cubbyhole "is" or equals (=), language, literature and art show the truths of discovering what a cubbyhole is not; that there are worlds beyond the cubbyhole of the present equation, and that the relations with those other worlds matter as much as the cubbyholes themselves. These are dimensions to which Pascal alluded with his proverb: "the heart has its reasons which reason does not know" (*Le coeur a ses raison, que la raison ne connâit pas*).

While traditional science[113] functioned on quiddity, which defines cubbyholes and necessary relations, art fosters relations, which are bridges across and beyond cubbyholes, which may be true, while not being truly essential to the workings of nature as such. The ambiguity of this metaphorical spirit of art, means that much is open to interpretation. Whence, there arises a fourth category of relations, which attempt to explain the interventions of art. These are the domain of disciplines such as literary criticism, literary history, aesthetics, art criticism and art history. Finally, there is a fifth category, where relations and associations are made without a clear method or direct evidence. These range from interesting intuitions, which may, or may not be true, to unfounded claims, hoaxes, or even deliberate disinformation (Figure 8).

Using these categories, we see that contemporary efforts towards a semantic web are largely focussed on systematic relations, namely, 1) science (taxonomy) and 2) knowledge (classifications and thesauri) under the rubric of ontologies. Meanwhile, hotwords and hyperlinks in the electronic world, are direct descendents of a quest to link a claim with the source thereof in 3) scholarship. Categories 3, 5 and 6 have yet to be addressed seriously. A future semantic web will potentially need to address all these categories. In practical terms, this implies that hyperlinks as one-to-one links between a word in a text and a reference, need revision. Such links address only direct relations of scholarship. Needed are multi-layered links, to reflect the various kinds of relations considered above. .

A semantic web in this a deeper sense also needs to trace a history of how Dialectic (cubbyhole 2), shifted to logic (cubbyhole 8). It needs to describe and if possible explain a) how the rise of philosophy, through natural philosophy to science, eventually led to 30 and later any more cubbyholes; b) how art created an increasingly complex set of relations bridging the cubbyholes; c) how scholarship established a great many serious claims for possible relations, some carefully documented (e.g. proper footnotes), others less so.

We noted earlier that the best way to ask and receive was to have more precise terms when asking questions. If we treat ontology as a unique key to search algorithms we are limited to the terms of that ontology. However, if we treat ontologies as alternative lists of relations, then these multiple systems can be combined to generate richer vocabularies for our pre-searching phase. Positioning these richer vocabularies within matrices potentially multiplies a single question into 30 more precise questions. The art of asking the right question thus becomes largely an art of finding precise terms with which to reframe a question. This leads to better answers and also opens new approaches to knowledge.

In 1967, Edward de Bono wrote a book, *The Use Lateral Thinking.*[114] He claimed that the way to solve a problem often requires being able to look at it in a different way. This insight led him to become a world authority in what is now called creative thinking.[115] We need, in the long term, to apply this personal insight to the realm of knowledge as a whole, using methods from the history of philosophy and history of knowledge organization, to make different ways of knowing part of our systems. We also need new comparative histories of knowledge, which adapt matrices such as those outlined above in order to show how choosing a given way of knowing also determines, which kinds of things we know and cannot know. Such efforts are much more than attempts to create a modern day *Encyclopédie* on steroids. If lateral thinking is a way towards creative thinking, then systematic study of the history of ways in which man has bridged his concepts (cubbyholes), and a history of border crossings of the mind and spirit, offer new approaches to creativity.

## 7. Conclusions

The thrust of this paper has focussed on virtual and digital reconstructions, outlining key moments in their development during the past 50 years. We explored seven application areas, namely, restoration, tourism, architecture, history, entertainment, education and games. (Figure 2), which have evolved in parallel. These developments have come together through two waves of convergence. A first wave brought Multi-Sensory Media or Multimedia. A second wave brought networked Information and Communication Technologies (ICT). In the past decade, there is evidence of a third wave towards Universal Convergence Technologies (UCT), whereby Mapping, Reconstructing, Recognition, and Embedding are also becoming interconnected. One important feature of this latest convergence is that the physical world, which was once seen as a passive object of study, now potentially becomes an interface to link with knowledge in memory institutions. In the past, we went to memory institutions such as libraries to study the world. In future, we can also use the world to study the contents of memory institutions.

These waves of convergence linked with the rise of the Internet entail an explosion in information and knowledge. In the late 19th and early 20th centuries, an early wave of expansion led to visions of a global brain (*Gehirn der Welt*), and to institutions such as the Mundaneum and International Union of Associations (UIA) with a commitment to new levels of bibliographical control. It follows that the explosion of the Internet requires new levels of

knowledge organization. Anthony Judge, a long-time head of the UIA has outlined some possibilities, which mark a valuable contribution. In our view, there is also a need to have more systematic access through scales of knowledge and worlds of knowledge.

Central to the human condition is the notion of relations, which are the basis of taxonomy, classification systems, thesauri, which are now typically called ontologies. Using matrices which combine worlds and basic questions (Appendices 2-4) we can arrive at new insights into the differences in goals of art and science as a starting point for a new organization of knowledge. In this quest, we need to maintain a multilingual approach, which also reflects multiple ways of knowing. Science attempts to define concepts (cubbyholes) of knowing. Scholarship establishes clear one-to-one links between claims, references, footnotes and ultimately the sources themselves. Language, literature and art insist on suggesting, implying and inviting metaphorical relations that allow us to jump between and among such concepts, categories and cubbyholes. In so doing, they constantly remind us that beyond everything that exists, there are many other things that could be. Artists call this the spark of inspiration. Others call this the essence of creativity. This is why the creation of virtual and digital reconstructions is much more than an immaterial copying of physical buildings. It points beyond the five worlds (metaphysical, mental, physical, man-made and social) to a sixth world, a world of dreams, of the possible, of the one thing that Pandora's box could not disturb: hope. Some call it creativity. Others call it one of the highest expressions of the human condition along with faith and love.

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Appendix 1: Some key companies in the fields of Graphics, Visualization, and Simulation.

Military
1968 Evans and Sutherland > Rockwell Collins

Projection, Film and Television
1849 Carl Zeiss
1926 Goto Inc.
1934 Barco
1934 Walt Disney
1945 Spitz Inc. > Evans and Sutherland
1967 IMAX

1971 Robert Abel and Assoc. > Wavefront > Autodesk
1975 Industrial Light and Magic

1983 Alias > SGI > Autodesk
1984 Wavefront Technologies > SGI > Autodesk
1984 BUF
1984 Pixar > Disney
1986 Softimage > Microsoft > Avid
1987 Side Effects
1987 Avid
1987 Rhythm and Hues
1994 Dreamworks LLC > Viacom

Architecture and Engineering
1981 CATIA Dassault Systemes
1982 Archicad Graphisoft
1982 AutoCAD Autodesk
1984 Microstation Bentley Systems
1992 Chief Architect Chief Architect Inc.
1999 SketchUp Last Software > Google

Appendix 2. Worlds, Questions and Disciplines

| | Who? | What? | Where? | When? | How? | Why? |
|---|---|---|---|---|---|---|
| 1.Metaphysical | | Dialectic | | | | Religion<br>Philosophy |
| 2. Mental | | Language<br>Grammar<br>Logic<br>Arithmetic<br>Geometry | | | Rhetoric | |
| 3. Physical | Biography | Science<br>Medicine | Geography | History | | |
| 4. Man-Made | | Architecture<br>Engineering | | | | |
| 5. Social | | Law<br>Sociology | | | | Pyschology |

Appendix 3: A grid of worlds and questions for angels.

| | Who? | What? | Where? | When? | How? | Why? |
|---|---|---|---|---|---|---|
| 1.Metaphysical | Archangel Michael Archangel Raphael | 9 Orders of Angels | | | | Causes of Angels |
| 2. Mental | Angels: Lists | Angel: Novels | Positions of Angels in Heavens | History of Angels | | |
| 3. Physical | | Angel Flower | | | | |
| 4. Man-Made | | Angel: Statues | | | | |
| 5. Social | | | | | | |

Appendix 4: A grid of worlds and questions for schools of knowledge.

| | Who? | What? | Where? | When? | How? | Why? |
|---|---|---|---|---|---|---|
| 1.Metaphysical | 1 | 2 | 3 | 4 | 5 | 6 |
| 2. Mental | 7 | 8 | 9 | 10 | 11 | 12 |
| 3. Physical | 13 | 14 | 15 | 16 | 17 | 18 |
| 4. Man-Made | 19 | 20 | 21 | 22 | 23 | 24 |
| 5. Social | 25 | 26 | 27 | 28 | 29 | 30 |

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> Man would no longer need documentation if he were assimilated into an omniscient being - as with God himself. But to a less ultimate degree, a technology will be created acting at a distance and combining radio, X-rays, cinema and microscopic photography. Everything in the universe, and everything of man, would be registered at a distance as it was produced. In this way a moving image of the world will be established, a true mirror of his memory. From a distance, everyone will be able to read text, enlarged and limited to the desired subject, projected on an individual screen. In this way, everyone from his armchair will be able to contemplate creation, as a whole or in certain of its parts.

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> The computer will become the hub of a vast network of remote data stations and information banks feeding into the machine at a transmission rate of a billion or more bits of information a second. Laser channels will vastly increase both data capacity and the speeds with which it will be transmitted. Eventually, a global communications network handling voice, data and facsimile will instantly link man to machine--or machine to machine--by land, air, underwater, and space circuits. [The computer] will affect man's ways of thinking, his means of education, his relationship to his physical and social environment, and it will alter his ways of living... [Before the end of this century, these forces] will coalesce into what unquestionably will become the greatest adventure of the human mind.--from *David Sarnoff* by Eugene Lyons, 1966.

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> Today, as a member of the Federal Homeland Security Science and Technology Committee, I am pleased to tell you that the gaming industry could become an important ally in our fight to secure our homeland from terror.
> I can't stress strongly enough the value of using simulation technology to help educate the public about the threats that we face: from SARs, anthrax, and avian flu to weapons of mass destruction and natural events like hurricanes – these different types of threats all pose the same life-threatening consequences.
> We need to be able to respond to these various types of natural and man-made threats — an atomic bomb vs. a dirty bomb….anthrax vs. Ebola…a terrorist attack on a building vs. an earthquake — but the best response in one instance will likely be different from the best solution in another.
> We will secure our citizens with a cookie-cutter approach to dealing with homeland security threats. Indeed, we all want to move away from having a sheet of plastic and duct tape reflect our response to these threats

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http://images2.ggl.com/articles/3972/flyboys.jpg
[91] Linux : www.zwahlendesign.ch/en/node/130
[92] Mira Lab, Media Gallery: http://www.miralab.unige.ch/

Meanwhile, there have been other attempts such as RetroFilm.com, which foresaw taking images of Marilyn Monroe, creating avatars that performed every possible motion that Marilyn might ever have made and literally try to copyright her every move. This venture formerly at http://www.retrofilm.com/monroe/marilyn.jpg is now bankrupt. If the Renaisance had copyrighted the Life of Christ and the Saints we probably would not have had a Renaissance.

[93] See: http://sumscorp.com/kavai/newmedia/ under subjects: Convergence.

[94] For a more thorough discussion see the author's *Augmented Knowledge and Culture*, Calgary: University of Calgary Press, 2006. and also the website: http://sumscorp.com/kavai/newmedia/ under Subjects under Convergence 3.

[95] For a discussion of a larger philosophical context see: "The New Book of Nature", *eARCOM 07. Sistemi informativi per l'Architettura Convegno Internazionale,* Con il Patrocinio di UNESCO. Ministero dei Beni Culturali, CIPA, Regione Marche, Ancona-Portonovo Hotel La Fonte, 17-18-19 Maggio 2007, Ancona: Alinea Editrice, 2007, pp. 659-669.

[96] See note 78 above.

[97] For a more thorough discussion see the site on New Media: http://sumscorp.com/kavai/newmedia/ under Subjects under World Brain.

[98] Union of Imaginative Associations: http://www.un-imagine.org/

[99] Complementary Initiatives and their Historical Associations: http://un-intelligible.org/context/fourfold.php

[100] Wiki: http://en.wikipedia.org/wiki/Powers_of_Ten

[101] For a more detailed discussion see the author's: "Towards a Semantic Web for Culture," *JoDI* (*Journal of Digital Information*)**,** Volume 4, Issue 4, Article No. 255, 2004-03-15. Special issue on New Applications of Knowledge Organization Systems. See: http://jodi.ecs.soton.ac.uk/Articles/v04/i04/Veltman/ (87 pp.).

[102] Dr. Alan Radley, Spectasia: http://www.spectasia.com/

[103] Cf. Wiki: http://www.search.com/reference/Pope_Innocent_X

[104] Philippe Quéau, "Information Policies for Knowledge Societies," *EVA Moscow*, 1-5 December 2003. See: http://evarussia.ru/upload/doklad/dokladEn_1080.doc**.**

[105] World Internet Stats: http://www.internetworldstats.com/stats.htm

[106] Internationale Kommunikationskulturen: www.payer.de/kommkulturen/kultur031.htm

[107] Ethnologue: http://www.ethnologue.com/

[108] Scientists claim that the relations of science are persistent and true. They begin with hypotheses. If they are experimentally confirmed they are called scientific laws. If these claims be disproven then they are outside the realm of science. In the real world, the claims of science are constantly being adjusted and developed. That is why history of science is a discipline.

[109] In the 1960s, the work of Ingetraut Dahlberg and Jean Perreault distinguished between subsumptive, determinative and ordinal relations in an attempt to bring greater precision to the Universal Decimal Classification (UDC), which Otlet and La Fontaine had created by refining Dewey's original DDC. See: J. M. Perreault, "Categories and relators: a new schema", *Revue internationale de la documentation*. V. 32.4, 1963, pp. 136 -144. Dr. Ingetraut Dahlberg contributed to this work although she is not listed as a co-author. This work built on a major contribution by Eric De Grolier, *A Study of General Categories Applicable to Classification and Coding in Documentation,* Paris: UNESCO, 1962. Also important in this context is are the efforts of UNISIST: http://www.db.dk/bh/Core%20Concepts%20in%20LIS/articles%20a-z/unisist_model_of_information_dis.htm

For a more thorough bibliography see: ISKO Italia. Integrative level classification: http://www.iskoi.org/ilc/ref.htm

[110] These are:

1. Library of Congress (LC)
2. . Dewey Decimal Classification (DDC)
3. Universal Decimal Classification (UDC)
4. Riders International
5. Ranganathan
6. Bliss.

In addition there are two art classifications which aspire to be international:

1. Iconclass
2. Art and Architectural Thesaurus (AAT).

For a comprehensive history of claasifications see: E.I. Samurin, *Geschichte der bibliotekarisch-bibliographischen Klassifikation. Band I-II, 1967***.** München: Verlag Dokumentation. Cf. Classification System: Library Science: http://www.db.dk/bh/Lifeboat_KO/CONCEPTS/classification_systems.htm

[111] As Heisenberg noted there are paradoxes: to search for these laws requires experiments that involve human intervention which, in turn, change the conditions of that which is being studied.

[112] Wiki: http://en.wikipedia.org/wiki/Pope_Innocent_X

[113] Since the advent of Einstein's theory of relativity, the situation of science, has become more complex . Cf. Ernst Cassirer, Structure and Function, *Substanzbegriff und Funktionsbegriff: Untersuchungen über die Grundfragen der Erkenntniskritik*. Berlin: Bruno Cassirer, 1910. Translated as *Substance and Function*. Chicago: Open Court, 1923: http://plato.stanford.edu/entries/cassirer/

[114] Edward de Bono, *The Use of Lateral Thinking*, London: Jonathan Cape, 1967. Cf: http://www.edwdebono.com/debono/lateral.htm

[115] Edward de Bono: http://www.edwdebono.com/

[116] SUMS: http://sumscorp.com/

[117] Virtual Heritage: http://www.virtualheritage.net/.

[118] Augmented Knowledge and Culture: http://sumscorp.com/kavai/newmedia/