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Electronic Media, The Rebirth of Perspective and the Fragmentation of Illusion.

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1. Introduction

In the first decades of the twentieth century a number of famous artists abandoned traditional spatial techniques and experimented with new forms of art: cubism, expressionism, abstract expressionism. Some critics believed that these experiments heralded a new period of non-figurative art. For instance, Novotny[1] claimed that scientific perspective had ended with Cezanne. Arnason[2], in his standard history of modern art, spread this view that perspective had died in the early twentieth century.[3]

In retrospect it is clear that non-figurative art has become a new alternative rather than replacing all the earlier goals of art. Realism has not died: it has taken on new forms:

including surrealism, hyper-realism, and super-realism. As a result, although there was a significant drop in the publications on perspective from 1914 to 1945 (during and between the two great wars), since then the number of books on perspective has continued to rise. Indeed more books have been published on the subject in this century than during the fifteenth, sixteenth and seventeenth centuries combined (fig. 1).

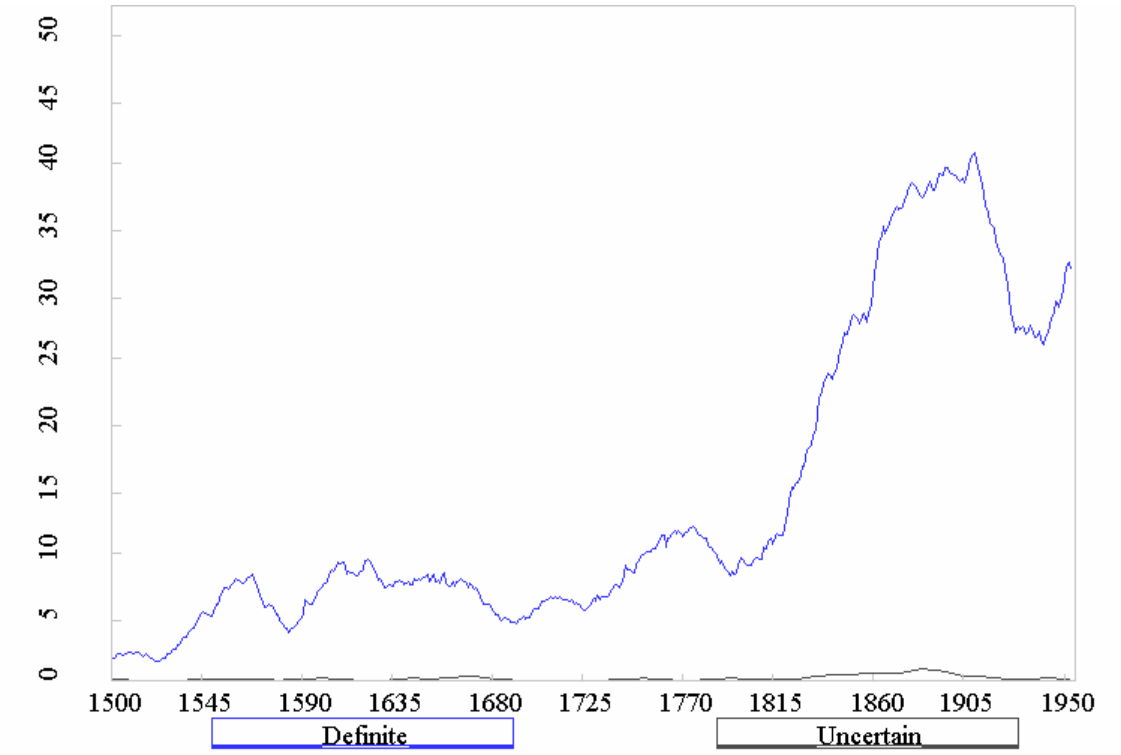

Fig. 1. Graph of publications on perspective in the twentieth century.

There are a number of reasons for this rebirth of perspective particularly in the second half of the twentieth century. The enormous rise in world population has brought a hitherto unprecedented emphasis on the built environment, with a corresponding rise in publications on architectural perspective and technical drawing[4]. Related to this has been a dramatic rise in the fields of surveying and mapping culminating in the emergence of Geographical Information Systems (GIS) and Area/Facilities Management (AM/FM) in the context of public administration at the town, municipal and provincial levels, concerns with lw and order (police departments) and security (insurance companies).

New technologies have played an integral role in these developments. In the course of World War I the introduction of aerial photography brought new challenges of relating terrestial maps with aerial photographs often taken at an angle and led to the new field of photogrammetry. The rise of satellite photography added an unprecedented quantity of raster images such that even today only an estimated ten percent of all satellite images are ever examined.

Integrally connected with this quest for recording the world has been a quest for reconstructing it electronically in terms of vector images. The discovery of basic algorithms for perspective[5] in electronic form led to computer graphics and the emergence of the so-called four C's, namely, Computer Aided Design (CAD), Computer Aided Engineering (CAE), Computer Aided Manufacturing (CAM), and Computer Integrated Manufacturing (CIM), each of which assumes the use of systematic spatial co-ordinates in the rendering of objects and contexts. This has expanded greatly the use of linear and other forms of perspective because once an image has been rendered in vector form it can be rotated, tilted and viewed from any direction either in its true dimensions (e.g. ground plan, elevation) or perspectivally.

Analogue cameras are increasingly being replaced by both digital cameras and by virtual cameras[6]: i.e. where computers reproduce the effects of a photographic image through graphics software. This is leading to ever greater links between analogue and digital methods in terms of vector and raster images.

Cinema, as an application of photography has also implicitly broadened the scope of perspective. New explicit uses for perspective have been introduced by set designers who replace actual cityscapes with illusionistic painted facades in order to save money, adapting techniques of accelerated perspective used from stage scenery in the theatre. Some of these dramatic effects have become permanent fixtures in theme parks such as Disneyworld and Universal Studios (Orlando).

The emergence of virtual reality is a further stimulus for this resurgence of perspective, because it entails a combination of different viewpoints (see § 4 below) . For the purposes of this essay, developments since 1950 will be referred to as modern perspective and will be compared and contrasted to Renaissance perspective where appropriate.

2. Renaissance Themes

It is well known that Renaissance artists made copies of paintings. They also copied individual elements of paintings such that a hand from Leonardo's *Last Supper* was used in a painting of a *Virgin and Child*. In modern terms they introduced the equivalent of clip art long before the notion was formally introduced.

One aspect of the rebirth of interest in Renaissance perspective in the twentieth century has been the adaptation of particular objects and motifs in new contexts. For instance, fifteenth century artists such as Piero della Francesca and Leonardo da Vinci revived an interest in regular and semi-regular solids. Modern artists use these shapes in holographic art. Euclid, in his *Elements*, described the construction of a seventy two-sided figure. Leonardo da Vinci, included this figure in his illustrations for Pacioli's *Divine Proportion* (1496-1499, printed 1509). It was taken up by Fra Giovanni da Verona in his inlaid wood panels (intarsia) in Santa Maria in Organo, was a symbol for perfection in the Renaissance and became a recurrent theme in perspective treatises by Jamnitzer, Sirigatti, Dubreuil and others. In modern perspective, Salvador Dali adapts a

variant of this seventy two-sided figure in a painting of a woman's head. Other semi-regular solids found in Jamnitzer, recur as garden ornaments in a book by Nielsen (1812) and recur in variant form in Escher's famous engraving of a *Waterfall*. Similarly, a cylindrical shape or toroid, known in the Renaissance as a *mazzocchio*, which became a leit-motif in Barbaro's *Practice of Perspective* (1568), recurs in variant form in a woodcut by Escher. While the shapes are similar their function changes. During the Renaissance colour and shading were used to distinguish clearly between different sides and layers of a solid or series of nested solids. In modern perspective artists such as Escher deliberately use colour and shading to introduce ambiguities in our reading of such shapes.

This continuity of images extends to other objects such as stairs, which are an important theme in the treatises of Jan Vredeman De Vries, and are said to have inspired at least one of the staircases in a painting by Rembrandt. In the twentieth century this theme of stairs continues in the famous staircases of Escher. Individual elements also recur in new contexts, as with the perspectival dragon in Uccello's *Saint George and the Dragon* (London, National Gallery) which recurs in one of David Hockney's stage sets. Or individual elements are substituted, as with the protagonist in Botticelli's *Birth of Venus* (Florence, Uffizi), who is replaced by Elvis Presley in Richard W. Maile's adaptation (Siggraph, 1990).

Sometimes the adaptation is merely a small part of the original as with the hands in Michelangelo's *Creation of Man* (Vatican, Sistine Chapel), which recur in variant form in *E.T.* Hence while there is a continuity of objects and motifs a two way process transforms the Renaissance examples into modern ones. Objects which were originally isolated figures during the Renaissance become integrated into complex scenes in modern perspective. Alternatively, objects which were originally integrated in a scene during the Renaissance recur either as isolated objects or in new contexts in the twentieth century. This is one of the sources of the fragmentation of illusion considered below (§ 7) and is important becuase it means that the problems associated with electronic image editing packages were pre-figured by Renaissance artists.

3. Transformations

During the Renaissance, artists devised a number of means of recording perspectival views. The two chief means were instruments and constructions. Instruments included the perspectival window, *camera obscura* and various surveying instruments such as the Jacob's staff, astrolabe, pantograph and proportional compass. By the nineteenth century there were other instruments such as the *camera lucida* (or Claude glass). Constructions included mainly the legitimate construction (*costruzione legittima*) and distance point construction although there is evidence that a great number of other makeshift constructions were in use. The twentieth century has seen many developments in both physical instruments such as pantographs and electronic equivalents through CAD programmes (from high end packages such as Softimage and Alias, through Autodesk products and lower level products, such as TurboCAD, and illustration programmes such as Corel Draw).

In terms of perspective the rise of photogrammetry focussed attention on problems of translating anamorphic images into regular linear perspective and conversely. With the advent of high altitude photography and subsequently satellite photography, there were new problems of translating spherical perspective to linear perspective. This greatly increased experience in both alternative projection methods and translation from these alternative methods to linear perspective.

The quest to record and reproduce systematically the physical and the built environment led to algorithms for the construction of linear perspectival space, its translation into alternative forms, and conversely. These algorithms are gradually being incorporated into software programs. For instance, Aldus Photo Styler includes a function for changing a regular perspectival scene to a fish-eye view, spherical perspective or cylindrical perspective. Image Ware includes a whole range of painterly effects including a volume devoted to brush-stroke techniques and another to motion and time sequences. More recently such algorithms are being incorporated directly into hardware chips. For instance the Genesis Acuity gm833x2 chip permits one to take a regular video image and transform it into its anamorphic equivalents (through translation), spherical perspective and other transformations. A construction that would have taken days to do manually is now performed almost instantaneously with software and hardware: a globe is transformed to a flat map of the earth which, in turn, becomes a three-dimensional landscape. As a result operations that would once have required the hand of a master artist can now be executed in a few simple steps by anyone in a matter of minutes.

While there is no doubt that the rise of new technologies such as satellites and new software packages have played an enormous role in this new emphasis on transformational geometries it is important to note that this process was initiated in large part by twentieth century artists. While some aspects of their contribution have been examined elsewhere[7], a comprehensive history thereof has yet to be written. Such a history would need to begin with the transformations in the function of the window. One might, for instance, begin with cubist paintings such as Juan Gris' *Still Life with a Landscape* (Philadelphia, 1915) showing the Place Ravignan in Paris. In Renaissance perspective there was a fundamental assumption that windows were transparent and that walls occluded. In cubist perspective this assumption is challenged. Hence we find ourselves looking through walls.

Artists such as Magritte and Dali take these experiments much further and make them the basis of a new movement in art: surrealism. For instance, Magritte, in his *Promenades of Euclid* (New York, Iolas Gallery, 1955), creates deliberate ambiguities between a window that reveals a scene beyond it and an easel painting based thereon which occludes the scene beyond it. In the same painting he also creates deliberate ambiguities between a pyramidal tower and the pyramidal diminution of a street. Dali takes these ideas even further in a painting that shows the posterior view of a nude woman framed by a cross-shaped transparent window in one focus, which is reduced to the occluding portrait of Abraham Lincoln when viewed in another focus. More complex transformations of the window principle are found in the context of holography.

Another of the underlying assumptions of Renaissance linear perspective was that the window would be plane or flat. Some artists experimented with alternatives: Jan van Eyck in his *Arnolfini Wedding* (London, National Gallery) or Parmigianino in his *Self-Portrait* (Vienna, Kunsthistorisches Museum), which are famous precisely because they were exceptions to the rule. Modern perspective, by contrast, makes much greater use of spherical and other alternative methods of perspective. It also combines these methods to create new hybrids. For instance, Escher, depicts spaces which begin as spherical perspective and recede into linear perspective. Dick Termes (Spearfish, North Dakota) adapts this theme and renders it more complex by depicting on a spherical surface which can then be viewed from all points of the compass. In one of his most intriguing paintings entitled *Pieces of the Whole*, Termes paints on a large sphere, this time depicting several individual boys in the act of painting their own canvases some of which use linear perspective while others use curvilinear perspective. Termes also experiments with a number of other variations by combining two or more spheres as the surface of his painting or using regular solids as his projection planes.

In addition to experimenting with alternative picture planes, modern perspective also explores alternative directions in the projection process. For instance, in the Renaissance, anamorphosis entailed taking a regular object which was projected onto a picture plane in an elongated or distorted form which, when viewed from a proper angle appeared in its original shape. The skull in Holbein's *Ambassadors* is a classic case in point. As Baltrusaitis[8] has shown these themes continue in the twentieth century. But there has also been a trend to reverse the process. Hence a contemporary Swiss artist, Bourset[9], builds anamorphic chairs, the projections of which are regular shapes. This approach also has unexpected applications in the realm of stage design. The walls of stages in theatres are often curved or irregular in shape. As a result when a regular image was projected onto such a wall, it appeared in distorted form (keystoning). To resolve this problem, Julie O'B. Dorsey (Cornell), came up with an ingenious solution. She studied the irregular shape of the wall, then pre-distorted the original image in such a way that when it was projected onto the curved wall the image appeared in undistorted form. In other words, whereas Renaissance perspective used anamorphosis to create deliberate distortions in images, modern perspective uses anamorphosis deliberately to hide the distortions of images. Similar techniques are being adopted in the cas of virtual reality glasses.

4. Inside-Outside

The early practitioners of proto-perspective and linear perspective explored the uses of these new techniques in the context of both exteriors and interiors. The development of these new genres typically went hand in hand, such that perspectival views of rooms contained windows which revealed exterior views. Only gradually did these new genres emerge as independent forms of expression such that landscapes and interiors were treated separately. Hence the window became a window in a room and then a window in an interior which gave a view of an exterior in the form of a landscape.

Modern perspective continues these themes but is also transforming the nature of inside-outside, inner and outer. Video shows interiors and exteriors in ways that remove the distinctions between them. Two-dimensional virtual reality as developed by Myron Krueger increases this ambiguity. Some modern paintings based on photography continue distinctions between inner and outer. Others blur these distinctions as in the case of a painting by Robert Gonsalves (Toronto) showing book shelves from an interior outside on a lawn. A young American student has painted a puzzle such that the man depicted in the puzzle is constructing the puzzle from the outside. A young English artist, photographed a house, which was then cut up in puzzle-form and re-photographed such that what is in and out is difficult to discern. A painting by Gonsalves pursues these themes. We are shown a painting of a puzzle in which a boy inside a house making a puzzle of a boy outside a house.

Some examples of spherical perspective take even further these ambiguities of inner and outer. For instance, Dick Termes, has a painting entitled *God's Eye View* showing the interior of San Spirito (Florence) by Brunelleschi, (said to have been the first church constructed with a view to co-ordinating perspectival effects into architecture). Termes depicts this interior on the exterior of a sphere. In the case of *Order in Disorder*, this interplay of interior-exterior is rendered the more extreme when we recognize that the artist painted these exteriors from inside the sphere. In Termes' *Pieces of the Whole* we have a viewpoint from the outside showing boys painting the scenes in which they are painting.

The introduction of various alternative mapping techniques has increased these paradoxical treatments of inner and outer. Cartographers have explored new ways of morphing planes such that satellite images can be "draped" over contour maps to transform two-dimensional photographs into three-dimensional spatial images. For instance, Brandenberger[10] shows how a map of the University of Zurich can be warped to fit different curved planes. It is intriguing to note that artists such as Escher have been pursuing analogous experiments in spatial transformation[11]. One of his early woodcuts shows a ship outside the island of *Senglea* in Malta (1935). Some ten years later, in a lithograph called the *Balcony* (1945), he introduces the equivalent of spherical perspective into the central portion of this view. A later lithograph of a *Picture Gallery* (1956) further transforms the same scene. The view of Senglea is now a picture in the inside of a gallery in the upper left of the lithograph and spills out to the right in such a way that the awning of one of the houses becomes the roof of the gallery and we find ourselves simultaneously outside the gallery looking in at the viewer looking at the picture which also functions as if it were a window. In short inner and outer are fully ambiguous.

More importantly for our theme, the transformations and alterations of images which we now associate with electronic tools were introduced by artists. The difference, of course, is that artists' transformations required a great deal of effort and had built into them a personal signature, whereas their electronic equivalents require hardly any effort and lack a personal signature. For this reason it makes sense to distinguish a spectrum of possibilities ranging from direct correspondence to non-correspondence.

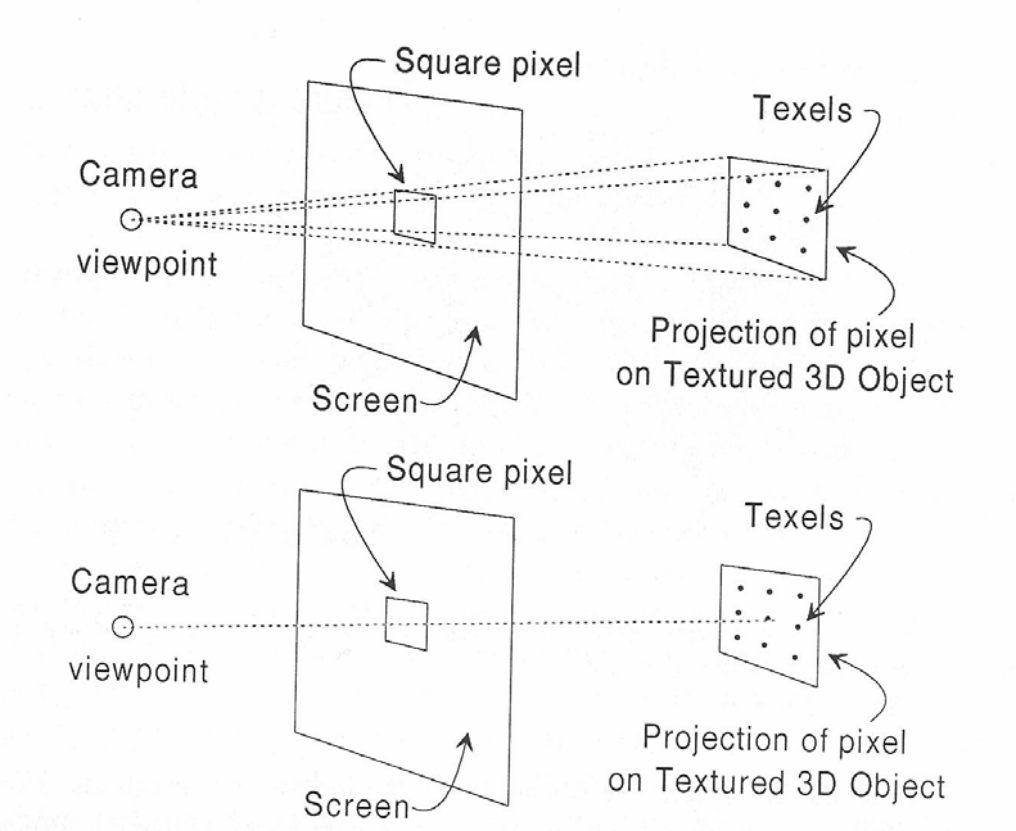

Fig. 2- 3. Two examples of perspectival principles being applied to contemporary ray tracing. From Robert Lansdale (1991, 14).

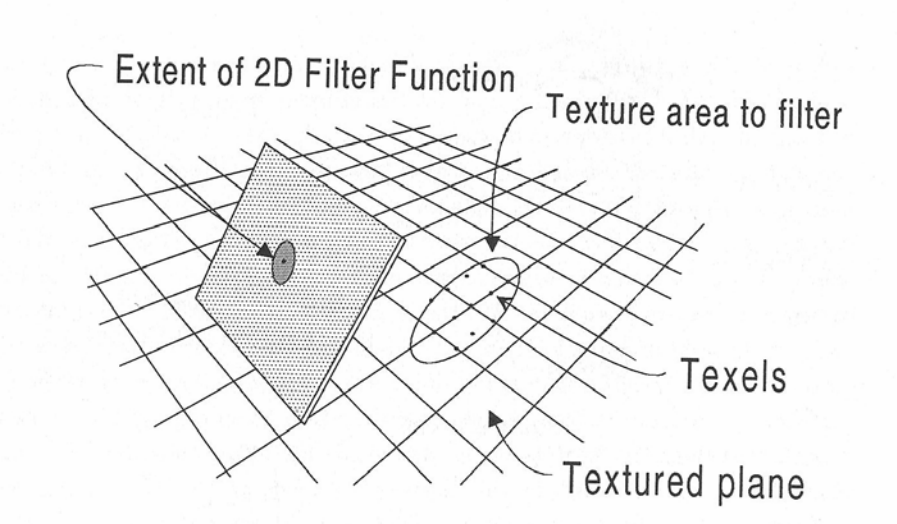

Fig. 4. An example of anamorphic principles of perspective being used in contemporary ray tracing. From Robert Lansdale (1991, 33).

5. Correspondence and non-Correspondence

Renaissance perspective assumed a one-to-one correspondence between each point on an original object and an image. Modern perspective sometimes entails a one-to-one correspondence, but the nature thereof varies greatly: sometimes it is theoretical, assumed, possible, transposed or deliberately not a direct correspondence. These new kinds of correspondence have greatly expanded the scope of perspective.

Theoretical Correspondence

Technically speaking a one-to-one correspondence is only possible in the case of vector graphics, where entire lines are copied. In the case of raster graphics[12] the copying of points presents problems of aliasing especially in the case of distant objects. Even so it is noteworthy that the underlying assumptions governing perspective apply equally to pixel projection used in ray tracing. As Mitchell noted in *The Re-configured Eye*: "The basic strategy implemented by ray-tracing algorithms is to consider the picture plane as a fine grid of pixels placed between the viewer's eye and the screen and to send a ray from the eye through each pixel to the scene"[13]. Scholars such as Mitchell[14] have also emphasized differences between the continuous lines of analogue methods and the discrete pixels of digital methods, suggesting that perspective applies only to the former.

By contrast, Lansdale[15], in a fundamental dissertation on the subject, has demonstrated lucidly how the principles of linear perspective can be extended to discrete pixels in ray tracing and radiosity programs. In traditional Renaissance perspective one often begins with a square tile parallel or at right angles to the picture plane and records its projected size. In Lansdale's approach this procedure is reversed: i.e. a square pixel is treated in the manner of a projected square tile on the picture plane or screen and is then projected back onto the textured 3-D object. In this way the specific texels (unprojected pixels of the textured 3-D object) occluded by the projected pixel can be calculated.

Although the direction is reversed, the projection of this pixel from a screen onto a textured object in modern perspective corresponds precisely to the projection of a square from a wall or pavement onto a perspectival window in Renaissance perspective. Seen in this way the recording of electronic pixels is analogous to a microscopic approach in recording tiles of a wall or pavement perspectivally (fig. 2-3). In other examples, a spherical shape on the picture plane or screen is projected as an oval shape onto the pavement positioned at an angle relative to the plane (fig 4). This is precisely the reverse of an anamorphic form which is projected as a regular sphere on a tilted projection plane (fig. 4). Hence perspective remains a valuable tool in understanding the frontiers of aliasing problems in image processing[16].

Until recently these operations were difficult and often infeasible from a sheer computational point of view. For example a screen of 1000x1000 pixels requires one million rays

which meant that even a single object required hours and sometimes days to render. As computing power becomes ever more efficient and affordable more complex perspectival effects involving light and shade, colour and even aerial perspective are becoming increasingly popular.

Fractals pose one of the most complex examples with respect to theoretical correspondence between original and image. According to Mandelbrot[17] the rectilinear properties of Euclidean geometry imposed serious restrictions on attempts to analyze the curvilinear complexities of (organic and inorganic) Nature. As an example he gave the coast of England, pointing out that if one chose smaller measuring sticks the number of sides and length of the coastline would increase greatly. Perspective had assumed that only size changed with distance or scale. In Mandelbrot's example, shape was also a function of scale or distance. He proposed that fractals offered a way of getting beyond these restrictions. Unfortunately because fractals involve iterations, changes in scale affect only their size but not their shape. Hence, strictly speaking, discussions concerning fractals have brought into focus a important problem which fractals are not able to solve.

Needed is a new approach to perspective which defines the scales within which the traditional laws of size as a function of distance are maintained, and identifies those changes of scale where both shape and size become a function of distance. Interestingly enough this is a case where we have been familiar with the underlying problem for centuries in a quite different context. Anyone who has used a microscope knows perfectly well that increasing the scale changes the shape as well as the size of the insect or specimen which we examining and yet within a certain range of scales shape remains effectively constant while size changes. It is this phenomenon to which fractals have drawn attention and which a future scaled approach to perspective will need to solve.

The limitations of present day fractals have not prevented enthusiasts such as Barnsley[18] from claiming that fractals can in fact reproduce Nature efficiently. Paradoxically as compression ratios increase fractal landscapes look increasingly plausible as illustrated by software programs such as VistaPro. When combined with ancillary programmes one can create impressive perspectival fly-bys. As a result, fractals, which seem to contradict the principles of perspective have become a new source of perspectival experiences.

Assumed Correspondence

In Europe there has been tendency to use experience of present objects to visualize past objects. Among the most striking examples to date are IBM's elaborate reconstruction of the former Abbey at Cluny[19] and of the Frauenkirche in Dresden which was bombed in the second World War. Also impressive is the reconstruction to scale by Chimenti and Menci (Arezzo) of 11,000 houses and buildings in Florence at the time of Lorenzo the Magnificent.

In these cases there is an assumed correspondence between image and the original object which is sometimes no longer extant. This applies equally to persons and animals. For example, in the case of *Terminator II* (1991), the animated robot is so impressive largely

becuase it is a perfect clone of a real figure. Similarly the animated dinosaurs in *Jurassic Park* (1993) are assumed to correspond to how they actually looked in real life according to the latest theories.

Possible Correspondence

In the United States the exploration of possible correspondence is much more marked than elsewhere. Indeed it has been the subject of a new field called scientific visualization, championed by centres such as the National Center for Supercomputing Applications (NCSA) at Urbana-Champaign, Illinois. This entails a whole range of applications including dynamic simulations of chemical bonding, visualizations of shock patterns and models of complex weather phenomena such as smog and violent storms. Much of this visualization is concerned with the frontiers of quantitative science and frequently requires the use of Cray computers. At the same time there are other contexts whereby such possible corespondence serves as a starting point in very different directions as in the following quote:

> Image Capture is where the image actually begins its trip into reality.
> If you can call it reality. Often our ideas are conceived with reality as the basis, but they depend on our audience's ability to suspend disbelief and play along with you as toy with their perception of what is real and what is fantastic. The fun comes when we can make a seamless transition into a world we know is not real but into which we gladly enter[20].

What makes this striking is not so much the statement itself as its context, namely, the introduction to a recent booklet by Kodak. There is of course considerable interest in realism in the United States: witness the amount of attention paid to news. Yet, increasingly the approach to news as a documentary of what actually happened is being undermined by a notion of news as a combination of real and imaginary. Information is combined with entertainment to pose as info-tainment; education is combined with entertainment to pose as edu-tainment such that the event in itself is considered somehow to be suspect because it lacks the (enter-) tainment side of things. Individuals watch the CNN version of the Iraq war, conscious that they are witnessing a staged event reported from one side, and yet there is no framework for making visible other versions of the reality.

In the United States there has also been a deliberate strategy of using experience of real places and things to visualize unexperienced ones. For instance, members of NASA study rocky places in Nevada and California deserts in preparing for explorations on the moon, Mars and other planets[21]. While this has obvious pragmatic advantages, it introduces a danger philosophically that persons lose their sense of difference and the other. Is the American tourist abroad who is continually saying that there is something bigger, better or very similar back home in in the United States merely a stereotype or actually a direct consequence of this mentality[22]? Klotz has recently suggested that this marks a rejection of Renaissance perspective, which deserves further analysis:

> Simulation is a further step away from the vanishing point of Renaissance perspective towards a world of appearances which is virtually real for the subject. A person can get so wrapped up in this apparent world, as if they could live in it, as if they themselves as a three dimensional being existed in an artistically produced three-dimensional space. This is a new theme that one should study[23].

On the positive side, there have been a number of famous applications of this principle in the case of the cinema. For instance, Steven Spielberg has explored this in films such as *E.T.* (1982) and *Gremlins* (1984, 1990). Equally, if not more famous, is George Lucas[24], whose special effects facility, Industial Light and Magic (ILM) has produced movies such as *Star Wars* (1977), *Raiders of the Lost Ark* (1981), *Willow* (1988) and worked with the great Japanese filmmaker, Kurosawa in producing *Dreams* (1990).

Transposed Correspondence

Sometimes one may deliberately choose to have no direct correspondence between original and image and yet use an external visible experience as a metaphor for some otherwise invisible experience. For example, some investment firms have begun using images of grain fields as a metaphor for fluctuations in the stock market[25]. Is this insistence on visualizing situations of transposed correspondence (where no direct correspondence is possible) one of the reasons why metaphors have become such a buzzword in the United States and why they are treated with such unexpected seriousness? To a European, *Metaphors we live by* could readily sound more like a parody than the title of a scholarly tome.

It should be noted that some individuals take this metaphorical treatment seriously. A Toronto based firm, *Visible Decisions*, has copyrighted the term “information animation” and sees in these new techniques a new methodology for understanding statistics in a space-time continuum. Interestingly enough a Singapore scholar working in the realm of knowledge navigation has reached similar conclusions independently[26].

No Direct Correspondence

Sometimes there is no direct correspondence at all as in cases when the external world is used as as a point of departure for images of the internal world. In the case of films such as *Fantastic Voyage* (1966) this reconstruction can be remarkably realistic. In others such as *Tron* (1982), the spaces are much more idealized.

Renaissance perspective assumed a strict one-to-one correspondence and led to a limited number of perspectival applications. By contrast, twentieth century perspective entails a whole spectrum in kinds of correspondence, ranging from direct and theoretical, to assumed, possible, transposed and deliberately no direct correspondence, and has contributed to the enormous increase in perspectival applications.

Europe Integration of historical and projected objects with real landscapes

Japan	Development of futuristic scenarios independent of present
Canada	Development of future scenarios building on the present
United States	Development of fictive scenarios blurring present and future.

Figure 5. Cultural differences in approaches to virtual reality

6. Virtual Reality in External and Internal Worlds

During the Renaissance, artists used linear perspective to represent a static space in a picture as determined by the position of a viewer looking at the scene from a given viewpoint. In virtual reality much more is involved. First, artists use perspective dynamically to create different spaces of the picture such that one can see how the relative sizes and positions of objects change as one travels through this space. Second, as one's viewpoint in this space changes, one can move different persons and/or objects at will. Third, one can move through the space from the viewpoint of a person or an object such as an automobile moving through this space. Fourth, one can move through this space at a set distance from such a moving person or object. For instance, the World Editor in Dimension International's software[27] includes a plan view, perspective view, a North, West view and an East, South view. Hence, whereas Renaissance perspective was concerned mainly with the static space of the picture, recent developments in virtual reality integrate dynamic views of observers in their picture space. Which is one of the reasons why virtual reality has also played a major role in expanding the scope of perspective.

The possible uses of virtual reality vary with different cultures (cf. fig. 5). In Japan the trend of cartoon films such as *Akira* (1987) and Sega games involve highly imaginative futuristic city-scapes with little reference to actual buildings in everyday experience. In Europe there has been a trend to use virtual reality as a means of linking imaginary images with physical reality. A project by Renault superimposes a computer image of a prototype car, the Racoon, onto a real landscape[28]. A project at the ETH in Zurich uses virtual reality to visualize real Roman ruins such as Aventicum, or the underlying structures of mediaeval monasteries[29]. An Italian project called the *City of Giotto*[30] uses virtual reality to re-construct the Upper Church of Saint Francis at Assisi such that one can go down (or up) its aisles, enter the space of any of the frescoes on the walls and explore their features. A virtual reality project of the Gesellschaft für Matehematik und Datenverarbeitung (GMD) at Schloss Birlinghoven reconstructs the interior of the castle, but warns: "What you see is never what you get"[31] . Another project of the GMD reconstructs a pulsating human heart and allows one to change one's views of sections in real time.

This European concern with visualizing hidden elements of existing physical structures is paralleled in Canada by a concern with visualizing potentially physical structures: hence more concern with design of future buildings than with the study of past buildings (often for purposes of conservation). In this respect Canada is closer to traditions of Europe than of the United States. The software of companies such as Alias and SoftImage typically

serves as a tool for heightening our understanding of planned, existing, and possible objects rather than in creating visions with no (possible) basis in physical reality[32].

Whereas Europeans and Canadians often focus on visualizing external objects, there is a trend in the United States towards visualizing processes that would otherwise be invisible[33]. Some, such as Robinett[34], see virtual reality as an electronic expansion of human perception. More often, virtual reality is treated as an environment in which one can be immersed such that it can be seen as a direct extension of illusionistic worlds such as *Back to the Future* at the Universal Studios theme park and more generally of the celluloid recreations of Hollywood. Opinions differ concerning the extent to which this can imitate physical reality. For instance, Aukstakalnis and Blatner are convinced that it will not: "be possible to create realities so clear and complex that we won't be able to perceive the difference between our everyday reality and a computer generated one....But the worlds that we use computers to create may eventually be so realistic, so enticing, and so interesting that we may intensely want to believe in them and they will become like mirages in the desert."[35]

Others, such as Pimentel and Teixeira, are more optimistic concerning the power of computers to simulate realistic effects:

> Virtual reality is all about illusion. Its about computer graphics in the theatre of the mind. Its about the use of high technology to convince yourself that you're in another reality, experiencing some event that doesn't physically exist in the world in front of you....Simply, virtual reality, like writing and mathematics is a way to represent and communicate what you can imagine with your mind...and it can be shared with other people[36].

In this view virtual reality is the the best means of externalizing the contents of the mind, an ultimate tool for exteriorization, for perfecting the extrovert. Ironically in a culture where the passive tendencies of television are a dominant mode, there is a danger that this tool for externalizing the interior, becomes a weapon for imposing onto the internal minds of most the carefully crafted external views of some few. This is a major problem. Of interest for the purposes of this paper is that the European, Canadian, Japanese and American interpretations of virtual reality all entail extensions of perspective. Hence virtual reality is yet another reason for the rebirth of perspective in the latter twentieth century.

7. Fragmentation of Illusion

During the Renaissance, perspective aimed at a representation that potentially copied an image of the physical world such that it created a coherent illusion of that physical world. Initially this quest involved mainly the medium of paint. By the Baroque period sculpture and architecture had been integrated within this framework and one could argue that the next centuries saw an extension of these principles culminating in the Viennese concept of the comprehensive work of art ("*Gesamtkunstwerk*").

Not all art followed this ideal. Already in the sixteenth century there was a practice of combining elements of a series of ruins in a single composite picture. By the seventeenth century this had become the fashion in the art form known as *capriccios*. Even so these fanciful combinations remained within carefully defined limits. For instance, Pannini[37] combined a series of Roman ruins in one painting and a series of modern Roman buildings in another. The *capriccios* shifted the physical locations of buildings. They questioned neither the principles of creating coherent illusionistic views of buildings nor of revealing the source of the original image. Even when it was hidden, the visual equivalent of a footnote or reference was always in place.

The electronic versions of perspectival space have brought fundamental changes to this process. They entail a fragmentation in the process of creating illusion and amount to removing this implicit footnote to the original object in the physical world. In its simplest version an image of a location in the physical world may have superimposed on it an image from the world of animation as in *Roger Rabbit* or *Terminator 2*. Conversely, a computer animated space may have superimposed upon it the figure of a live person from the physical world as also happens in *Roger Rabbit* and more dramatically in Kurosawa's *Dreams* where a modern spectator in a museum walks into two paintings of Van Gogh. In both of these cases the illusion of the context is quite separate from and provides no hint concerning the source of the isolated figures within them. Traditionally there was a challenge of making classical quotations which could and would be recognized. Notwithstanding, isolated demonstrations in the Hitchcock pavilion at Universal Studios, and occasional studies on the subject, the modern art appears to be in hiding the source (*ars est celare artis* in a new sense). Indeed, special effects have become the main theme of movie series such as *FX* (1986, 1991) and play a serious role in other movies such as *Darkman* (1991), *Lawnmower Man* (1992) and *Ghost in the Machine* (1994).

In the case of multi-media contexts, this process of fragmentation becomes more marked. For instance, in the preparation of the first full-length feature computer- animated film, an adaptation of Jules Verne's *Twenty Thousand Leagues Under the Sea* (1995), Channels software of SoftImage is used to copy information from sensors attached to the face of a live actor onto the face of a computer generated figure. As a result the facial expressions of this computer animated version of Captain Nemo are perfectly "realistic" but there is no way of knowing the source of this realism, namely the facial expressions of a given live actor.

In the case of virtual reality this fragmentation process is even more complex. Turning the head in the physical world leads to a corresponding turning of the head in the virtual world. Turning the hand within a data-glove leads to a corresponding movement of the virtual body. Other systems use a hand controlled space-ball to introduce six degrees of freedom with respect to movement. With other parts of the body there is no

Process	Physical World	Virtual World
Channels Software	Sensors on Face	Movements on Face of Model Figure
Virtual Reality	Turning Head	Turning Head
Virtual Reality	Moving Glove	Moving Body

Virtual Reality	Moving Other Parts	No Effect

Figure 6. Some examples of correspondences and non-correspondences between actions in the physical and the virtual world.

correspondence between physical motions and virtual worlds. As a result beginners experience considerable confusion because correlations are neither intuitive nor systematic.

8. New Veracity Tests and Source Criteria

In the case of books and articles, scholars have developed the use of footnotes and references to document these sources and as a means of checking the reliability of any claims made. In the case of images, captions served an equivalent function. Because the medium of print brought to words and images a stability with respect to content, if changes were made they were documented clearly as a revised or new edition. Hence, footnotes, references and captions sufficed as tools for establishing the authenticity of claims.

Electronic media are transforming our abilities to edit collections of words and images. An article or book written in a word processing package such as Word or WordPerfect can all too easily be amended. If such texts are online how are we to know which version is being cited? At present backups are dated but this information does not usually appear in printouts. We need new techniques that document the time of changes and new ways of archiving earlier versions of texts. We need electronic equivalents for revised versions and new editions. Workflow software such as Digital's Linkworks version manager allows one to see who modified which details when. Thus software also provides a series of seven different levels of access to materials. These standards being introduced to the corporate world need to be adapted by the scholarly world.

1. Standard
2. Personal
3. Internal Use
4. For Information
5. Internal Use Info
6. For Notification
7. For Feedback

Fig. 7. Seven different levels of access used in Digital's Linkworks Software.

Similar problems obtain in the case of Computer Aided Design packages which presently enable users to edit and transform images. Parts of a scene can readily be taken and integrated elsewhere to form new composite pictures and hence these new tools have contributed considerably to the fragmentation of illusion noted above. At present image editing software such as PhotoShop, PhotoStyler or TBase offer choices in terms of

image resolution (e.g . 1024x768 or 640x480), dithering, filtering, resampling and scaling. However, once an image has gone through these transformations they are not recorded on the the image. Needed is a set of captions, which might usually be invisible, that documents technical characteristics of the original image and changes that it has undergone.

Some of the attendant difficulties these image editing programs introduce with respect to certifying the veracity of images have been the subject of an important recent study by Mitchell[38] and are currently a subject of discussion on the Internet[39]. Meanwhile, firms such as Kodak[40] have been investing considerable energies to introduce hidden methods for determining whether or not an image that began as a photograph has been altered. Without such precautions the uses of photography in legal evidence would soon disappear.

If images are to retain their scholarly as well as their legal respectability it will prove useful to adapt other techniques that have been developed in the case of textual studies. For instance, scholars of manuscripts (codicologists and palaeographers) have devised subtle tools for determining which manuscript was copied from another manuscript in order to arrive at the equivalent of family trees (*stemma*) of tradition. Corresponding pedigrees of images are needed such that one can determine (where possible) the number of generations they are removed from the original, analogous to the way that one distinguishes among different states of engravings (fig. 8). In addition to this we need to know who owns (or owned) the copyright to each of these generations. Only then will we be able to write captions that serve as equivalents to footnotes in the realm of images.

Using such a system for determining the pedigree of an image, museums and galleries might decide that only second and third generation images fall within their purview and are subject to copyright controls with respect to reproduction. Hence images beyond three generations would not be acceptable as “official “ images. In future it might be decided that new scholarly claims should only be made on the basis of such official images.

1. Original	1. Original	1. Original	1. Original
2. Digital Image	2. Photograph	2. Photograph	2. Photograph
	3. Digital Image	3. Slide	3. Photograph in Book
		4. Digital Image	4. Slide
			5. Digital Image

Fig. 8. Pedigree of an image defined in terms of numbers of generations between the original and its digital version.

1. Original	Physical Object
2. Model of	“ “
3. Photograph of	“ “
4. Drawing of	“ “
5. Geometrical Figure of	“ “

6. Algebraic Formula of “ “

Fig. 9. Levels of abstraction seen in relation to the media used to record knowledge of the physical world.

In a penetrating study on Renaissance wall paintings Sandström distinguished between different levels of unreality[41]. An electronic equivalent is needed such that a user can see how many levels an image on the screen is removed from the physical world (fig. 9). Some of these levels such as geometrical figures would be further divided into different modes, such that one could distinguish between those which were drawn by hand, by instrument, and electronically. The introduction of such levels would have a further advantage of providing a new sense of context for various images and versions of objects.

In the case of image manipulation we probably need to make a number of further distinctions, namely whether reality was subtracted or added. Professional photographers are all too familiar with photographs of Mr. or Mrs. X in which the light on a pimple or blemish was unflattering. With the aid of finishing techniques, this was quietly removed. Such covering up of unwanted reality is rather different than cases where a figure has been added to a scene in order to put someone in a compromising context. Experts are aware that each medium and each technology leaves its own traces and produces its own particular artifacts (or artifacting as they say). This evidence should be documented and placed in a header file such that it remains hidden under normal situations but can be consulted much in the way that one can turn to endnotes when one is concenred with checking an author’s sources.

9. Conclusions

Following a temporary decline during the period 1914-1945, the latter twentieth century has witnessed a dramatic rebirth in the uses of perspective. A number of reasons for this rebirth were offered: a radical increase in population which has led to new concern with recording and reconstructing the built environment in particular and the physical world generally; new developments in aerial photography, cinema, computer graphics and virtual reality.

Part two of the paper compares and contrasts Renaisance and modern perspective. Whereas Renaissance artists favoured static, one point, linear perspective, modern perspective has focussed ever more attention to dynamic transformations. Whereas Renaissance perspective assumed a strict one-to-one correspondence between original object and image, modern perspective entails a whole range of alternatives including theoretical, assumed, possible, transposed and deliberate non-correpondence. These new kinds of correspondence have greatly expanded the scope of perspective, as have recent developments in virtual reality. Among the more complex ancillary effects of modern perspective has been a new fragmentation of illusion. To counter these developments new veracity tests are proposed.

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April 1994.

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[1] Fritz Novotny, *Cezanne und das Ende der wissenschaftliche Perspektive*, Vienna: Schroll, 1939.

[2] H. H. Arnason, *A History of Modern Art*, London: Thames and Hudson, (1969), 1983, p.9..

[3] During this period Panofsky (1927) also wrote his landmark essay on perspective as a symbolic form, but major discussions concerning its implications did not begin until later. See for instance, John White, "Developments in Perspective", *Journal of the Warburg and Courtauld Institutes*, London, (1949-1951) and the rebuttal by M. H. Pirenne, "The Scientific Basis of Leonardo da Vinci's Theory of Perspective", *The British Journal for Philosophy of Science*, Edinburgh, 3, 1952, pp. 169-185. There will be a considerably more thorough survey of these discussions in the author's *Literature on Perspective*, which is volume three of a four volume standard bibliography on perspective.

[4] It is noteworthy that national standards for technical drawing were established with respect to distinctions between first angle (Britain) and third angle projection (United States) in the 1920's and 1930's.

[5] For an introductory bibliography on algorithms for perspective in computer graphics see: William G. Mitchell, *The Re-Configured Eye, Visual Truth in the Post-Photographic Age*, Cambridge, Mass.: MIT Press, 1993, pp. 244-245.

[6] See: Mitchell, *The Re-Configured Eye*, (as in note v above), pp. 117-135.

[7] See the author's "Developments in Perspective", *The Visual Mind. Art and Mathematics*, ed. Michele Emmer, Cambridge, Mass.: MIT Press, 1993, pp. 199-205.

[8] Jurgis Baltrusaitis, *Anamorphoses ou perspectives curieuses*, Paris: Vrin, 1957 etc.

[9] I am grateful to my colleague and friend André Corboz for bringing this example to my attention.

[10] Christoph G. Brandenberger, *Koordinatentransformation für digitale kartographische Daten mit Lagrange- und Spline- Interpolation*, Zürich: Institut fur Kartographie, Eidgenössische Technische Hochschule, 1985.

[11] For another description see: Bruno Ernst, *Der Zauberspiegel des Maurits Cornelis Escher*, Berlin: Taco, 1986.

[12] For a basic description of the difference between vector and raster graphics see: William G. Mitchell, *The Re-Configured Eye*, (as in note v), pp. 4-6.
[13] See: William G. Mitchell, *The Re-Configured Eye*, (as in note v), p.154.
[14] Ibid, p. 4.
[15] Robert Lansdale, *Texture Mapping and Resampling for Computer Graphics*, M.A.Sc., Department of Electrical Engineering, University of Toronto, January 1991.
[16] A more detailed analysis of these problems would explore how Lansdale's approach, which is an extension of image precision algorithms, reverses the direction of projection used in Renaissance perspective, whereas object precision algorithms maintain the direction of the projection used in Renaissance perspective.
[17] Benoit Mandelbrot, *The Fractal Geometry of Nature*, New York: W. H. Freeman, 1977.
[18] Michael Fielding Barnsley, *Fractals Everywhere. The First Course in Deterministic Fractal Geometry*, Boston: Academic Press, 1988.
[19] See: L. Casey Larijani, *The Virtual Reality Primer*, New York: McGraw Hill, Inc., 1993, Colour Pl. 4.
[20] *The Kodak Guide to Imaging*, ed. Michael D. Gurley, Frederick P. Burger, Rochester: Eastman Kodak, 1993, p. 5.
[21] See: Michael McGreevy, "Virtual Reality and Planetary Exploration", *Virtual Reality. Applications and Explorations*, ed. Alan Wexelblatt, Boston: Academic Press, 1993, pp.163-197.
[22] For a further discussion of these problems see the author's "Ottica , percezione e prospettiva" in: *Specchi americani: riflessi e metamorfosi delle tradizioni filosofiche europee nel nuovo mondo*, ed. Caterina Marrone, San Sepolcro: , 1994, pp. . (III convegno di studi filosofici di San Sepolcro).
[23] Heinrich Klotz, Florian Rötzer und Peter Weibel, "Perspektiven der Computerkunst. Ein Gespräch": *Künstliche Spiele*, ed. Georg, Hartwagner, Stefan Iglhaut, Florian Rötzer, Munich: Boer, 1993, p. 123:
"Die Simulation ist ein weiterer Schritt weg vom Fluchtpunkt der Renaissanceperspektive hin zu einer Scheinwelt die für das Subjekt virtuell wirklich ist. Der Mensch kann sich diese Scheinwelt so vorgaukeln, als könne er in ihn leben, als würde er selbst als dreidimensionales Wesen in einem künstlich geschaffenen dreidimensionalen Raum existieren. Das ist eine neue Thematik, die man ausloten sollte."
[24] Charles Champlin, *George Lucas. The Creative Impulse. Lucasfilm's First Twenty Years*, New York: Harry Abrams, 1992. For a more detailed study see: Thomas G. Smith, *Industrial Light and Magic. The Art of Special Effects*, New York: Ballantine Books, 1986.
[25] Cf. Steve Aukstakalnis, David Blatner, *The Art and Science of Virtual Reality. Silicon Mirage*, Berkeley: Peachpit Press, 1992, pp. 238-242 re: two programmes that have been developed to this end, namely, n-Vision and Capri.
[26] Kim Michael Fairchild, "Information Management Using Virtual Reality-Based Visualizations",in: Alan Wexelblatt, ed., *Virtual Reality Applications and Explorations*, Boston: Academic Press Professional, 1993, pp. 43-74.
[27] See: Grigore Burdea, Philippe Coiffet, *La realité virtuelle*, Paris: Hermes, p. 196. This book also contains a useful bibliography on pp 355-376.

[28] Armand Fellous, "STV-Synthetic TV: From Laboratory Prototype to Production Tools", *Virtual Worlds and Multimedia*, ed. Nadia Magnenat Thalmann and Daniel Thalmann, Chichester: John Wiley and Sons, 1993, pp. 127-133.

[29] Gerhard Schmitt, "Virtual Reality in Architecture", *Virtual Worlds* (as in note xiv), pp. 85-97

[30] Francesco Antinucci (Rome), "La città di Giotto. Installazione di realtà virtuale", Realizzazione: Infobyte; Produzione: Istituto di psicologia del CNR in collaborazione con ENEL, Reported in: *Futuro remoto, 25 Novembre-15 Dicembre 1993, Mostra d'Oltremare, Napoli*, Ercolano: La Buona Stampa, 1993, [p.14].

[31] See the video "A Vision of Virtuality", GMD, Schloss Birlinghoven, 12/1993.

[32] One of the interesting aspects of the increasingly international scene is that the same software is being used for different ends in Japan, Canada and the United States, while at the same time, Toronto firms such as Topix and Spin Productions are creating applications for Canada, Japan and the United States.

[33] This has led to a new field of scientific visualization. For a basic introduction see: Richard Mark Friedhoff, William Benzon, *The Second Computer Revolution. Visualization*, New York: Harry Abrams, 1989.

[34] Warren Robinettt, "Electronic Expansion of Human Perception", *Whole Earth Review Magazine*, San Francisco, Fall 1991, pp. 16-21. One fascinating application of this principle is explored in Robinett's article:"The Nanomanipulator: A Virtual Reality Interface for a Scanning Tunneling Microscope", CB # 3175, UNC, Chapel Hill NC 27599-3175. Robinett has also produced one of the standard attempts to classify the experiences in new technologies in "Synthetic Experience. A Proposed Taxonomy", *Presence*, Cambridge, Mass., vol. 1, number 2, Spring 1992, pp.229-247.

[35] Steve Aukstakalnis, David Blatner, *The Art and Science of Virtual Reality*, (as in note xvi), pp. 23-24.

[36] Ken Pimentel and Kevin Teixeira, *Virtual Reality. Through the New Looking Glass*, New York: Intel/Windscrest/McGraw-Hill Inc., 1992, pp. 7....17.

[37] For a survey of recent studies see: Michael Kiene, *Giovanni Paolo Pannini. Römische Veduten aus dem Louvre*, Braunschweig: Hezog Anton Ulrich Museum, 1993.

[38] William G. Mitchell, *The Re-Configured Eye*, (as in note v).

[39] The following is taken from: Newsgroups: sci.crypt, talk.politics.crypto,sci.answers ,news.answers, talk.answers; Subject: Cryptography FAQ (01/10: Overview); Date: 17 Jan 1994.

Organization: The Crypt Cabal; Reply-To: crypt-comments@math.ncsu.edu

Many people have contributed to this FAQ. In alphabetical order: Eric Bach, Steve Bellovin, Dan Bernstein, Nelson Bolyard, Carl Ellison, Jim Gillogly, Mike Gleason, Doug Gwyn, Luke O'Connor, Tony Patti, William Setzer. We apologize for any omissions:

"6.8. What is `authentication' and the `key-exchange problem'?

The ``key exchange problem'' involves (1) ensuring that keys are exchanged so that the sender and receiver can perform encryption and decryption, and (2) doing so in such a way that ensures an eaves- dropper or outside party cannot break the code. `Authentication' adds the requirement that (3) there is some assurance to the receiver that a message was encrypted by `a given entity' and not `someone else'.

The simplest but least available method to ensure all constraints above are satisfied (successful key exchange and valid authentication) is employed by private key cryptography: exchanging the key secretly. Note that under this scheme, the problem of authentication is implicitly resolved. The assumption under the scheme is that only the sender will have the key capable of encrypting sensible messages delivered to the receiver. While public-key cryptographic methods solve a critical aspect of the `key-exchange problem', specifically their resistance to analysis even with the presence a passive eavesdropper during exchange of keys, they do not solve all problems associated with key exchange. In particular, since the keys are considered `public knowledge,' (particularly with RSA) some other mechanism must be developed to testify to authenticity, because possession of keys alone (sufficient to encrypt intelligible messages) is no evidence of a particular unique identity of the sender.

One solution is to develop a key distribution mechanism that assures that listed keys are actually those of the given entities, sometimes called a `trusted authority'. The authority typically does not actually
generate keys, but does ensure via some mechanism that the lists of keys and associated identities kept and advertised for reference by senders and receivers are `correct'. Another method relies on users to distribute and track each other's keys and trust in an informal, distributed fashion. This has been popularized as a viable alternative by the PGP software which calls the model the `web of trust'.

Under RSA, if a person wishes to send evidence of their identity in addition to an encrypted message, they simply encrypt some information with their private key called the `signature', additionally included in the message sent under the public-key encryption to the receiver. The receiver can use the RSA algorithm `in reverse' to verify that the information decrypts sensibly, such that only the given entity could have encrypted the plaintext by use of the secret key. Typically the encrypted `signature' is a `message digest' that comprises a unique mathematical `summary' of the secret message (if the signature were static across multiple messages, once known previous receivers could use it falsely). In this way, theoretically only the sender of the message could generate their valid signature for that message, thereby authenticating it for the receiver. `Digital signatures' have many other design properties as described in Section 7".

[40] On the problems involved see see, *Ethics, Copyright and the Bottom Line*, ed. Stewart McBride, Camden: Center for Creative Imaging, particularly, Fred Ritchin, "An Image Based Society", pp. 29-36. For reference to Kodak's research see: "When its created it's copyrighted" in: *The Kodak Guide to Imaging*, ed. Michael D. Gurley, Frederick P. Burger, Rochester: Eastman Kodak, 1993, pp. 39-40. There is also an electronic bulletin board sponsored by ASMP and supported by Kodak called the *Electronic Picture Round Table (EPIX).* See also the book by Fred Ritchin: *In our own Image. The Coming Revolution in Photography*.

[41] Sven Sandström, *Levels of Unreality. Studies in Structure and Construction in Italian Mural Painting*, Uppsala: Almqvist and Wiksells, 1963. (Acta Universitatis Upsallensis, Figura. New Series, 4).