3D Information Visualisation: an Historical Perspective

Theodor G Wyeld
IEP, ITEE, University of Queensland, Australia.
{twyeld@itee.uq.edu.au}

Abstract

The use of 3D visualisation of digital information is a recent phenomenon. It relies on users understanding 3D perspectival spaces. Questions about the universal access of such spaces has been debated since its inception in the European Renaissance. Perspective has since become a strong cultural influence in Western visual communication. Perspective imaging assists the process of experimenting by the sketching or modelling of ideas. In particular, the recent 3D modelling of an essentially non-dimensional Cyber-space raises questions of how we think about information in general. While alternate methods clearly exist they are rarely explored within the 3D paradigm (such as Chinese isometry). This paper seeks to generate further discussion on the historical background of perspective and its role in underpinning this emergent field.

Keywords--- **Perspective, 3D Visualisation**.

1. An Historical Perspective

Since Bertin [1] first used three-dimensional visualisation of digital information in the 80's it has enjoyed exponential growth. Typically, we see regular geometric solids floating in a spatial void, topographical 'landscapes' with alternating peaks and valleys, and complex matrices of columns and rows of variable data among others (see figure 1). All of these rely on the user's ability to interpret the three-dimensional perspectival spaces depicted (The technique of representing three-dimensional objects and depth relationships on a two-dimensional surface). This use of perspective as a method for viewing three-dimensional space has dominated Western visual culture since the Renaissance. Prior to the Renaissance the pictorial depiction of depth was not organised by the strict geometrical rules we are more familiar with today. This produced, what Edgerton [3] calls 'squashed view' perspectives – a primitive form of isometry. Few proponents, who adopt a core 3-D component as the main interface, question the premise by which they assume that their 3-D interfaces are universally understood.

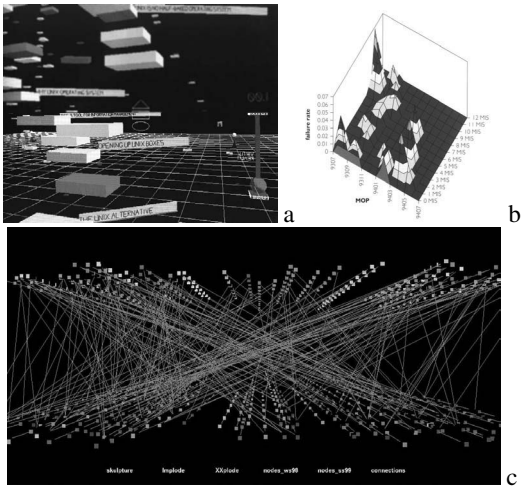


Fig. 1. a) Solids floating in a void [15]; b) topographical landscape [16]; and, c) a 3D data matrix [31].

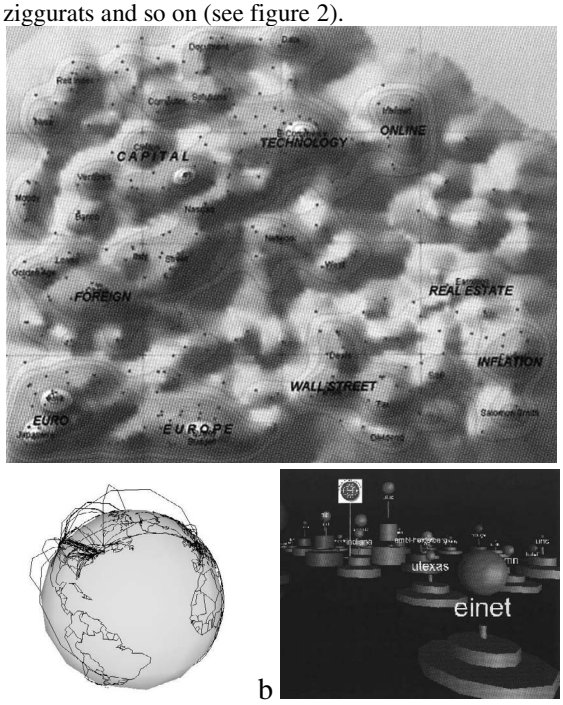
Just at what age one begins to conceive of these Euclidean spaces is open to debate [2, 3, 4]. According to Piaget [2] one must be able to adopt a 'viewpoint', to sense objects as empirical three-dimensional volumes in what he and other psychologists call 'psychophysiological space'. "Psychophysiological space is the realm of immediate sense experience, neither infinite, isotropic, nor homogeneous" [3, p69]. Objects near to us are sensed as Euclidean or three-dimensional. At the edge of our psychophysiological space objects lose these qualities. For example, we perceive the distant moon not as a ball but as a disc painted onto the inner surface of a hemisphere. Computer-graphics-generated three-dimensional representations of space, on the other hand, are perceived entirely within Euclidean space[1].

Some theorists [3, 4] claim that our ability to image regular three-dimensional objects in the mind's eye is universal regardless of race, gender, or culture. Others [5, 6] counter claim that one needs cultural conditioning, and exposure to a normal variety of (Western) visual media, before we collude with what is otherwise merely an illusion. This distinction is most pertinent to 3-D

[1] Euclid proposed that if certain 'obvious' axioms could be accepted on faith then subsequent theorems should hold. For example, if we accept that the shortest distance between two Euclidean points is a straight line then we can use straight lines to map out the distance between ourselves and objects in space. Descartes finally organised this schema into an arbitrary 3-dimensional axial system.

Proceedings of the Ninth International Conference on Information Visualisation (IV'05)
1550-6037/05 $20.00 © 2005 **IEEE**

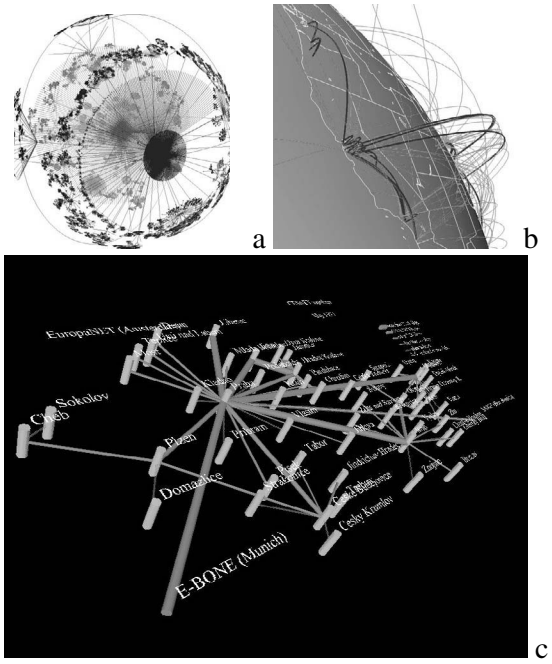
information visualisation where the images displayed often have no physical-world counterpart other than as abstract metaphors, such as a deformed 3D mesh, globes, ziggurats and so on (see figure 2).



a b c

Fig. 2. a) Data terrain mesh [16]; b) MBone globe [13]; and, c) abstract 3D forms[15].

Experiments conducted [3, 7, 8] to confirm or otherwise the universal optical-physiological accessibility of a perspective tend to suggest that when we reflect on how the world appears to us the images formed in our imagination follow familiar conventions – perspective being the most common in the West[2]. Whether or not it is a convention or physiological fact, (see Gombrich [9], Topper [10], and Wartofsky [5] for a detailed analysis of this debate), perspectival representation is now such a strong cultural influence that it has become *the* method of thinking and communicating about the world around us [11]. Hence, its real import is how it has conditioned the mind's eye to 'read' three-dimensional images as a primary visual method [3]. In the case of network visualisation (such as the CAIDA 3D Hyperbolic graphs [12], Stanford's MBone graphics [13], CESNET 3D grids [14], and so on) its three-dimensionalisation seems to provide a clarity of information which only a 3-D perspective gives (see figure 3). For example, the ability to display information along a third axis which is not available in a simple 2D graphic (such as proximity in 3-dimensions, or other volumetric value specific to a particular point in space – file size, traffic flow, relative importance and so on).



a b c

Fig. 3. a) 3D hyperbolic map of internet topology [12]; b) part MBone globe [13]; and, c) local interest network geographically scaled [14].

Other *2D* network visualisations, such as Beck's (1931) London Underground map [16] (and its various digital network corollaries: Interoute i-21 [17], PSINet [18], GEANT [19], and so on) may, however, provide more meaningful information 'at a glance' (see figure 4).

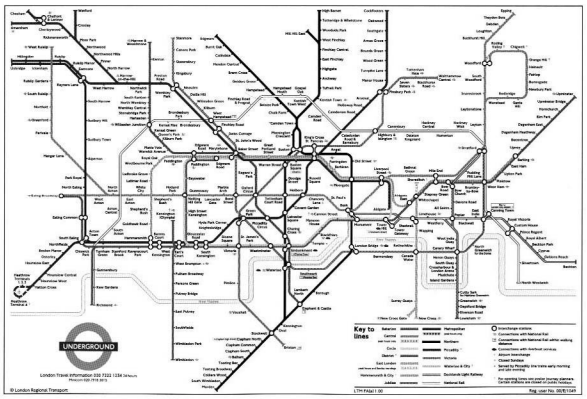


Fig. 4. Beck's London Underground Map [16].

Nevertheless, there tends to be an overriding impression of the insistence on using 3D as an interface (See Dodge and Kitchin's [15] *An Atlas of Cyberspaces* for a comprehensive overview of visualisation methods). This may be because the power to do so is relatively recent. However, the *negative* implications for perspectival information visualisation have not yet surfaced. It includes the inherent locus of meaning and

[2] Edgerton [3] demonstrated how college students visualise in perspective by their ability to sketch a perspective of a prism with little or no tutoring in less than one hour. Deregowski [7] and Gregory [8], on the other hand, used the Hudson perception test to demonstrate how non-Western peoples often cannot recognise a perspective picture, only piecing together various elements with difficulty.

privileged viewing position in a perspective[3]. This implies that there is only one 'correct' view, in turn, affecting what we see and look for in information displays. Even when we can manipulate a 3D view in real-time we are simply presented with a series of individual views, each with its own 'correct' centre of projection. Although it could be argued that other factors can be inculcated such what the third dimension is used to represent.

Such scientific reductionisms[4] are well documented (see the works of Feyerabend, Popper, Lakatos, and Kuhn). To demonstrate *how* this reduces the potential information available we need only to observe the way pre-perspective infants see and represent the world around *them*. An infant will draw a table showing all legs at once, even though they can't ordinarily see them all, because they 'know' they are there (see figure 5a). Similarly, we often lament the inability for our 3-D representation media to show the relationships between data which we know exist but are obscured (see figure 5b & 5c) – we know there are two halves to the MBone globe (see figure 2b), with their many interrelations, but at least one of them is obscured at any moment by the single perspective view. Even if we spin the globe around we have to 'remember' what we saw first.

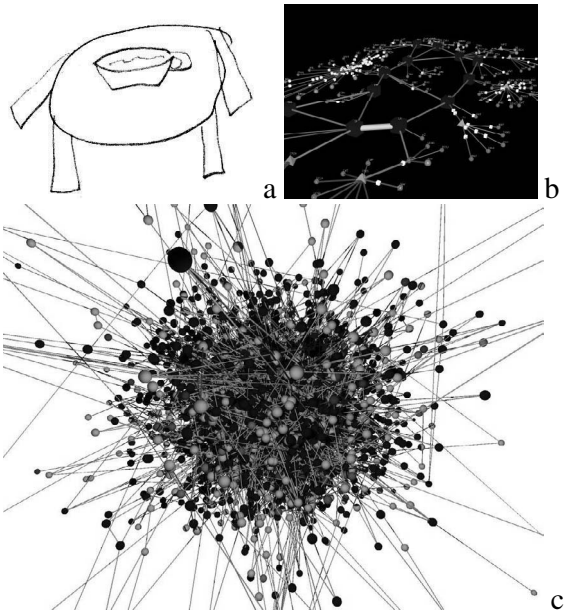


Fig. 5. a) 4-year-old child's drawing of a table; b) animated model of the vBNS network showing traffic flow [25]; and, c) IP cluster mapping [26].

[3] The traditional perspective implied that the viewer should adopt the very position that the artist did in constructing their picture – a position close to God. Indeed, in the case of Pozzo's 17thC ceiling frescos a dot on the floor beneath marks the spot where one must stand. In science this 'correct' positioning is reflected in the singularities that scientists search for to explain the world around them. They are called natural laws.

[4] The idea that nature can be described scientifically; that there are no unknowable facts.

2. Perspective as Thought Grammar

Following the intuitive conventions of linear perspective, and orthographic projection was the photograph – the physical embodiment of *automated* picture making [4]. While for a time, the photograph enjoyed the title of arbiter of the 'truth', computer-generated perspective constructions now assume similar truths. It could be argued, however, that the objects portrayed in a 3D computer-generated image, and their replication of real-world objects, simply relies on our instantaneous recognition of them. In other words, instead of seeing a 'picture' we *read* a predictable convention and accept it as the truth [20]. Real estate images rely on this when they use computer-generated images of desirable urban spaces. These are the same truths we rely on when analysing the images created by three-dimensional information arrays. Indeed, any restructuring of information is always circumstantially framed by the methods we use to represent it [15, 21]. 3D computer-generated perspective is a method for separating a code from its content (legend from a map or diagram) to communicate a particular *kind* of information. We use it to filter out redundant information, encoding only those features that we want to convey to the recipient.

In medical science, anatomical drawings are used rather than photographs of dissection because the photograph often fails to demonstrate the desired aspects (not to mention arousing aversion) (see figure 6a). This mapping, or diagrammatic information communication, uses a standardized code to show hidden relations. But such encodings often hide more than they reveal (see figures 6b & 6c).

Sketches and modellings such as Leonardo's and the MBone globe are useful as thought experiments tested graphically. They are not just thought experiments resolved by graphic modelling, however. They are thought experiments that are *encouraged* by their modelling. Leonardo's sketchings were a kind of virtual ideas modelling that followed a perspectival thought grammar – the grammar of organising discrete objects in a three-dimensional coordinated space as if they were real or part of the 'physical' world[5]. But just as we don't know anything about the cadaver that Leonardo used, the MBone 3-D graphic too, shows relationships, size, and extent of a world-wide network as if it were 'real.' It ignores the political, social, and economic access to such networks. It presents a reality sanitised of these encumbrances.

[5] Indeed, the psychologist Romanyshyn [11] maintains perspective, and its incumbent technologies, have affected the very way we view and describe the world around us and our personal interrelations. We use terms such as 'point of view', 'perspective', and 'through a scientific lens' in discourse on nature. As such, perspectival concepts have entered common language and form part of everyday grammar.

Proceedings of the Ninth International Conference on Information Visualisation (IV'05)
1550-6037/05 $20.00 © 2005 **IEEE**

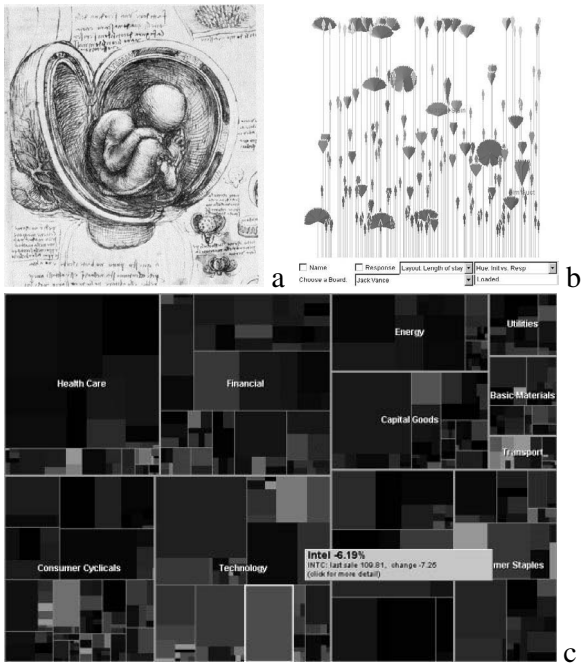


Fig. 6. a) Embryo, Leonardo da Vinci (1509) [22]; b) multi-users' interaction mapping [28]; and, c) stock market map [27];

Does this matter? It matters if we consider that any complex system represented in such an easily recognisable way recreates symbolic re-configurations of everyday images instilling a perception that what we see is real, and thus believable (even desirable in the case of contemporary 3D real estate compositions). In other words, a primary assumption in the use of perspective follows that what we *can* see may be all that matters. But, like in the infant's drawing of a table, what is obscured does matter – at least to a child!

Ignoring the obvious ethics of this argument, more pragmatically, Renaissance artists used aesthetic measures to compensate for perspectival distortions. Unlike the rigid mathematical precision of contemporary computer graphics, they tried to make their images appear more harmonious. They used multiple vanishing points, curvilinear perspective and anamorphism, among others. (Although, in many cases this simply created different kinds of distortion.) Modern computer algorithmic notions of perspective, on the other hand, are unfailing in their mathematical accuracy. In this way, 3-D Computer graphics tend to acutely expose the anomalies in the one-to-one isomorphism between the world around us and a perspective picture of it.

Extensions to the perspective paradigm *are* possible within contemporary 3D computer graphics, but are only recently being investigated. Extensions such as: animation, real-time navigable spaces, database-linked dynamically-updated displays, parameterized displays with multiple manual and automated input sources, and so on. Although these extensions are still circumstantially framed within the prevailing perspective paradigm. Alternately, non-Western perceptions about how to represent a multi-dimensional world are rarely explored – such as Asian isometry, African and South American iconographics, and Australian Aboriginal dot painting, to name a few. What could be made of these techniques in information visualisation? To attempt an answer is to look at those examples of multi-dimensional visualisations that do not rely on a core 3D component (such as the mappings found in figures 6b & 6c). While many digital examples come to mind, what most are attempting to emulate is achieved in Minard's historical, manually-drafted, graphic of Napoleon's march into Russia in 1812 (see figure 7a). In his graphic, he presents us with at least six dimensions of information[6]. It succinctly captures the essence of the journey. The drama is in the line thicknesses and data contained rather than the aesthetics of the diagram itself. This begs the question: what would be gained by its three-dimensionalisation? It is difficult to imagine how the same information presented in a 3D format would enhance our knowledge of the events. In fact, much of the succinctness of Minard's presentation would be lost in the confectionery of a 3D topological landscape, as it is in CASA's [29] three-dimensionalisation of Beck's London underground map (see Figure 7b). While at first the potential to navigate this 3D map seems limitless, what we find is, due to the arbitrary nature of the routes depicted, one is more likely to lose their way!

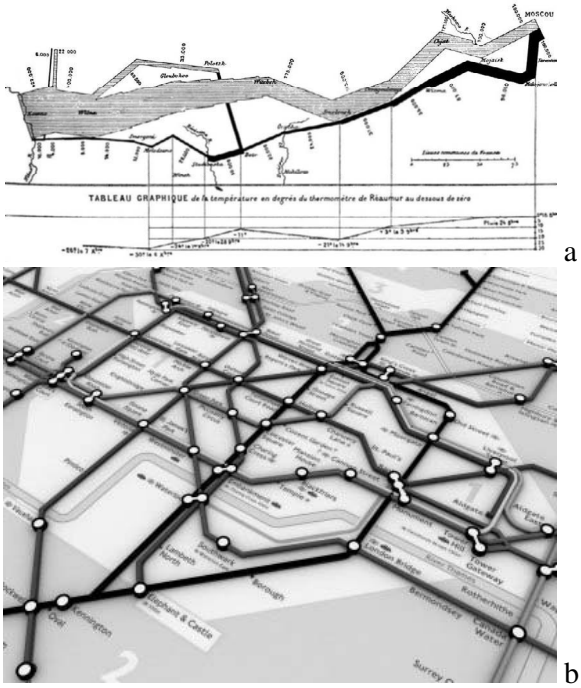


Fig. 7. a) Napoleon's 1812 march [21]; and, b) 3D model of the London Underground [29].

[6] Minard's graphical depiction of Napoleon's march traces the movement of troops across time, distance, geographical location, numbers of soldiers, direction, and temperature.

3. The Neutrality of Perspective

The final point to address concerns the notion that perspective provides a 'neutral' viewpoint[7]. This underpins the scientific legitimacy of perspectively generated three-dimensional spaces in information visualisation. According to Coyne [23] this convincing neutral viewpoint is based on a rationalistic orientation which supports such technologies as largely a matter of interface – in time, we have become so engaged by perspective's power that we are simply numbed to its effects.

From Leonardo's 15th Century *Last Supper* fresco, the first photographed view of the earth from a hot air balloon in the 19th Century, the earth as seen from the Apollo 11 moon shot in 1969, to the computer-generated models of the elusive mobile chemical weapons factory in Iraq (see figure 8), clearly perspective has had profound implications in the way Western society interprets the images it uses to articulate its ontology[8]. (Indeed, Burnett [24] questions whether it is the images we react to or the information they contain).

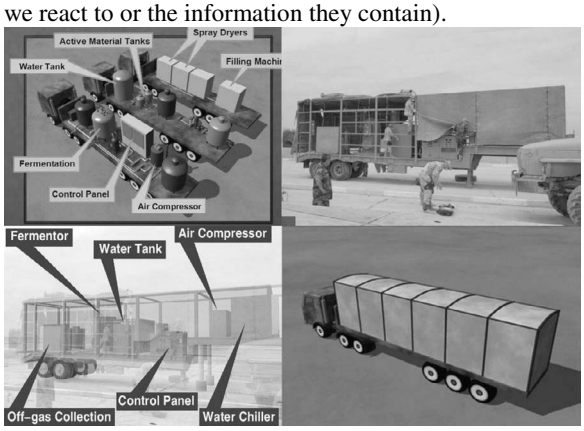


Fig. 8. Computer model and photographs of a mock-up of the elusive Iraqi chemical weapons factory [30].

It demonstrates our reliance on images as neutral purveyors of information. Perspectival devices – the camera, cinema, TV, and so on – have encouraged us to view the world as perspectivally constructed – every 'thing' taking up its correct position in a 3-coordinate Cartesian space. For example, cyberspace is essentially a non-dimensional information space – we give it dimensions when we try to visualise it (see figure 3a). Its interrelationships follow *our* organisational structuring. Such contemporary organising strategies are founded on displaying information in a three-dimensional manner. This reflects how we now think about information – discrete parcels interconnected across a range of values distributed along spatial axes. These organisational strategies are both informed by and respond to what 'information' is. Unlike information, however, we describe other values, such as our desires, as near or far from us. These are nonlinear values for which we can't apply a metric distance, hence escape representation within the perspective paradigm.

[7] The scientifically neutral viewpoint in a perspective implies, as does most scientific endeavour, a value-free, objective position not sullied by subjective opinion; that if another were to adopt the same position they would see/experience the same thing and that this is repeatable.

[8] Increasingly the primary commodity in Western society is the exchange of information. Much of this information is manifest in imagery (print, cinema, TV, computer graphics, and so on). Its citizens rely on everyday imagery to establish their social, commercial, and intellectual identity – sense of being – by the exchange of images. The most common format is perspectival by nature.

4. Conclusion

While not an *exhaustive* overview of the state of 3D information visualisation, what emerges from this study is: the ideologically dominant role perspective plays in Western visual thought means alternate strategies are rarely explored. However, the increasing complexity of human global interaction – cultural and information exchange – dictates that simplified three-dimensional representations may no longer be appropriate for conveying the depth of all possible understandings. While the conventional depiction of 3-D space, as a visual medium for organising information, is far from exhausted, it has often been pursued at the expense of possible alternate methods. This has the potential to obscure information both literally and metaphorically.

References

[1] J. Bertin, "*Graphics and Graphic Information Processing*", Walter de Gruyter, New York, NY., 1981.

[2] J. Piaget, and B. Inhelder, "*The Child's Conception of Space*", Langdon, F. J., and Lunzer, J. L. (trans.) Routledge and Kegan Paul, London, 1956.

[3] S. Y. Edgerton, "*The Heritage of Giotto's Geometry: Art and Science on the Eve of the Scientific Revolution*", Cornell University Press, Ithaca, London, 1991.

[4] M. Kubovy, "*The Psychology of Perspective and Renaissance Art*", Cambridge University Press, Cambridge, 1989.

[5] M. Wartofsky, "*Models: Representations and the Scientific Understanding*", D. Reidel Publishing, Holland, USA, England, 1979.

[6] M. Kemp, "*The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat*", Yale University Press, New Haven and London, 1990.

[7] J. B. Deregowski, "Pictorial Perception and Culture", in *Scientific American*, Vol 227, No. 5 September, 1972, pp82-88, 1972.

[8] R. L. Gregory, "*Eye and Brain: the Psychology of Seeing*", Weidenfeld and Nicolson, London, 1966.

[9] E. H. Gombrich, "*Art and Illusion: A Study in the Psychology of Pictorial Representation*", Princeton University Press, Princeton and Oxford, 2000.

[10] D. Topper, "Perspectives on Perspective: Gombrich and his Critics", in *Gombrich on Art and Psychology*, Woodfield, R., (Ed.), Manchester University Press, Manchester and New York.,1997.

[11] R. D. Romanyshyn, "*Technology as Symptom and Dream*", Routledge, London and NY, 1992.

[12] CAIDA http://www.caida.org/tools/visualization/walrus/ Nov, 2004.
[13] MBone network globe graphics: www-graphics.stanford.edu/papers/mbone, Nov, 2004.
[14] CESNET 3D grids : www.ces.net/network, Nov, 2004.
[15] M. Dodge and R. Kitchin, "*An Atlas of Cyberspace*", Addison-Wesley, London, NY, 2001.
[16] R. Spence, "*Information Visualisation*", Addison-Wesley, London, NY, 2001.
[17] Interoute i-21 maps: www.interoute.com, Nov, 2004.
[18] PSINet networks: www.psi.net/network, Nov, 2004.
[19] GEANT network: www.dante.net/geant, Nov, 2004.
[20] W. J. Mitchell, "*The Reconfigured Eye: Visual Truth in the Post-photographic Era*", MIT Press, London, 1994.
[21] E. R. Tufte, "*The Visual Display of Quantitative Information*", Graphics Press, Cheshire, Connecticut, 1983.
[22] *Embryo*, Leonardo da Vinci (1509): www.wga.hu, Nov, 2004.
[23] R. Coyne, "*Designing Information Technology in the Postmodern Age*", Cambridge, Massachusetts, The MIT Press.,1995.
[24] R. Burnett, "*How Images Think*", The MIT Press, Camb., Mass., London, England, 2004.
[25] Cichlid data visualisation software: http://moat.nlanr.net/Software/Cichlid/, Feb, 2005.
[26] [26] IP Mapping: http://www.fractalus.com/steve/stuff/ipmap, Feb, 2005.
[27] Map of the Market: http://www.smartmoney.com/marketmap/, Feb, 2005.
[28] R. Xiong and J. Donath, "*PeopleGarden: Creating Data Portraits for Users*", UIST, 1999, source: http://www.geog.ucl.ac.uk/casa/martin/atlas/info_maps.html, Feb, 2005.
[29] Centre for Advanced Spatial Analysis (CASA): http://www.casa.ucl.ac.uk/news/index.htm, Feb, 2005.
[30] Report on proof for the existence of a chemical weapons factory in Iraq: www.news.bbc.co.uk, May, 2003.
[31] Strehlke, K., and Engeli, M., 2001, "*[roomz]&[connectionz]: Scenarios in Space and Time*", in de Vries, B., van Leeuwen, J., and Achten, H., (eds), Proceedings of the international CAAD Futures conference, 8-11 July 2001, Eindhoven, The Netherlands, pp173-186.