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New Media and Transformations in Knowledge (I)

Introduction

As media change so also do our concepts of what constitutes knowledge. This, in a sentence, is a fundamental insight that has emerged from research over the past sixty years.[1] In the field of classics, Eric Havelock (Havelock 1963), showed that introducing a written alphabet, shifting from an oral towards a written tradition, was much more than bringing in a new medium for recording knowledge. When claims are oral they vary from person to person. Once claims are written down, a single version of a claim can be shared by a community, which is then potentially open to public scrutiny, and verification.[2] The introduction of a written alphabet thus transformed the Greek concept of truth (*episteme*) and their concepts of knowledge itself. In the field of English Literature, Marshall McLuhan (McLuhan 1962; McLuhan 1964)[3] influenced also by historians of technology such as Harold Innis (Innis 1986; Innis 1964, Stamps 1995)[4] went much further to show that this applied to all major shifts in media. He drew attention, for example, to the ways in which the shift from handwritten manuscripts to printed books at the time of Gutenberg had both positive and negative consequences on our world-view (Gordon 1997). In addition, he explored how the introduction of radio and television further changed our definitions of knowledge. These insights he distilled in his now famous phrase: *the medium is the message*.

Pioneers in technology, such as Vannevar Bush[5], Douglas Engelbart[6], and visionaries such as Ted Nelson[7], have claimed from the outset that new media such as computers and networks also have implications for our approaches to knowledge. Members of academia and scholars have become increasingly interested in such claims, leading to a spectrum of conclusions. At one extreme, individuals such as Derrick de Kerckhove (Kerckhove 1995; Kerckhove 1997)[8], follow the technologists in assuming that the overall results will invariably be positive. This group emphasizes the potentials of collective intelligence. This view is sometimes shared by thinkers such as Pierre Lévy (Lévy 1998; Lévy 1996)[9] who also warn of the dangers of a second flood, whereby we shall be overwhelmed by the new materials made available by the web.

Meanwhile, others have explored more nuanced assessments. Michael Giesecke (Giesecke 1991; see also Stock 1983), for instance, in his standard history of printing (focussed on Germany), has examined in considerable detail the epistemological implications of printing in the fifteenth and sixteenth centuries and outlined why the advent of computers invites comparison with Gutenberg's revolution in printing. Armand Mattelart (Mattelart 1985; Mattelart 1994; Mattelart 1997)[10], in his fundamental studies, has pointed out that the rise of networked computers needs to be seen as another step towards global communications. He has also shown masterfully that earlier steps in this process, such as the introduction of the telegraph, telephone, radio and television, were each accompanied by more global approaches to knowledge, particularly in the realm of the social sciences. The present author has explored some implications of computers for museums (Veltman 1992), libraries (Veltman 1998), education (Veltman 1993a; Veltman 1997) and knowledge in general (Veltman 1983; Veltman 1993b).

In the context of museums seven elements were outlined: scale, context, variants, parallels, history, theory and practice; abstract and concrete; static and dynamic. Two basic aspects of these problems were also considered. First, computers entail much more than the introduction of yet another medium. In the past, each new innovation sought to replace former solutions: papyrus was a replacement for cuneiform tablets; manuscripts set out to replace papyrus and printing set out to replace manuscripts. Each new output form required its own new input method. Computers introduce fundamentally new dimensions in this evolution by introducing methods of translating any input method into any output meth-

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od. Hence, an input in the form of an oral voice command can be output as a voice command (as in a tape recording), but can equally readily be printed, could also be rendered in manuscript form or potentially even in cuneiform. Evolution is embracing not replacing.

Second, networked computers introduce a new cumulative dimension to knowledge. In the past, collections of cuneiform tablets, papyri, manuscripts and books were stored in libraries, but the amount of accessible knowledge was effectively limited to the size of the largest library. Hence knowledge was collected in many parts but remained limited by the size of its largest part. In a world of networked computing the amount of accessible knowledge is potentially equal to the sum of all its distributed parts.

In deference to the mediaeval tradition, we shall begin by expressing some doubts (*dubitationes*), concerning the effectiveness of present day computers. In a fascinating recent article, Classen assessed some major trends in new media (Classen 1998).[11] He claimed that while technology was expanding exponentially, the usefulness[12] of that technology was expanding logarithmically and that these different curves tended to balance each other out to produce a linear increase of usefulness with time. He concluded i) that society was keeping up with this exponential growth in technology, ii) that in order to have substantial improvements especially in education *fortunes have to be spent on R&D to get there*, and finally iii) that *we in industrial electronics research can still continue in our work, while society eagerly adopts all our results*. (Classen 1998: 184)

Dr. Classen's review of technological progress and trends is brilliant, and we would fully accept his second and third conclusions. In terms of his first conclusion, however, we would offer an alternative explanation. He claims that the (useful) applications of computers have not kept up with the exponential expansion of technology due to inherent limits imposed by a law of usefulness. We would suggest a simpler reason: because the technology has not yet been applied. In technical terms, engineers and scientists have focussed on ISO layers 1–6[13] and have effectively ignored layer 7: applications.

Some examples will serve to make this point. Technologists have produced storage devices, which can deal with exobytes at a time (figure 1). Yet all that is available to ordinary users is a few gigabytes at a time. If I were only interested in word processing this

would be more than sufficient. As a scholar, however, I have a modest collection of 15,000 slides, 150 microfilms, a few thousand books and seven meters of photocopies. For the purposes of this discussion we shall focus only on the slides. If I wished to make my 15,000 slides available on line, even at a minimal level of 1 MB per slide, that would be 15 gigabytes. Following the standards being used at the National Gallery in Washington of using 30 megabytes per image, that figure would rise to 450 gigabytes. Accordingly, a colleague in Rome, who has a collection of 100,000 slides, would need either 100 gigabytes for a low-resolution version or 4 terabytes for a more detailed version.

Figure 1: Basic terms of size in electronic storage

1000 bytes	=	1 kilobyte
1000 kilobytes	=	1 megabyte
1000 megabytes	=	1 gigabytes
1000 gigabytes	=	1 terabyte
1000 terabytes	=	1 petabyte
1000 petabytes	=	1 exobyte

In Europe museums tend to scan at 50 MB/image which would raise those figures to 5 terabytes, while research institutions such as the Uffizi are scanning images at 1.4 gigabytes per square meter. At this resolution 100,000 images would make 1400 terabytes or 1.4 petabytes. There are no machines available at a reasonable price in the range of 450 gigabytes to 1.4 petabytes. The net result of this math exercise is thus very simple. As a user I cannot even begin to use the technology so it might as well not exist. There is no mysterious law of usefulness holding me back, simply lack of access to the technology. If users had access to exobytes of material, then the usefulness of these storage devices would probably go up much more than logarithmically. It might well go up exponentially and open up undreamed of markets for technology.

Two more considerations will suffice for this brief excursus on usefulness. Faced with the limitations of storage space at present, I am forced as a user to employ a number of technologies: microfilm readers, slide projectors, video players (sometimes in NTSC, sometimes in PAL), televisions, telephones, and the usual new technologies of fax machines, computers and the Internet. All the equip-

ment exists. It is almost impossible to find all of it together working in a same place, and even if it does, it is well nigh impossible to translate materials available in one medium, to those in another medium. We are told of course that many committees around the world are busily working on the standards (e.g. JPEG, JHEG, MPEG) to make such translations among media simple and nearly automatic. In the meantime, however, all the hype in the world about interoperability, does not help me one iota in my everyday efforts as a scholar and teacher. The net result again is that many of these fancy devices are almost completely useless, because they do not address my needs. The non-compatibility of an American, a European and a Japanese device may solve someone's notion of positioning their country's technology, but it does not help users at all. Hence most of us end up not buying the latest device. And once again, if we knew that they solved our needs, their usefulness and their use might well rise exponentially.

Finally, it is worthwhile to consider the example of bandwidth. Technologists have recently demonstrated the first transmission at a rate of a terabyte per second. A few weeks ago at the Internet Summit a very senior figure working with the U.S. military reported that they are presently working with 20–40 gigabits a second, and that they are confident they can reach terabyte speeds for daily operations within two years. Meanwhile, attempts by G7 pilot project five to develop demonstration centres to make the best products of cultural heritage accessible on an ATM network (a mere 622 MB / second) have been unsuccessful. A small number of persons in large cities now have access to ADSL (1.5 MB / second), while others have access to cable modems (0.5 MB / second). Even optimistic salesmen specializing in hype are not talking about having access to ATM speeds directly into the home anywhere in the foreseeable future. Hence, most persons are limited to connectivity rates of .028 or .056 MB / second, (in theory, while the throughput is usually much lower still), which is a very long way from the 1,000,000,000 MB (i.e. terabyte) that is technically possible today.

With bandwidth as with so many other aspects of technology, the simple reality is that use in real applications by actual users has not nearly kept pace with developments in technology. If no one has access to and chances to use the technology, if there are no examples to demonstrate what the technology can do, then it is hardly surprising that so-called usefulness of the technology lags behind. We would conclude therefore that there is no need to as-

sert logarithmic laws of usefulness. If technology is truly made available, its use will explode. The Internet is a superb example. The basic technology was there in the 1960's. It was used for over two decades by a very select group. Since the advent of the World Wide Web, when it was made available to users in general, it has expanded much more each year than it did in the first twenty years of its existence.

So what would happen if all the technological advances in storage capacity, processing power, bandwidth were available for use with complete interoperability? What would change? There would be major developments in over thirty application fields. Rather than attempt to examine these systematically, however, this paper will focus instead on some of the larger trends implicit in these changes. I shall assert that computers are much more than containers for recording knowledge, which can then be searched more systematically. They introduce at least seven innovations, which are transforming our concepts of knowledge. First, they offer new methods for looking at processes, how things are done, which also helps in understanding why they are done in such ways. Second, and more fundamentally, they offer tools for creating numerous views of the same facts, methods for studying knowledge at different levels of abstraction. Connected with this is a third innovation: they allow us to examine the same object or process in terms of different kinds of reality. Fourth, computers introduce more systematic means of dealing with scale, which some would associate with the field of complex systems. Fifth, they imply a fundamental shift in our methods for dealing with age-old problems of relating universals and particulars. Sixth, they transform our potential access to data through the use of meta-data. Seventh and finally, computers introduce new methods for mediated learning and knowledge through agents. This paper explores both the positive consequences of these innovations and examines some of the myriad challenges and dangers posed thereby.

Processes

Media also affect the kinds of questions one asks and the kinds of answers one gives to them. The oral culture of the Greeks favoured the use of *What?* and *Why?* questions. The advent of printing in the

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Renaissance saw the rise of *How?* questions. As storage devices, computers are most obviously suited to answering questions concerning biography (*Who?*), subjects (*What?*), places (*Where?*) and chronology (*When?*). But they are also transforming our understanding of processes (*How?*) and hence our comprehension of relations between theory and practice. In the past decades there has, for instance, been a great rise in workflow software, which attempts to break down all the tasks into clearly defined steps and thus to rationalize the steps required for the completion of a task. This atomization of tasks was time consuming, expensive and not infrequently very artificial in that it often presented isolated steps without due regard to context.

Companies such as Boeing have introduced augmented reality techniques to help understand repair processes. A worker fixing a jet engine sees superimposed on a section of the engine, the steps required to repair it. Companies such as Lockheed are going further: reconstructing an entire workspace of a ship's deck and using avatars to explain the operating procedures. This contextualization in virtual space allows users to follow all the steps in the work process (McCarthy/Stiles 1998).[14]

More recently companies such as Xerox (Pycock/Palfreyman/Allanson/Button 1998) have very consciously developed related strategies whereby they study what is done in a firm in order to understand what can be done. In the case of her Majesty's Stationary Office, for example, they used VRML models to reconstruct all the workspaces and trace the activities on the work-floor. As a result one can examine a given activity from a variety of different viewpoints: a manager, a regular employee or an apprentice. One can also relate activities at one site with those at a number of other sites in order to reach a more global view of a firm's activities. Simulation of precisely how things are done provides insights into why they are done in that way.

In the eighteenth century, Diderot and D'Alembert attempted to record all the professions in their vast encyclopaedia. This monumental effort was mainly limited to lists of what was used with very brief descriptions of the processes. The new computer technologies introduce the possibility of a new kind of encyclopaedia, which would not only record how things were done, but could also show how different cultures perform the same tasks in slightly or even quite different ways. Hence, one could show, for instance, how a

Japanese engineer's approach is different from that of a German or an American engineer. Instead of just speaking about quality one could actually demonstrate how it is carried out.

Computers were initially static objects in isolation. The rise of networks transformed their connectivity among these terminals into a World Wide Web. More recently there have been trends towards mobile or nomadic computing. The old notion of computers as large, bulky objects dominating our desks is being replaced by a whole range of new devices: laptop computers, palmtop and even wearable computers.[15] This is leading to a new vision called ubiquitous computing, whereby any object can effectively be linked to the network. In the past each computer required its own Internet Protocol (IP) address. In future, we are told, this could be extended to all the devices that surround us: persons, offices, cars, trains, planes, telephones, refrigerators and even light bulbs.

Assuming that a person wishes to be reached, the network will be able to determine whether they are at home, in their office, or elsewhere and route the call accordingly. If the person is in a meeting, the system will be able to adjust its signal from an obtrusive ring to a simple written message on one's portable screen, with an option to have a flashing light in urgent cases. More elaborate scenarios will adjust automatically room temperatures, lighting and other features of the environment to the personal preferences of the individual. Taken to its logical conclusions this has considerable social consequences,[16] for it means that traditionally passive environments will be reactive to users' needs and tastes, removing numerous menial tasks from everyday life and thus leaving individuals with more time and energy for intellectual pursuits or pure diversion.

At the international level one of the working groups of the International Standards Organization (ISO/IEC JTC1/WG4) is devoted to Document Description and Processing Languages, SGML Standards Committee. At the level of G8, a consortium spearheaded by Siemens is working on a Global Engineering Network (GEN).[17] Autodesk is leading a consortium of companies to produce Industry Foundation Classes, which will effectively integrate standards for building parts such as doors and windows. Hence, when someone wishes to add a window into a design for a skyscraper, the system will *know* what kind of window is required. In future, it will be desirable to add to these foundation classes both cultural and historical dimensions such that the system can recognize the differences

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between a Florentine door and a Sienese door of the 1470's or some other period.

The Solution Exchange Standard Consortium (SEL) consists of 60 hardware, software, and commercial companies, which are working to create an industry specific SGML markup language for technical support information among vendors, system integration and corporate helpdesks. Meanwhile, the Pinnacles Group, a consortium which includes Intel, National Semiconductor, Philips, Texas Instruments and Hitachi, is creating an industry specific SGML markup language for semiconductors. In the United States, as part of the National Information Infrastructure (NII)[18] for Industry with Special Attention to Manufacturing, there is a Multidisciplinary Analysis and Design Industrial Consortium (MADIC), which includes NASA, Georgia Tech, Rice, NPAC and is working on an Affordable Systems Optimization Process (ASOP). Meanwhile, companies such as General Electric are developing a Manufacturing Technology Library, with a Computer Aids to Manufacturing Network (ARPA/CAMnet).[19] ESI Technologies is developing Enterprise Management Information Systems (EMIS).[20] In the automotive industry the recent merger of Daimler-Benz and Chrysler point to a new globalization. A new Automotive Network eXchange (ANX)[21] means that even competitors are sharing ideas, a process which will, no doubt, be speeded by the newly announced automotive consortium at MIT. A preliminary attempt to classify the roles of different interaction devices for different tasks has recently been made by Dr. Flaig (Flaig 1998).

As Mylopoulos et al. (Mylopoulos/Jurisica/Yu 1998) have noted, in the database world, this tendency to reduce reality to activities and data goes back at least to the Structured Analysis and Design Technique (SADT). It is intriguing to note that the quest for such an approach has a considerable history. In the United States, where behaviorism became a major branch of psychology, Charles S. Pierce claimed that: *The only function of thinking is to produce acting habits.*[22] Such ideas have been taken up particularly in Scandinavia. For instance, Sarvimäki (Sarvimäki 1988), claimed that there is a continuous interaction between knowledge and action; that knowledge is created through and in action. These ideas have more recently been developed by Hjørland (Hjørland 1997).[23] Some would see this as part of a larger trend to emphasize subjective dimensions of reality in terms either of purpose (Hjelmslev 1961) or interest (Habermas 1972). Meanwhile, Albrechtsen and Jacob (Al-

brechtsen/Jacob 1998; cf. Albrechtsen 1993), have attempted to analyse work from a descriptive rather than a normative point of view. Building on the ideas of Davenport,[24] Star (Star 1989) and Law,[25] they have outlined an activity theory in terms of four types of work, namely, industrialized bureaucratically regulated work, learning network organization, craft type of individualized work and semi-independent market-driven result units.

If activities are seen as one aspect of the human condition such an activities based approach makes perfect sense. If, however, such activities are deemed to be the sole area to be studied, then one encounters the same problems familiar with a number of Marxist theoreticians. While claiming that reality must be reduced to the visible dimensions of practical, physical activities, they wish, at the same time, to create a conceptual, theoretical framework which goes beyond those very limits on which they insist.

Views and Levels of Abstraction

One of the fundamental changes brought about by computers is increasingly to separate our basic knowledge from views of that knowledge. Computer scientists refer to such views as contextualization, and describe them variously in terms of modules, scopes and scope rules (Norrie/Wunderli 1994). The importance of these views has increased with the shift towards conceptual modelling (Motschnik/Mylopolous 1992; Bubenko/Boman/Johannesson/Wangler 1997). In the case of earlier media such as cuneiform, manuscripts and books, content was irrevocably linked with a given form. Changing the form or layout required producing a new edition of the content. In electronic media this link between form and content no longer holds. Databases, for instance, separate the content of fields from views of that content. Once the content has been input, it can be queried and displayed in many ways without altering the content each time. This same principle applies to Markup Languages for use on the Internet. Hence, in the case of Standard Generalized Markup Language (SGML) and Extensible Markup Language (XML), the rules for content and rules for display are separate. Similarly in the case of programming, the use of meta-object protocols is leading to a new kind of open implementation whereby software defined aspects are separated from user defined aspects (figure 2). An emerging vision of network computers, foresees a day

when all software will be available on line, and users will need only to state their goals to find themselves with the personally adapted tools. Linked with this vision are trends towards reusable code (cf. Kelly 1998).[26]

Figure 2: Separation of basic software from user defined modalities through meta-object protocols in programming

Software Defined	User Defined
Base Program	Meta Program
Base Interface	Meta Interface

Related to the development of these different views of reality, is the advent of spreadsheets and data-mining techniques, whereby one can look at the basic facts in a database from a series of views at different levels of abstraction. Once a bibliography exists as a data-base, it is easy to produce graphs relating publications to time, by subject, by city, country or by continent. In the past any one of these tasks would have comprised a separate study. Now they are merely a different *view*.

One of the serious problems in the new electronic methods is that those designing the systems are frequently unfamiliar with the complexities of historical knowledge. An excellent case in point is the entity-relationship model, developed by Chen (Chen 1976),[27] which is the basis of most relational databases and object-oriented approaches. On the surface it is very simple. It assumes that every entity has various relationships in terms of attributes. Accordingly a person has attributes such as date of birth, date of death and profession. In the case of modern individuals this is often suffi-cient. In historical cases, however, the situation may be much more complex. For instance, there are at least five different theories a-bout the year in which the painter Titian died, so we need not only these varying dates but also the sources of these claims. Although entity-relationship models do not cope with this, other systems with conceptual modelling do. We need new attention to the often, implicit presuppositions[28] underlying software and databases and we need to bring professionals in the world of knowledge organiza-tion up to date concerning the developments in databases.

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Scale

These developments in views and different levels of abstraction are also transforming notions of scale. Traditionally every scale required a separate study and even a generation ago posed serious methodological problems.[29] The introduction of pyramidal tiling[30] means that one can now move seamlessly from a satellite image of the earth (at a scale of 1:10,000,000) to a life-size view of an object and then through a spectrum of microscopic ranges. These innovations are as interesting for the reconstruction of real environments such as shopping malls and tourist sites as they are for the creation of virtual spaces such as Alpha-World (Dramer 1998). Conceptually it means that many more things can be related. Systematic scales are a powerful tool for contextualization of objects.

These innovations in co-ordinating different scales are particularly evident in fields such as medicine. In Antiquity, Galen's description of medicine was limited mainly to words. These verbal descriptions of organs were in general terms such that there was no clear distinction between a generic description of a heart and the unique characteristics of an individual heart. Indeed the approach was so generic that the organs of other animals such as a cow were believed to be interchangeable with those of an individual.

During the Renaissance, Leonardo added illustrations as part of his descriptive method. Adding visual images to the repertoire of description meant that one could show the same organ from a number of different viewpoints and potentially show the difference between a typical sample and an individual one. However, the limitations of printing at the time made infeasible any attempts to record all the complexities of individual differences.

Today, medicine is evolving on at least five different levels. The GALEN project is analysing the basic anatomical parts (heart, lung, etc.) and systematically studying their functions and inter-relationships at a conceptual level. The Visible Human project is photographing the entire human body in terms of thin slices, which are being used to create Computer Aided Design (CAD) drawings at new levels of realism. In Germany, the Medically Augmented Immersive Environment (MAIE), developed by the Gesellschaft für Mathematik und Datenverarbeitung (GMD) and three Berlin hospitals, dedicated to radiology (Virchow), pathology (Charité) and surgery (RRK) respectively, are developing models for showing structural relations among body parts in real time. This system

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includes haptic simulation based on reconstructed tomographic scans. Other projects are examining the human body at the molecular and atomic level (figure 3). At present these projects are evolving in tandem without explicit attempts to co-relate them. A next step will lie in integrating all this material such that one can move at will from a macroscopic view of the body to a study of any microscopic part at any desired scale.

Figure 3: Different levels of scale in the study of contemporary medicine

Conceptual	GALEN[31]
Physical	Visible Human[32]
Structural	OP 2000 Medically Augmented Immersive Environment (MAIE)[33]
Molecular	Bio-Chemical
Atomic	Human Genome[34]

In the past, anatomical textbooks typically provided doctors with a general model of the body and idealized views of the various organs. The Virtual Human is providing very detailed information concerning individuals (three to date), which can then serve as the basis for a new level of realism in making models. These models can then be confronted with x-rays, ultra-sound and other medical imaging techniques, which record the particular characteristics of individual patients.

Elsewhere, in the Medical Subject Headings (MeSH) project, a semantic net includes five relationship classes: identity, physical, spatial, conceptual and functional, with tree category groupings for anatomic spaces, anatomic structural systems, anatomic substances and diseases (Bean 1998). Potentially such projects could lead to a systematic linking of our general knowledge about universals and our specialized knowledge about particulars (see section 7 below).

A somewhat different approach is being taken in the case of the human genome project. Individual examples are studied and on the basis of these a »typical model« is produced, which is then used as a set of reference points in examining other individual examples. Those deviating from this typical model by a considerable amount are deemed defective or aberrant, requiring modification and improvement. A danger in this approach is that if the parameters of

the normal are too narrowly defined, it could lead to a new a version of eugenics seriously decreasing the bio-diversity of the human race.[35] If we are not careful we shall succumb to believing that complexity can be resolved through the regularities of universal generalizations rather than in the enormously varying details of individuals. Needed is a more inductive approach, whereby our models are built up from the evidence of all the variations.

Kinds of Reality

Another important way in which computers are changing our approach to knowledge relates to new combinations of reality. In the 1960's the earliest attempts at virtual reality created a) digital copies of physical spaces, b) simplified digital subsets of a more complex physical world or c) digital visualizations of imaginary spaces. These alternatives tended to compete with one another. In the latter 90's there has been a new trend to integrate different versions of reality to produce both augmented reality and augmented virtuality. As a result one can, for instance, begin with the walls of a room, superimposed on which are the positions of electrical wires, pipes and other fixtures.

Such combinations have enormous implications for training and repair work of all kinds. Recently, for instance, a Harvard medical doctor superimposed an image of an internal tumour onto the head of a patient and used this as an orientation method for the operation. (This method is strikingly similar to the supposedly science fiction operation of the protagonist's daughter in the movie *Lost in Space*). As noted elsewhere, this basic method of superimposition can also be very fruitful in dealing with alternative reconstructions of an ancient ruin or different interpretations of a painting's spatial layout. Other alternatives include augmented virtuality, in which a virtual image is augmented and double augmented reality in which a real object such a refrigerator has superimposed on it a virtual list which is then imbued with further functions.[36] (cf. figure 4).

Other techniques are also contributing to this increasing interplay between reality and various constructed forms thereof. In the past, for instance, Computer Aided Design (CAD) and video were fundamentally separate media. Recently Bell Labs have introduced the principle of pop-up video, which permits one to move seamlessly between a three-dimensional CAD version of a scene and the

Figure 4: Basic classes of simulated reality and their proponents

Reality, Nature, Man Made World	
Virtual Reality	Sutherland, Furness
Augmented Reality	Feiner, Stricker
Augmented Virtuality	Gelernter, Ishii
Double Augmented Reality	(Mankoff 1998)[37], Mankoff[38]

two-dimensional video recording of an identical or at least equivalent scene (Carraro/Edmark/Ensor 1998).[39] Meanwhile, films such as *Forrest Gump* integrate segments of »real« historical video seamlessly within a purely fictional story. This has led some sceptics to speak of the death of photographic veracity,[40] which may well prove to be an overreaction. Major bodies such as the Joint Picture Expert Group (JPEG) are working on a whole new framework for deciding the veracity of images, which will help to resolve many of these fears.

On the positive side, these developments in interplay among different kinds of reality introduce immense possibilities for the re-contextualization of knowledge. As noted earlier, while viewing images of a museum one will be able to move seamlessly to CAD reconstructions of the rooms and to videos explaining particular details. One will be able to move from a digital photograph of a painting, through images of various layers of the painting to CAD reconstructions of the painted space as well as x-rays and electron-microscope images of its micro-structures. One will be able to study parallels, and many aspects of the history of the painting. A new integration of static and dynamic records will emerge.

Complex Systems

The systematic mastery of scale in the past decades has lent enormous power to the zoom metaphor, to such an extent that one could speak of *Hollywoodization* in a new sense. Reality is seen as a film. The amount of detail, the granularity, depends on one's scale. As one goes further one sees larger patterns, as one comes closer one notices new details. Proponents of complex systems such as Yaneer Bar-Yam (Bar-Yam 1997),[41] believe that this zoom metaphor can serve as a tool for explaining nearly all problems as one moves

from atomic to molecular, cellular, human and societal levels. Precisely how one moves from physical to conceptual levels is, however, not explained in this approach.

Complex systems entail an interdisciplinary approach to knowledge, which builds on work in artificial neural networks to explain why the whole is more than the sum of its parts. The director of the New England Center for Complex Systems (NECSI) believes that this approach can explain human civilization:

One system particularly important for the field of complex systems is human civilization the history of social and economic structures and the emergence of an interconnected global civilization. Applying principles of complex systems to enable us to gain an understanding of its past and future course is ultimately an important objective of this field. We can anticipate a time when the implications of economic and social developments for human beings and civilization will become an important application of the study of complex systems.[42]

Underlying this approach is an assumption that the history of civilization can effectively be reduced to a history of different control systems, all of them hierarchically structured. This may well provide a key to understanding the history of many military, political and business structures, but can hardly account for the most important cultural expressions. If anything the reverse could well be argued. Greece was more creative than other cultures at the time because it imposed less hierarchical structures on artists. Totalitarian regimes, by contrast, typically tolerate considerably less creativity, because most of these expressions are invariably seen as beyond the parameters of their narrow norms. Hence, complex systems with their intriguing concepts of emergence, may well offer new insights into the history of governments, corporations, and other bureaucracies. They do not address a fundamental aspect of creativity, which has to do with the emergence of new individuals and particulars, non-controlled elements of freedom, rather than products of a rule based system.

Individuals and Particulars

As was already suggested above, one of the central questions is how we define knowledge. Does knowledge lie in the details of

particulars or in the universals based on those details? The debate is as old as knowledge itself. In Antiquity, Plato argued for universals: Aristotle insisted on particulars. In the Middle Ages, the debate continued, mainly in the context of logic and philosophy. While this debate often seemed as if it were a question of either / or, the rise of early modern science made it clear that the situation is more complex. One needs particular facts. But in isolation these are merely raw data. Lists of information are one step better. Yet scientific knowledge is concerned with laws, which are effectively summaries of those facts. So one needs both the particulars as a starting point in order to arrive at more generalized universals, which can then explain the particulars in question.

Each change in media has affected this changing relationship between particulars and universals. In pre-literate societies, the central memory unit was limited to the brain of an individual and oral communication was limited to the speed with which one individual could speak to another. The introduction of various written media such as cuneiform, parchment, and manuscripts meant that lists of observations were increasingly accessible. Printing helped to standardize this process and introduced the possibility of much more systematic lists. The number of particular observations on which universal claims and laws could be established thus grew accordingly. While there were clearly other factors such as the increased accuracy of instruments, printing made Tycho Brahe's observations more accessible than those made at the court of Alphonse the Wise and played their role in making Kepler's new planetary laws more inclusive and universal.

The existence of regular printed tables greatly increased the scope of materials, which could readily be consulted. It still depended entirely on the memory and integrating power of the individual human brain in order to recognize patterns in the data and to reach new levels of synthesis. Once these tables are available on networked computers, the memory capacities are expanded to the size of the computer. The computer can also be programmed to search both for consistencies and anomalies. So a number of the pattern discoveries, which depended solely on human perception, can now be automated and the human dimension can be focused on discerning particularly subtle patterns and raising further questions.

In the context of universities, the arts and sciences have traditionally been part of a single faculty. This has led quite naturally to many comparisons between the arts and the sciences, and even

references to the art of science or the science of art in order to emphasize their interdependence. It is important to remember, however, that art and science differ fundamentally in terms of their approach to universals and particulars. Scientists gather and study particulars in order to discern some underlying universal and eternal pattern. Artists gather and study examples in order to create a particular object, which is unique, although it may be universal in its appeal. Scientists are forever revising their model of the universe. Each new discovery leads them to discard some piece or even large sections of their previous attempt. Notwithstanding Newton's phrase that he was standing on the shoulders of giants, science is ultimately not cumulative in the sense of keeping everything of value from an earlier age. Computers, which are only concerned with showing us the latest version of our text or programme, are a direct reflection of this scientific tradition.[43]

In this sense, art and culture are fundamentally different in their premises. Precisely because they emphasize the uniqueness of each object, each new discovery poses no threat to the value of what came before. Most would agree, for instance, that the Greeks introduced elements not present in Egyptian sculpture, just as Bernini introduced elements not present in Michelangelo, and he, in turn, introduced elements not present in the work of Donatello. Yet it would be simplistic to deduce from this that Bernini is better than Michelangelo or he in turn better than Donatello. If later were always better it would be sufficient to know the latest artists' work in the way that scientists feel they only need to know the latest findings of science. The person who knows about the Egyptians, Greeks, Donatello, Michelangelo and Bernini is much richer than one who knows only the latest phase. Art and culture are cumulative. The greatest scientist succeeds in reducing the enormity of particular instances to the fewest number of laws which to the best of their knowledge are unchanging. The most cultured individual succeeds in bringing to light the greatest number of unique examples of expression as proof of creative richness of the human condition. These differing goals of art and science pose their own challenges for our changing understanding of knowledge.

Before the advent of printing, an enterprising traveller might have recorded their impressions of a painting, sculpture or other work of art, which they encountered in the form of a verbal description or at best with a fleeting sketch. In very rare cases they might have attempted a copy. The first centuries after Gutenberg

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saw no fundamental changes to this procedure. In the nineteenth century, lithographs of art gradually became popular. In the late nineteenth century, black and white photographs made their début.[44] In the latter part of the twentieth century colour images gradually became popular.

Even so it is striking to what extent the horizons of authors writing on the history of their subject remained limited to the city where they happened to be living. It has often been noted, for example, that Vasari's *Lives of the Artists*, focussed much more on Florence than other Italian cities such as Rome, Bologna, Milan or Urbino. At the turn of the century, art historians writing in Vienna tended to cite examples found in the Kunsthistorisches Museum, just as others since living in Paris, London or New York have tended to focus on the great museum that was nearest to home. The limitations of printing images meant that they could give only a few key masterpieces by way of example. From all this emerged a number of fascinating glimpses into the history of art, which were effectively summaries of the dominant taste in the main halls of the great galleries. It did not reflect the up to 95 Prozent of collections that is typically in storage. Nor did it provide a serious glimpse of art outside the major centres.

A generation ago scholars such as Chastel (Chastel 1965) pointed to the importance of studying the smaller cities and towns in the periphery of such great cities: to look not only at Milan but also at Pavia, Crema, Cremona, Brescia and Bergamo. Even so, in the case of Italy, for instance, our picture is still influenced by Vasari's emphases from over four centuries ago. Everyone knows Florence and Rome. But who is aware of the frescoes at Bominaco or Subiaco, of the monasteries at Grottaferata and Padulo, or the architecture of Gerace, Urbania or Asolo? The art in these smaller centres does not replace, nor does it even pretend to compete, with the greatest masterpieces which have usually made their way to the world's chief galleries. What they do, however, is to provide us with a much richer and more complex picture of the variations in expression on a given theme. In the case of Piero della Francesca, for example, who was active for much of his life in San Sepolcro, Arezzo and Urbino, we discover that these masterpieces actually originated in smaller centres although they are now associated with great cities (London, Paris, Florence). In other cases we discover that the smaller centres do not simply copy the great masterpieces. They adapt familiar themes and subjects to their own tastes. The

narrative sequences at San Gimignano, Montefalco, Atri add dimensions not found even in Florence or Rome.

To be sure some of this richness has been conveyed by the medium of printing, through local guidebooks and tourist brochures. However, in these the works of art are typically shown in isolation without any reference to more famous parallels in the centres. Computers will fundamentally change our approach to this tradition. First they will make all these disparate materials accessible. Hence a search for themes such as *Virgin and Child* will not only bring up the usual examples by Botticelli or Raphael but also those in museums such as L'Aquila, Padua, and Volterra (each of which were centres in a previous era). Databases will allow us to study developments in terms of chronology as well as by region and by individual artist. Filtering techniques will allow us to study the interplay of centre and periphery in new ways.

More importantly, we shall be able to trace much more fully the cumulative dimensions of culture, retaining the uniqueness of each particular object. In the past, each of the earlier media precluded serious reproductions of the original objects. As noted above, colour printing has only been introduced gradually over the past half-century. Even then, a single colour image of a temple or church, can hardly do justice to all its complexities. The advent of virtual and augmented reality, and the possibility of stereo-lithographic printing, means that a whole new set of tools for understanding culture is emerging. They will not replace the value and sometimes the absolute necessity of studying some of the originals in situ, but if we always had to visit everything, which we wished to study in its original place, the scope of our study would be very limited indeed.

Earlier media typically meant that one emphasized one example often forgetting that it represented a much larger phenomenon. The Coliseum in Rome is an excellent case in point. History books typically focus on this amphitheatre and tell us nothing of the great number of amphitheatres spread throughout the Roman empire. Networked computers can make us aware of all known examples from Arles and Nîmes in France to El-Djem in Tunisia and Pula in Croatia. This new encyclopaedic approach means that we shall have a much better understanding of how a given structure spreads throughout a culture to form a significant element in our cultural heritage such as the Greek temple, the Romanesque and Gothic Church, and the Renaissance villa. It means that we shall also have

a new repertoire of examples for showing even as these styles spread, each new execution of the principle introduces local uniqueness. Hence the cathedrals at St. Denis, Chartres, Notre Dame, Cologne, Magdeburg, Bamberg, Ulm and Burgos are all Gothic, and yet none is a simple copy of the other.

A generation ago when Marshall McLuhan coined the phrase »the global village«, some assumed that the new technologies would invariably take us in the direction of a world where every place was more or less the same: where Hiltons and McDonalds would spread throughout an increasingly homogenized planet. This danger is very real. But as critical observers such as Barber have noted (Barber 1995), the new technologies have been accompanied by a parallel trend in the direction of regionalism and new local awareness. The same technologies, that are posing the possibility of global corporations, are introducing tremendous new efforts in the realms of citizen participation groups and of local democracy. Networked computers may link us together with persons all over the world as if we were in a global village but this does not necessarily mean that every village has to look the same. Indeed, the more the mass-media try to convince us that we are all inhabitants of a single interdependent ecosystem, the more individuals are likely to articulate how and even why their particular village is different from others. In this context, the new access to individuals and particulars introduced by networked computers, becomes much more than an interesting technological advance. It provides a key to maintaining the cultural equivalent of bio-diversity, which is essential for our well being and development in the long run.

In themselves the particulars are, of course, only lists and as such merely represent data or, at best, information. Hence they should be seen as starting points rather than as results per se. Their vital importance lies in vastly increasing the sample, the available sources upon which we attempt to draw conclusions. The person who has access to only one book in art history will necessarily have a much narrower view than someone who is able to work with the resources of a Vatican or a British Library. In the past, scholars have often spent much more time searching for a document than actually reading it. In future, computers will greatly lighten the burden of finding. Hence, scholarship will focus increasingly on determining the veracity of sources, weighing their significance, interpreting and contextualizing sources, and learning to abstract from the myriad details which they offer, some larger

patterns of understanding. Access to new amounts of particulars will lead to a whole new series of universal abstractions.

Implicit in the above discussion are larger issues of knowledge organization that go far beyond the scope of this paper. We noted that while the arts and science typically share the same faculty and are in many ways interdependent, there are two fundamental ways in which they differ. First, the sciences examine individual facts and particulars in order to arrive at new universal summaries of knowledge. The arts, by contrast, are concerned with creating particulars, which are unique in themselves. They may be influenced by or even inspired by other particular works, but they are not necessarily universal abstractions in the way that the sciences are. Second, and partly as a result thereof, the sciences are not cumulative in the same way that the arts and culture are. In the sciences only the latest law, theory, postulate etc. is what counts. In the arts, by contrast, the advent of Picasso does not make Rubens or Leonardo obsolete, any more than they made Giotto or Phidias obsolete. The arts and culture are defined by the cumulative sum of our collective heritage, all the particulars collected together, whereas the sciences are concerned only with the universals abstracted from the myriad particulars they examine.[45]

It follows that, while both the arts and sciences have a history, these histories ultimately need to be told in very different ways. In the arts, that history is about how we learned to collect and remember more and more of our past. Some scholars have claimed, for instance, that we know a lot more about the Greeks than Aristotle himself. In the sciences, by contrast, that history is at once about how scientists developed ever better instruments with which to make measurable that which is not apparent to the naked eye, and how they used the results of their observations to construct ever more generalized, universal, and at the same time, testable theories. To put it simply, we need very different kinds of histories to reflect these two fundamentally different approaches to universals and particulars, which underlie fundamental differences between the arts and sciences. With the advent of networked computers the whole of history needs to be rewritten: at least twice, a process that will continue in future.

Now and Eternity

Not unrelated to the debates concerning particulars and universals are those connected with the (static) fine arts versus (semi-dynamic) arts such as sculpture and architecture[46] and (dynamic) performance arts such as dance, theatre, and music. Earlier media such as manuscripts or print were at best limited to static media. They could not hope to reproduce the complexities of dynamic performance arts. Even the introduction of video offered only a partial solution to this challenge, insomuch that it reduced the three-dimensional field to a particular point of view reduced to a two-dimensional surface. Hence, if a video captured a frontal view of actors or dancers their backs were necessarily occluded. These limitations of recording media have led perforce to a greater emphasis on the history of fine arts such as painting than on the semi-dynamic arts such as sculpture and architecture or the dynamic arts such as dance and theatre.[47]

These limitations have had both an interesting and distorting effect on our histories of culture. It has meant, for instance, that we traditionally knew a lot more about the history of static art than dynamic art: a lot more about painting than about dance, theatre or music. It has meant that certain cultures such as the Hebrew tradition, which emphasize the now of dynamic dance and music over the eternal static forms of sculpture and painting were underrepresented in traditional histories of culture. Conversely, it has meant that the recent additions of film, television, video and computers have focussed new attention on the dynamic arts, to the extent of undermining our appreciation of the enduring forms. Our visions of eternal art are being replaced by a new focus on the now.

From a more global context these limitations have also had a more general, subtle, impact on our views of world culture. Those strands, which focussed on the static, fine arts were considered the cornerstones of world cultural development. Since this was more so in the West (Europe, the Mediterranean and more in recently North America), sections of Asia Minor (Iran, Iraq, Turkey), and certain parts of the Far East (China, Japan and India),[48] these dominated our histories of art. Countries with strong traditions of dance, theatre and other types of performance (including puppet theatre, shadow theatre and mime) such as Malaysia, Java and Indonesia were typically dismissed as being uncultured. The reality of course was quite different. What typically occurred is that these

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cultures took narratives from static art forms such as literature and translated them into dynamic forms. Hence, the stories of an Indian epic, the *Ramayana*, made their way through Southeast Asia in the form of theatre, shadow puppet plays, dances and the like. Scholars such as Mair (Mair 1988)[49] have rightly drawn attention to the importance of these performance arts (figure 5).

Figure 5: Examples of narrative based performance art in various countries

Art	Country
Etoki	Japan
Par	India
Parda Da	Iran
Pien Wen	China
Waysang Beber	Malaysia

Ultimately, however, the challenge goes far beyond simple dichotomies of taste, namely, whether one prefers the static, eternal arts of painting to the dynamic, now, arts of dance and music. A more fundamental challenge will lie in re-writing the whole of our history of art and culture to reflect how these seeming oppositions have in fact been complementary to one another. In the West, for instance, we know that much Renaissance and Baroque art was based directly on Ancient mythology either directly via books such as Ovid's *Metamorphoses*, or indirectly via Mediaeval commentaries on these myths. We need a new kind of hyper-linking to connect all these sources with the products, which they inspired. Such hyper-links will be even more useful in the East where a same mythical story may well be translated into half a dozen art forms ranging from static (sculpture and painting) to dynamic (dance, mime, shadow theatre, puppet theatre, theatre). From all this there could emerge new criteria for what constitutes a seminal work: for it will become clear that a few texts have inspired works over the whole gamut of cultural expression. The true key to eternal works lies in those which affect everything from now to eternity.

Den zweiten Teil dieses Beitrages finden Sie auf S. 131; die Literaturangaben zu Teil I finden Sie ab S. 161.

Notes

1   It is instructive to note that although the impulses for this research came from various centres, notably, Cambridge, many of the key ideas developed at the University of Toronto in the context of classical studies, history, English literature and media studies.

2   In the past generation scholars such as Jack Goody (Cambridge) have explored the implications of this phenomenon in the context of developing cultures, particularly, Africa. See, for instance, Goody 1977 (cf. http://gopher.sil.org/lingualinks/library/literacy/GFS8 12/cjJ360/GFS3530.htm). See also Goody 1996 (cf. http://www.uc m.es/info/especulo/numero05/goody.htm.

3   Cf. http://www.mcluhanmedia.com/mmclm005.html.

4   See http://www.mala.bc.ca/~soules/paradox/innis.htm.

5   See http://www.daimi.aau.dk/~dibuck/hyper/bush.html.

6   See http://www2.bootstrap.org/.

7   See http://www.sfc.keio.ac.jp/~ted/.

8   See http://www.mcluhan.toronto.edu/derrick.html.

9   Cf. http://www.unesco.or.kr/culturelink/mirror/research/21/cl21-levi.html and http://www.georgetown.edu/grad/CCT/tbase/levy.ht ml.

10   See http://www.geoscopie.com/guide/g7170pi.html.

11   I am grateful to Eric Livermore (Nortel) for this reference.

12   The definition of usefulness could readily detour into a long debate. For the purposes of this article we shall take it in a very broad sense to mean the uses of computers in terms of their various applications.

13   The ISO identifies seven basic layers to the telecommunications network: three which belong to the network layer (physical, data-link, network), one which belongs to the transport layer (transport) and a further three which belong to the user service layer (session, presentation and application). These seven layers have been applied to computers. With respect to the Internet discussions usually focus on the bottom three layers. These seven layers focus on pipelining and while this is of fundamental value it does not differentiate sufficiently the many elements on the application side.

14   See http://www.isi.edu/vet.

15   See Steve Mann at http://n1nlf-1.eecg.toronto.edu/index.html.

16   The potential problems with such responsive environments are actually quite considerable. It is all fine and well to have the television turn on to channel two when A enters the room. But what if B enters the room at the same time, who has programmed the same device to display channel three. What then is the decision strategy? Is it in favour of the older rather than the younger, the owner rather than the guest?

17　See http://gen.net/index.htm.
18　See http://www.npac.sgr.edu/users/gcf/asopmasterB/foilsephtmld
　　ir/001HTML.html and http://www.npac.sgr.edu/users/gcf/asopma
　　sterB/fullhtml.html.
19　See http://ce-toolkit.crd.ge.com.
20　See http://www.interex.org/hpuxvsr/jan95/new.html#RTFToC33.
21　See http://www.anxo.com/.
22　Charles. S. Pierce, *Collected Papers*, 5400.
23　He draws also on the ideas of Buckland 1993.
24　Davenport (1997).
25　John Law, Multiple Laws of Order.
26　See http://ricis.cl.uh.edu/virt-lib/soft-eng.html.
27　According to F. Miksa (personal communication), this system was
　　further developed while Chen was a professor of computer science
　　at Louisiana State University in 1980.
28　For some discussion of the philosophical and sometimes subjec-
　　tive assumptions underlying such methods see Kent 1978; Klein/
　　Hirscheim 1987; Phelan 1998.
　　One might expect that librarians, whose lives are dedicated to or-
　　ganizing knowledge should be very sensitive to these problems. In
　　fact, their professional lives are typically spent cataloguing and
　　dealing with materials concerning which the reality is not in ques-
　　tion. Each call number applies to a physical book. If there is no
　　physical book in evidence, then it is »because the book is missing,«
　　which is typically »a user problem.« Their daily work engages
　　them in simple realism. This helps to explain why librarians have
　　frequently accepted and in most cases continue to accept naïve
　　systems such as the entity-relationship model.
29　Mandelbrot, for instance, noted how the length of the coast of
　　England changed as one changed scale. See: Mandelbrot 1967.
　　These ideas were dramatically developed in his major book: Cf.
　　Mandelbrot (1982).
30　This is being developed in the context of the Joint Picture Experts
　　Group (JPEG) at http://www.jpeg.org and http://www.periphere.
　　be/ lib/jpeg.htm; and http://www.gti.ssr.upm.es/~vadis/faq–MPEG/
　　jpeg.html. This is CCITT/ISO(JTC1/SC2/WG10 and has the follow-
　　ing standards:
　　T.80 Common components for image and communication-basic
　　principles
　　T.81 Digital compression and encoding of continuous tone still
　　image
　　T.82 Progress compression techniques for bi-level images
　　T.83 Compliance testing

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As well as Still Picture Interchange File Format (SPIFF), Registration Authority (REGAUT) and JPEG Tiled Image Pyramid (JTIP), their spokesperson, Jean Barda, has developed a System of Protection for Images by Documentation identification and Registration of digital files (SPIDER), which combines two important elements:

(1) a system for registering ownership over an image

(2) metadata tags embedded within the image (header and directory) that identify the image and its owner. SPIDER is one of the first applications to employ SPIFF, the newly developed ISO standard designed to supersede the JFIF/JPEG file storage format. AVELEM, the company that developed SPIDER, also has built a system called Saisie numerique et COnsultation d'images PYRamidales (SCOPYR), i.e. Digital image capture and exploitation of pyramidal images. See: http://www.sims.berkeley.edu/courses/is290-1/f96/ Lectures/Barda/index.html.

31 See http://www.cs.man.ac.uk/mig/giu/.

32 See http://madsci.wustl.edu/~lynn/VH/.

33 See http://www.igd.fhg.de/www/igd-a7/Projects/OP2000/op2000-e.html.

34 See http://www2.igh.cnrs.fr/HUM-Genome-DB.html.

35 To take a hypothetical example, suppose it was decided that a »normal« male is 6 feet in height. Hence, the whole range of variation from small pygmies (c. 3 feet) to very tall persons (over 7 feet) would require »modification.«

36 For an alternative and more subtle classification see: Verna/ Grumbach 1998.

37 See: http://www.cc.gatech.edu/fce/domisilica.

38 Jmankoff@cc.gatech.edu.

39 The author distinguishes between two distinct types integrated video space and complementary videos. In an integrated video space a CAD space and a video space are merged. In a complementary video one might be watching a golf player whose swing interests one. A CAD version of the player would allow one to view the person who had been merely two-dimensional in the video image from all directions in the model. See also: Carraro/Edmark/Ensor 1998.

40 For a more balanced assessment see: Mitchell 1992.

41 Cf. http://www.necsi.org/mclemens/viscss.html. For a rather different approach to complex systems see: Casti 1997.

42 See http://www.necsi.org/html/complex.html.

43 This is not to say of course that there cannot be a history of science and technology. There definitely is and it is essential that we continue to foster awareness of that history. Without a clear notion

of the steps required to reach our present machines for working in the world and models for understanding that world, it would be all but impossible to understand many aspects of present day science, and we would be in sore danger of constantly re-inventing the wheel.

44   For a brief history see the excellent study by Ivins 1953.

45   It may be true that the masterpieces of art also represent a selection from the many particulars, but the masterpieces are not generalizations of the rest: they remain individuals per se.

46   I owe this distinction to my colleague and friend André Corboz, who notes that although sculpture and architecture are static in themselves, they require motion on the part of the observer in order to be seen completely from a number of viewpoints.

47   There are of course histories of these dynamic subjects but their contents are limited to verbal descriptions and give no idea of the richness of performances. In the case of dance there have been some attempts to devise printed notations, which can serve as summaries of the steps involved. In the case of music there are of course recordings. More recently there are also films and videos to cover performances of dance and theatre.

48   China, Japan and India also had rich traditions of theatre and dance which, for the reasons being discussed, were typically ignored until quite recently.

49   On this topic I am grateful to Niranjan Rajah who gave a lecture »Towards a Universal Theory of Convergence. Transcending the Technocentric View of the Multimedia Revolution« at the Internet Society Summit, Geneva, July 1998 (see niranjan@faca.unimas. my).

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