RDF/XML developments which probably will lead to its even wider adoption than if it remained a Web browser plug-in. Now that the RDF standardization process is nearly concluded, it only remains to wait and see how RDF is picked up. All indications are positive. Considered in the light of the open development process and public availability of the source code for next generation Web browsers, the odds are strong that another VR information browsing tool will become available. As RDF/XML move out of the development stages, it seems reasonable to assume that next generation geographic metadata will be written in RDF/XML, opening opportunities for improving access through information spaces and other means.

References

Buttenfield, B. and Beard, M.K. 1994. Graphical and geographical components of data quality. In Hearnshaw, H. and Unwin, D. (eds) *Visualization in Geographic Information Systems*. New York: Wiley, pp. 150–7.

Chrisman, N.R. 1984. The role of quality information in the long term functioning of a GIS. *Cartographica,* 21, 79–87.

Deming, E.W. 1989. *Out of the Crisis*. Cambridge, MA: MIT Center for Advanced Engineering Study.

Dobson, J. 1998. Commentary. *GIS World*, 11, 32.

Goodchild, M., Chih-Chang, L. and Leung, Y. 1994. Visualizing fuzzy maps. In Hearnshaw, H. and Unwin, D. (eds) *Visualization in Geographic Information Systems*. New York: John Wiley & Sons, pp. 158–67.

Guha, R.V. 1997a. Meta Content Framework. http://mcf.research.apple.com/hs/mcf.html.

Guha, R.V. 1997b. Meta Content Framework: A white paper. http://mcf.research.apple.com/wp. html.

Guha, R.V. 1997c. Towards a theory of meta-content. http://mcf.research.apple.com/mc.html.

ISO. 1989. *Quality Management and Quality Assurance – Vocabulary (8402)*. International Standards Organization, Zurich.

Paradis, J. and Beard, K. 1994. Visualization of spatial data quality for the decision maker: A data-quality filter. *URISA Journal*, 6, 25–34.

Strong, D.M., Lee, Y.W. and Wang, R.Y. 1997. Data quality in context. *Communications of the ACM*, 40, 103–10.

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23 'There's no there there'

Virtual reality, space and geographic visualization

Rob Kitchin and Martin Dodge

Introduction

Virtual reality (VR) is providing fresh challenges for both theorisers and philosophers of space and to cartographers and those wishing to visualize the extent and form of virtual spaces. In this chapter, these challenges are identified and explored through an examination of the spatial qualities of VR, and the ways in which geographic metaphors (in particular the notion of mapping) are being employed to aid navigation in, and understanding of, VR spaces. Here, VR is defined broadly to incorporate a number of forms including (visual) virtual reality simulations, Web pages, chatrooms, bulletin boards, MUDs (both textual and visual) and 'game' spaces. To us, VR consists of computer-generated spaces that enable the user to interact with the computer, and other people connected to the network, in ways that simulate (though not necessarily replicate) real-world interactions (e.g. movement through a landscape or chatting to somebody). As the rapidly growing website, *Atlas of Cyberspaces* (Dodge, 1999) illustrates, the mapping of cyberspace has started in earnest, and in large part has been undertaken by researchers outside the fields of cartography and geography. However, this process of mapping has largely taken place in an uncritical manner, with little thought as to the wider implications or consequences of the techniques used. In this chapter, we critically detail and assess the mapping of VR spaces, outlining some of the difficulties and issues complicit in such a project.

Why 'map' VR?

VR spaces are complex. They are, quite literally, computer-supported, informational spaces, fundamentally composed of zeros and ones and connected in a myriad of ways. Some of the information is explicitly spatial with direct geographic referents (e.g. VR models of real-world places, such as the work of Batty (1998) *et al.*'s modelling of parts of London). Other information has an inherent spatial form without a geographic referent (e.g. MUDs), or has a real-world referent but no spatial form/attributes (e.g. a list of names, Web pages), or has no geographic referent and no spatial form/attributes (e.g. computer file allocation). In addition, as discussed in Chapter 20, information with a real-world referent may have a materiality (e.g. has a mass) or be immaterial in nature (e.g. gravity, heat). Mapping in both a literal and metaphorical sense can provide a means of facilitating comprehension of, navigation within, and documenting the extent of (marking out territories) these varying forms of informational space.

It has long been recognised that geographical visualizations in all their manifestations form an integral part of how we understand the world. For example, traditional cartographic maps have been used for centuries as a method to visualize geographical distributions across a world that is too large and too complex to be seen directly (MacEachren, 1995). At the end of the twentieth century, cartography has undergone two major evolutions. One has been digitalisation, and the widespread use of computer systems such as GISs and CADs that are able to store, process, manipulate and transform spatial and attribute data. The second has been in the move away from static maps to interactive, dynamic and animated geographic visualizations that can be designed by anyone with access to software and data. These two evolutions, widespread access to map-making technology and geographic visualizations, extends the power of mapping in qualitative and quantitative ways:

1 opening up new ways to comprehend the real world,
2 providing effective ways of structuring immaterial phenomenon and material that has no geographical referent to increase comprehensibility,
3 allowing static representations to be replaced with multiple representations that can be interactive and dynamic, and
4 empowering non-cartographers to be able to access data and produce their own maps, thus breaking one of the major principles of traditional map-making theory, that is that there is a clear separation between cartographer and user (Crampton, 1999).

In the case of information that has a geographic referent and spatial attributes, constructing a map or geographic visualization provides a means to visualize and describe that form. In some cases, this means producing a virtual model of the geographic world. Here, issues such as accuracy, precision, verisimilitude (having the appearance of truth, realistic depiction) and mimesis (imitation, mimicry) come to the fore (see Chapter 3). In other cases, this means producing geographic visualizations of what Batty (1997) has termed 'cyberplace', the infrastructure of the digital world – the wires, computers and people. An example of cyberplace visualization are the 'maps' of the Internet's MBone (multicast backbone) produced in 1995 by a team of computer science and visualization researchers in California (Munzner *et al.*, 1996). These visualizations used the powerful visual metaphor of the globe of the Earth onto which the MBone network linkages were plotted as arcs, as shown in Figure 23.1. As 3D models, in VRML format, the end-user is allowed greater freedom to interact with them – rotating and spinning them, so that they can be viewed from any position. Without these geographic visualizations, topological structure data are almost impossible for humans to interpret because they are held in large textual tables.

Another fascinating example of mapping cyberplace are the visualizations of the geography of Internet traffic computed by the National Center for Supercomputing Applications (NCSA) in 1995 (Lamm *et al.*, 1996). Figure 23.2 shows an image of one of their striking 'maps', with the traffic represented as virtual skyscrapers projecting into space from the Earth globe. These skyscrapers represent three different dimensions of the traffic data. First, the position of the base of the bar is at the approximate origin of the traffic (this is aggregated to the country level outside of North America). Second, the height of the bar represents the total volume of traffic for that time period from that region and, third, the different coloured bands on the bars indicate the type of traffic (such as images,

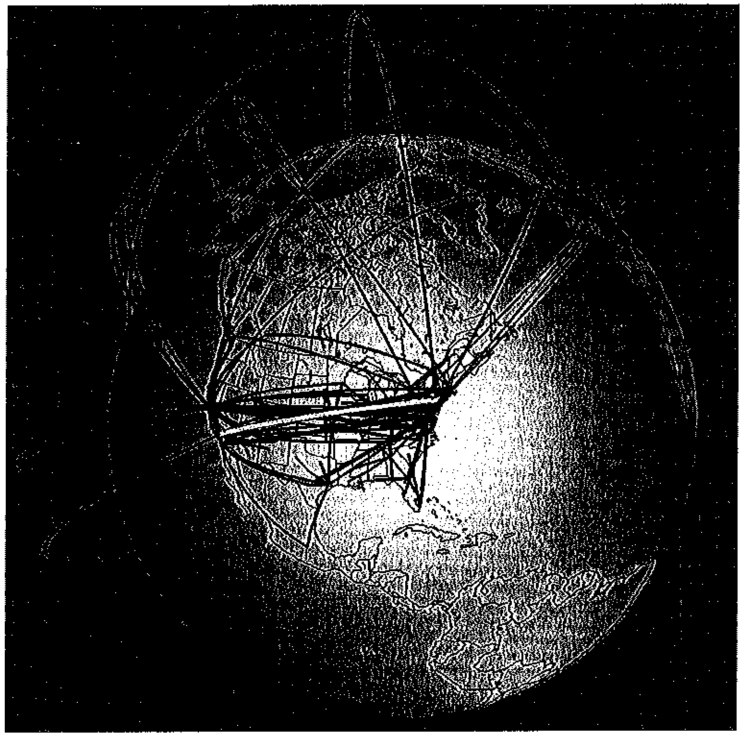


Figure 23.1 MBone linkages in the Internet.

HTML, text, video, data, etc.). Importantly, the Lamm *et al.* map could also encode another vital dimension of the traffic, that of change over time. Their 3D globe was rendered in a sophisticated VR environment that was dynamically linked to the Web server hosting the NCSA site, enabling traffic patterns to be mapped in near real-time. The VR environment enabled users to immerse themselves to a degree into the map, being able to move around the globe freely and interrogate the bars. Also provided were control panels, that can be seen in Figure 23.2 floating behind the globe, which allowed users interactively to change the display characteristics of the map.

Similarly, the spatial form attributes of VR data that have no geographic referent can be mapped in a process called spatialisation. There is an emerging body of research over the past decade into this type of information visualization (Card *et al.*, 1999; Gershon and Eick, 1995). In cases where there are no spatial attributes, we use the terms 'map' and 'mapping' metaphorically. Here, a spatial structure is applied where none exists in order to provide a means of visualizing and comprehending space; to utilise the power of spatial representation to describe complex informational spaces in a new, more easily interpretable form. Here, information attributes are transformed into a spatial structure through the application of concepts such as proximity (nearness/likeness). A number of researchers are now experimenting with the application of geographic metaphors to what Batty (1997) has termed c-space (the spaces on the screen) and cyberspace (spaces of computer-mediated communication) (see p. 348)

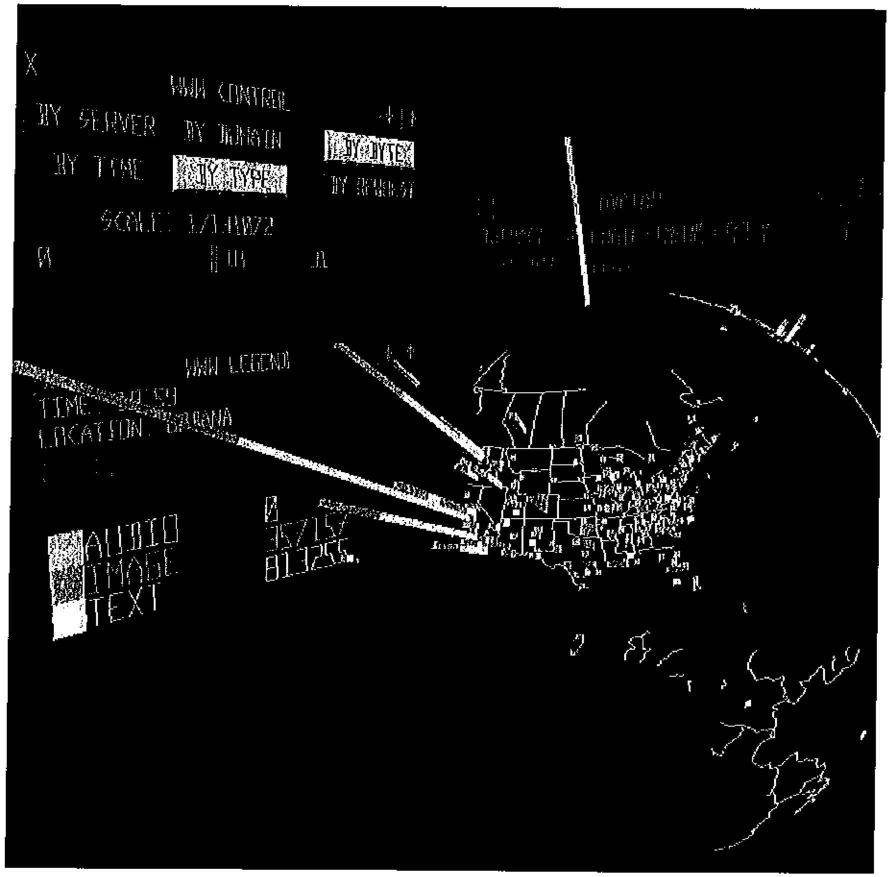


Figure 23.2 Mapping Internet traffic data.

In this chapter, we initially focus on detailing the nature of space within VR space, before examining the practicalities of mapping VR spaces. Next, we detail a topology of mapping, finishing with an exploration of wider issues.

Space and VR space

The challenge to those wishing to 'map' VR spaces with an inherent spatial form (e.g. visual virtual reality simulations; visual MUDs) is that they are qualitatively different from geographic space in a number of fundamental ways. In the following discussion the term cyberspace is often used synonymously with virtual reality. VR spaces are, to us, a sub-set of cyberspace and therefore what applies to cyberspace also applies to VR. This is particularly the case in relation to spatial qualities. As discussed, Memarzia (1997) stated:

> In cyberspace there are no physical constraints to dictate the dynamics or spatio-temporal qualities of the portrayed virtual space. Gravity or friction does not exist in cyberspace unless it has been designed and implemented.... cyberspace is not limited to three dimensions, since any two-dimensional plane or point may unfold to reveal another multidimensional spatial environment.... There are no ground rules concerning scale consistency in a virtual environment. Furthermore, the scale of the environment, relative to the user or viewer, may be altered at will.... Cyberspace can be non-continuous, multidimensional and self-reflexive ... In general, all principles of real space may be violated in cyberspace and the characteristics and constraints are only determined by the specifications that define the particular digital space.

Novak (1991: 251–2) thus argued that cyberspace has a 'liquid architecture':

> Liquid architecture is an architecture that breathes, pulses, leaps as one form and lands as another. Liquid architecture is an architecture

> whose form is contingent on the interests of the beholder; it is an architecture that opens to welcome me and closes to defend me; it is an architecture without doors and hallways, where the next room is always where I need it to be and what I need it to be. Liquid architecture makes liquid cities, cities that change at the shift of a value, where visitors with different backgrounds see different landmarks, where neighbourhoods vary with ideas held in common, and evolve as the ideas mature or dissolve.

VR spaces have spatial and architectural forms that are dematerialised, dynamic and devoid of the laws of physics; spaces in which the mind can explore free of the body; spaces that are in every way socially constructed, produced and abstract. Indeed, Holtzman (1994: 210) referred to the designers of virtual worlds as 'space makers'. While some VR spaces do have an explicit spatial form (e.g. visual virtual worlds) they exist only in code; a combination of zeros and ones – objects are merely surfaces, they have no weight or mass (Holtzman, 1994). Morse (1997) describes cyberspace as an infinite, immaterial non-space, suggesting that it takes the form of a liminal space:

> Virtual landscapes are liminal spaces, like the cave or sweat lodge . . . if only through their virtuality – neither here nor there, neither imaginary nor real, animate but not living and not dead, a subjunctive realm wherein events happen in effect, but not actually.
>
> (p. 208)

Indeed, as Mitchell (1995: 8–9) explained, cyberspace is:

> profoundly *antispatial* . . . You cannot say where it is or describe its memorable shape and proportions or tell a stranger how to get there. But you can find things in it without knowing where they are. The Net is ambient – nowhere in particular but everywhere at once. You do not go *to* it; you log *in* from wherever you physically happen to be . . . the Net's despatialization of interaction destroys the geocode's key [original emphasis].

As Memarzia (1997) points out, the digital landscapes of VR spaces only possess geographic qualities because they have been explicitly designed and implemented. As such, Holtzman (1994: 197–8) professes:

> there's no there there. It only exists in some hard-to-define place somewhere inside the computer . . . [and yet in virtual reality simulations] you are completely immersed in another world. It is not a picture that is being viewed, but rather a place. This world is not being observed but experienced. You sense that you are in it.

It is a space without space, 'a nonplace' (Gibson, 1987) and yet possesses a spatiality and has virtual places. Moreover, it is a space where geographic 'rules' such as the friction of distance can be broken through the creation of what Dieberger (1996) terms 'magic' clauses, for example, teleporting. Benedikt (1991: 128) argued that virtual realities need not, and will not, be subject to the principals of ordinary space and time, which will be:

> violated with impunity. After all, the ancient worlds of magic, myth and legend to which cyberspace is heir, as well as the modern worlds of fantasy fiction, movies, and cartoons, are replete with violations of the logic of everyday space and time: disappearance, underworlds, phantoms, warp speed travel, mirrors and doors to alternate worlds, zero gravity, flattenings and wormholes, scale inversions, and so on. And after all, why have cyberspace if we cannot (apparently) bend nature's rules there?

To Benedikt, VR spaces are a 'common mental geography' (in Gibson's famous phrase – a 'consensual hallucination'), a medium in which 'ancient spaces' (mythical or imaginal spaces) become visible; the abstract spaces of the imagination freed from Euclidean geometry and Cartesian mapping; spaces where the 'axioms of topology and geometry so compellingly observed to be an integral part of nature can . . . be violated or reinvented, as can many of the laws of physics' (p. 119). Indeed, many of the descriptions of VR space by novelists describe in detail its spatial qualities. In nearly all cases, Cartesian rules do not apply to the virtual spaces being envisioned. Except in relation to the body, where the mind/body distinction seemingly benefits significantly from VR space. The mind literally becomes free from the 'meat'.

Clearly these concerns relating to spatial geometries and sense of place also apply to metaphorically-constructed informational spaces – 'maps' of c-spaces and cyberspaces. They, too, are purely constructions with potentially complex spatial geometries that can bare no, or very little, resemblance to real-world geographies. Moreover, if the geographic visualizations are programmed to be interactive, the spatial representation (map) becomes the territory – map and territory become synonymous; rather than being external to a representation of data, we are navigating links within data. Here, the use of a geographic metaphor to structure the data becomes the means by which this new territory is navigated. For example, a VRML Web page is both the territory and the means in which to navigate that territory.

As discussed in Chapter 20, conceptions of space thus need to be reanalysed in light of how space is (re)formulated and used in VR spaces. VR spaces offer 'geographic-style' interaction, and yet the spaces are *not* essentialist (given) or absolutist. Instead they are purely relational (both spatially and socially). And yet, as discussed, unlike geographic space they possess a number of other qualities that set them apart. VR spaces can be Euclidean and Cartesian or multidimensional or a mixture of the two, and can be viewed from many different viewpoints in space or time. VR spaces (both those that seek to represent geographic space and those that do not) thus seem to us to offer challenges to the philosophers of space in both theorising the nature of space within VR spaces but also the consequences of that space upon geographic space.

Only a few academics have started to examine the geographies of cyberspace, the spatial geometries and forms, the intersections between different cyberspaces and the intersections between geographic space and cyberspace. For example, Batty (1997) has tried to assess the ways in which VR space and geographic spaces connect. He defined virtual geography as 'the study of place as ethereal space and its processes inside computers, and the ways in which this space inside computers is changing material place outside computers', with the space within computers (the spaces on the screen) defined as 'c-space', the space of computer-mediated communication as 'cyberspace' (of which there are different forms), and the infrastructure of the digital world (the actual hardware) as 'cyberplace'. These concepts link together and form a cyclical process of interaction and evolution, linking individual sites with real and virtual space (nodes) through distributed systems (networks). As such, c-spaces located in individual computers, and sited in real space, are linked together to form a distributed network: cyberspace. Cyberspace exists within the infrastructure of cyberplace and its use mediates the creation of new communications infrastructure and attendant services which, in turn, has material effects upon the infrastructure of traditional places. This change of infrastructure at specific sites gradually alters the geography of real space, in terms of patterns of production and consumption. To cope with, and maximise competitive advantage within, these new geographies, companies, institutions and individuals are computerising their practices and processes, creating new c-spaces, and so on. Gradually, then, real geographies are being virtualised, turned into cyberplaces.

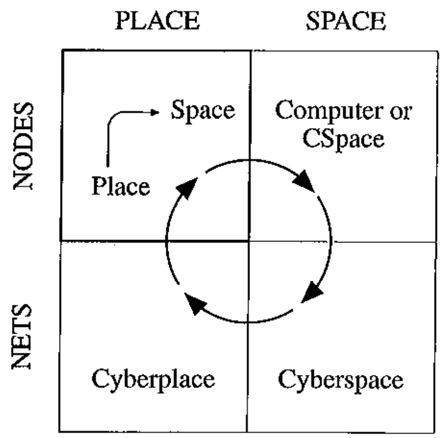


Figure 23.3 Virtual geography (Source: Batty, 1997).

Batty suggested that the three spaces have various, differing geographies and together are key components of what Castells (1996) refers to as 'real virtuality', a reality that is entirely captured by the medium of communication and where experience is communication. Castells refers to the linkages between c-space and cyberplace, that is cyberspace, as the space of flows. He argues that the space of flows is characterised by timeless time and placeless space. Castells (1996: 464–7) explained:

> Timeless time ... the dominant temporality in our society, occurs when the characteristics of a given context, namely, the informational paradigm and the network society, induce systemic perturbation in the sequential order of phenomena performed in that context.... The space of flows ... dissolves time by disordering the sequence of events and making them simultaneous, thus installing society in an eternal ephemerality. The multiple space of places, scattered, fragmented, and disconnected, displays diverse temporalities ... selected functions and individuals transcend time.

In other words, temporality is erased (p. 375), suspended and transcended in cyberspace. Stalder (1998) extends this idea to its logical conclusion, arguing that the defining characteristic of timeless time is its binary form. Timeless time has no sequence and knows only two states: presence or absence, now or never. Anything that exists does so for the moment and new presences must be introduced from the outside, having immediacy and no history. As such, 'the space of flows has no inherent sequence, therefore it can disorder events which in the physical context are ordered by an inherent, chronological sequence' (Stalder, 1998). In a similar way, geographical distance dissolves in the space of flows so that cyberspace becomes placeless. Movements within cyberspace are immediate, presences can be multiple, and distance as we currently understand it is meaningless. There are no physical places in cyberspace, just individual digital traces that are all equally distant and accessible (traces, however, might be considered metaphorically a place such as AlphaWorld, see Dodge, Chapter 21). Every location is each other's next-door neighbour; everything is on top of everything else; everywhere is local (Staple, 1995). Stalder (1998) extends the placeless space to its logical conclusion, again using a binary metaphor, to suggest that cyberspace is a binary space where distance can only be measured in two ways: zero distance (inside the network) or infinite distance (outside the network); here or nowhere.

Adams (1998) sought to understand cyberspace by drawing parallels between their network architecture and sense of place with those of geographic spaces. He argued that an analysis of how spatial/place metaphors combined with a comprehension of how network topologies affect communications within VR spaces will lead to an understanding of social interactions within cyberspace. He thus hypothesised that the virtual geography, the topologies of the network, affects the type and nature of social interactions. In other words, a way to explore the geographies of VR is not to map it formally but to chart and quantify network topologies and the nature of social interactions within a specific topology (geography). Using combinatorial theory (a method for comparing network forms) he identifies several network typologies that mirror their geographical equivalents in terms of their structure and the social interactions performed. Adams argued that, despite VR spaces and cyberspace being incongruent, they bear significant similarity. Relationships between structure and agency are replicated online. Places within both spaces are multiple, diverse, and linked by complex paths that need to be traversed. In contrast to the discussion above, Adams postulated that the spatialities of VR, visual spaces, are very similar to the spatialities of geographic space. This is a contention that needs further empirical examination.

One source of evidence as to whether the spatialities of visual VR mirror geographic space is through the examination of how people cognise spatial relations, and spatially behave, in visual VR spaces. Tlauka and Wilson (1996) concluded from their study that navigation in computer-simulated space and real space led to similar kinds of spatial knowledge. Following learning the locations of objects within a room either through virtual navigation or viewing a map, respondents were required to point to objects that were not directly visible from both aligned and contraligned perspectives and to draw a map. No differences were noted between conditions (navigation versus map). Ruddle *et al.* (1997) tested the spatial knowledge of two groups of respondents to complete distance, direction and route-finding tasks. The first group learned a building layout (135 rooms of which 126 were empty and nine contained landmarks) by studying a floor plan and the second group of respondents learned the same layout in a non-immersive, screen-based, virtual environment. Both groups were then tested in the virtual environment. They found no significant differences in the route-finding ability of respondents who had learned a building layout within a virtual environment or through map learning. Time in the environment seems of particular importance. In their initial trials respondents were disorientated. However, there was a steep learning curve across trials with the route through the building becoming progressively more accurate with trials.

Other studies have found significant differences between spatial learning within virtual and real environments, although they conclude that the processes of learning remain the same. Turner and Turner (1997) concluded from their study of distance estimates within a small five-room virtual environment that their respondents' spatial knowledge was similar to that gained from exploring the real world but is best described as being most like that gained from a restricted exploring of a real-world environment such as a cave, or exploring with a restricted field of vision (e.g. wearing a helmet). Similarly, Richardson *et al.* (1999) compared the ability of sixty-one respondents to learn the layout of two floors in a complex building from a map, from direct experience, or by traversing through a 'desktop' virtual representation of the building. Those learning in the virtual environment performed the poorest, although similar levels of performance were displayed for learning the layout of landmarks on a single floor. They also displayed orientation-specific representations defined by their initial orientation in the environment, and were particularly susceptible to disorientation after rotation. The authors conclude that, in general, learning a virtual environment is similar to learning geographic space, using the same cognitive processes, although respondents are more likely to become disorientated and have difficulty integrating layouts of other floors.

Similarly, Satalich (1995) explored the way-finding ability of sixty-five respondents in a visual virtual environment that comprised of a U-shaped building that measured 100 feet by 100 feet. The building contained thirty-nine separate rooms and over 500 objects. Collision detection was incorporated into the environment so that respondents could not walk through the walls, but was not incorporated for objects located throughout the building. Satalich found that regardless of the measure used ((1) self-exploration (free to explore the building as they wished); (2) active guided (follow a pre-determined path using the joystick); and (3) passive guided (the respondent was moved through the environment at a constant speed with no interaction, although they could move their head to look around), the control group (who learnt the same environment by studying a map) either performed equivalently or better than the group that experienced the virtual environment. Witmer *et al.* (1996) compared the spatial knowledge of respondents that had learned an environment through a virtual medium with those who had interacted with the real environment. They reported that their respondents could successfully learn a virtual model of a real building and were able to transfer this knowledge when tested in the building, although they made significantly more route finding errors than participants who were trained and tested in the building. Respondents in the Wilson *et al.* (1996) study, who learned a three-storey building in a virtual environment, performed significantly worse at estimating direction estimates than a control group who learned the real building.

Clearly, then, VR spatialities do not currently match real spaces. Richardson *et al.* (1999) and Ruddle *et al.* (1997) explain that one might expect differences to occur between spatial learning in virtual and real environments because of the lack of proprioceptive cues during navigation causing an optic (eye movement)/vestibular (leg muscles stationary) mismatch, the need for scale translations for movement in a 'smaller' world, and, if using a desktop VE, the elimination of peripheral vision, virtual environments being less visually complex, with fewer subtle landmark cues (notices, marks on walls, etc.), and the restriction on the inclusion of sound. It might therefore be expected that, as VR spaces become indistinguishable from real spaces, that spatial understanding will become equivalent. As noted, however, VR spaces are not spatially equivalent and will only be so if explicitly programmed to be so.

'Mapping' VR space

At one level, as illustrated in Figures 23.1 and 23.2, VR space is relatively easily mapped. The physical architecture and topology of the networks (cyberplace) can be mapped into Cartesian space and the traffic through this network represented using an appropriate form of visualization. Similarly, the physical location and characteristics of hardware, software and wetware (human users) can be mapped using traditional cartographic and demographic methods.

At another level, however, VR spaces are difficult to map. As noted above, these spaces of zeros and ones provide a much greater challenge – the effective mapping of visual spatial forms and the metaphorical use of geographic visualization to provide comprehensibility for non-spatial or immaterial information that is difficult to navigate through and understand due to its complexity and mutability. Visualizers of VR spaces face a much greater challenge than their counterparts charged with mapping geographic space: to find ways to map spaces with differing spatial forms and geometries, including some with no recognisable geometrical properties; to find ways to map spaces that break two of the fundamental conventions of geographic visualizations. These conventions are that (1) space is continuous and ordered, and (2) the map is not the territory but rather a representation of it (Staple, 1995). As noted, VR spaces can be discontinuous and non-linearly organised, and in many cases the spaces are their own maps. In a deeper sense, a session in VR space is the map, with each link providing a trail to retrace (Staple, 1995); rather than being external to a representation of data, we are navigating links within data. As Novak (1991) notes, however, this is not to deny that VR spaces have an architecture (geography), contains architecture, or even are architecture, just that this architecture is their own.

The challenge for geographic visualizers, however, is only partly a matter of spatial form. As Staple (1995) notes, mapping VR space is just one part of a wider project that aims to map places that cannot be seen, such as distant galaxies, DNA, brain synapses (see Hall, 1992, for fascinating examples of these). VR spaces, though, are 'infinitely mutable' (Staple, 1995), changing daily as new computers are added, the infrastructure updated, and content refined and expanded. VR spaces are transient landscapes; spaces that are constantly changing but where the changes are often 'hidden' until encountered. As time unfolds and more and more data are uploaded, visual sophistication and detail improves, the mutability of VR spaces will increase accordingly to create spaces that are constantly evolving, disappearing and restructuring. Geographic visualizations of geographic spaces are out-of-date as soon as they are published, as the landscape portrayed is modified. The vast majority of information portrayed, however, remains stable and the shelf-life of the map can be many years. The shelf-life of a VR map, given the current and projected dynamic nature of VR spaces, particularly those accessible across the Internet, is likely to be very short. To complicate matters further, as yet, unlike geographic space, there are no agreed conventions in relation to how a space is designed or how it is traversed, providing a diverse set of spaces which differ in form, geometry and rules of interaction.

The wider challenge, then, is to construct dynamic geographies of a variety of VR spaces, some with no explicit spatial relations, some with an in-built relational (topological) geography (e.g. textual and visual virtual worlds), and to map out the intersections between virtual and geographic spaces. To produce geographies that will aid the navigation within, and comprehension of different, cyberspaces at both theoretical and practical levels.

Map topology

To our knowledge there have only been two attempts to create a topology of maps of VR spaces. The first by Dodge (1997) divided what he termed cybermaps into a number of classes: geographical metaphors, conceptual maps, topology maps, landuse maps and landscape views, virtual cities and navigation tools. The second, by Jiang and Ormeling (1997), classified maps of VR spaces using a three-fold classification centred on function: navigation; cyberspatial analysis; persuasion. Both classifications adopted a position that fails to recognise the differences between data sources, and the complexities and differences between what the maps are seeking to represent spatially. As discussed, the mappings of VR vary as a function of geographic reference, spatial form/attributes, and materiality of the information that is mapped. We therefore propose a classification that varies along three axes: (1) geographic referent (cyberplace/cyberspace); (2) spatial attributes/materiality (material, spatial form/immaterial spatial form); (3) map form (static, animated, interactive, dynamic). Each axis is discussed in turn.

It is quite clear that in mapping VR spaces there is a strong difference between maps that, on the one hand, concern aspects of the real world (Batty's cyberplace – infrastructure, hardware, people, etc.), and other immaterial aspects of the real world such as VR maps of gravity and heat, and those that on the other hand concern VR spaces (data within the computer – the spaces of ones and zeros, the social and informational landscapes of virtual worlds inside, rather than composed of, the wires). In the first case there is a geographic referent, some correspondent in the real world that the VR space is seeking to represent. In the second case no geographic referent exists and a mapping metaphor is applied to make comprehensible data that would otherwise be too complex to understand. In the first case, then, issues such as the degree of spatial equivalence are key – the extent to which the visualization corresponds with reality. In the second case, such comparisons are impossible.

Mappings can also be defined along axes of materiality and their spatial attributes. For example, maps of cyberplace can have a material geographical referent (e.g. infrastructure) or an immaterial referent (e.g. heat). In the case of a material referent, cartographic qualities most often match those of geographic space in terms of conventions and design. Essentially data are mapped onto a geographic base. For example, in Figures 23.1 and Figure 23.2 data concerning network architecture are mapped onto a globe. Another form of visualization is a virtual model of geographic location (see Figure 23.4). In the case of the immaterial referent the data are mapped metaphorically placing the values into a two-dimensional or higher display. In relation to VR spaces, mappings can portray digital data with no geographic referent but with spatial attributes (e.g. visual MUDs, see Figure 23.5), data with a geographical referent but no spatial attributes (e.g. Web pages, see Figure 23.6) or relatedness of information, (see http://www.mappingcyberspace.com/gallery/plate6_1.html), and data with no geographical referent and no spatial attributes (e.g. computer file allocation, see Figure 23.7).

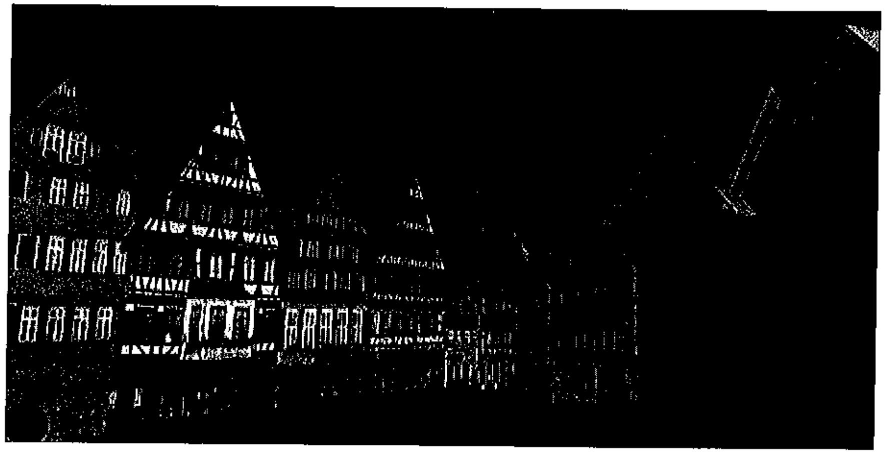


Figure 23.4 A virtual model of a geographic location.

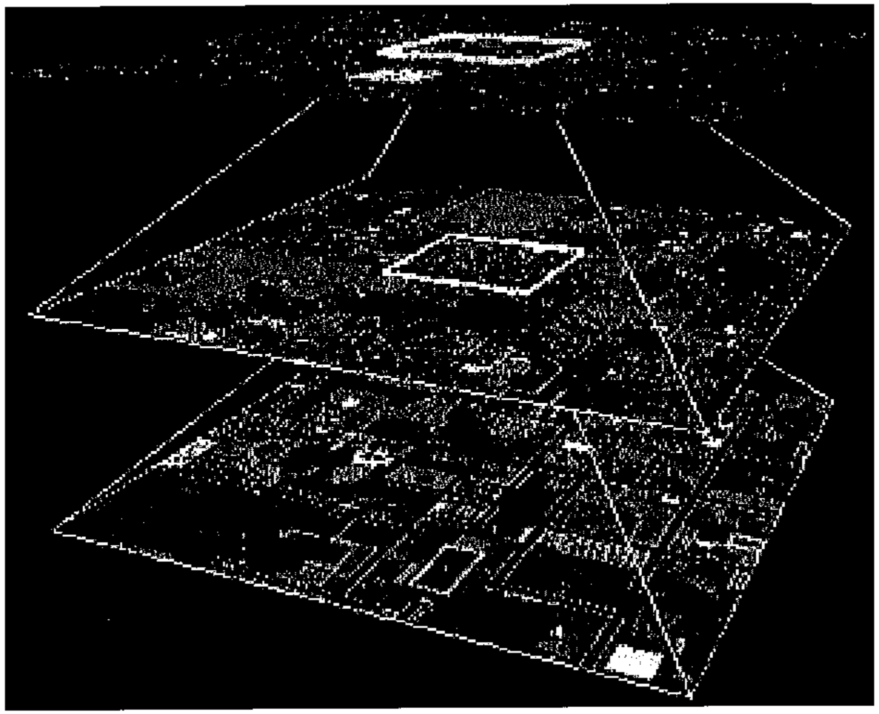


Figure 23.5 Mapping a visual MUD (Courtesy of Greg Roelofs and Peter Van Der Meulen, Philips Research, Silicon Valley.)

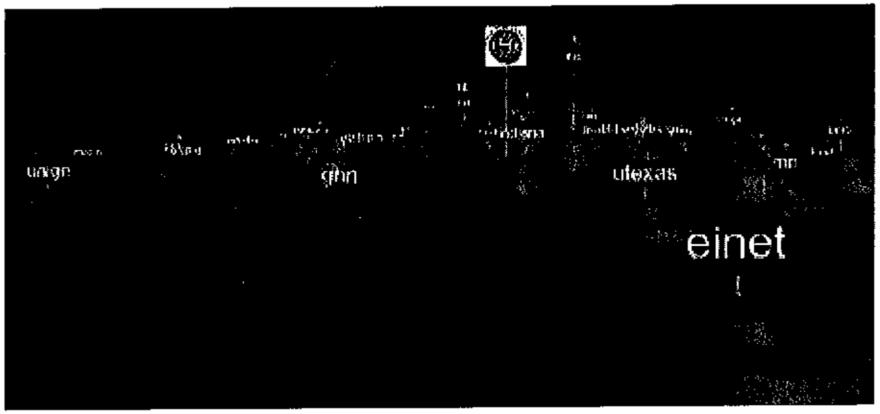
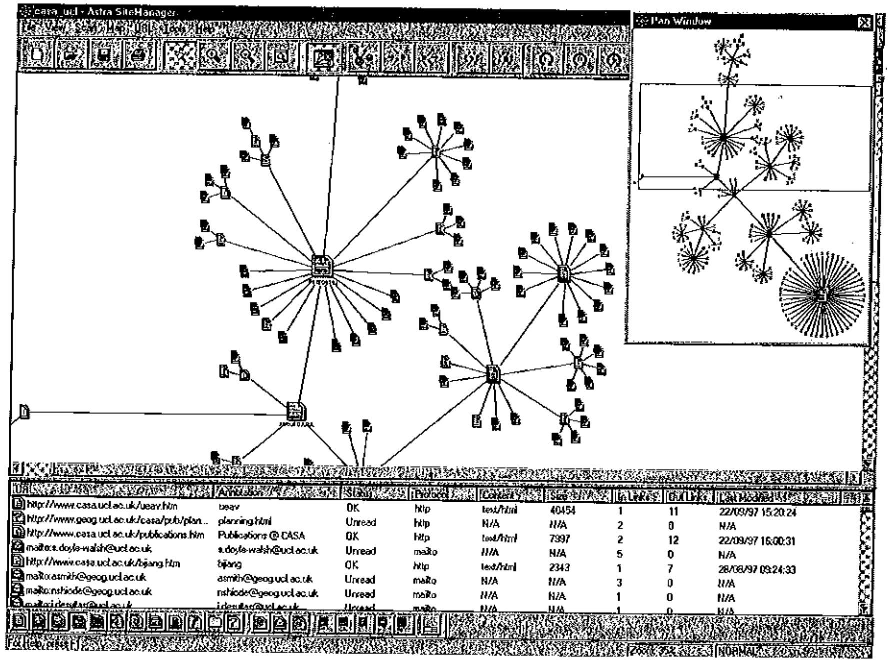


Figure 23.6 Mapping data with no spatial attributes.



URL	Annotation	Status	Protocol	Content	Size	In Links	Out Links	Last Modified
http://www.casa.ucl.ac.uk/ueav.htm	ueav	OK	http	text/html	40454	1	11	22/09/97 15:20:24
http://www.geog.ucl.ac.uk/casa/pub/plan...	planning.html	Unread	http	N/A	N/A	2	0	N/A
http://www.casa.ucl.ac.uk/publications.htm	Publications @ CASA	OK	http	text/html	7997	2	12	22/09/97 16:00:31
mailto:s.doyle-walsh@ucl.ac.uk	s.doyle-walsh@ucl.ac.uk	Unread	mailto	N/A	N/A	5	0	N/A
http://www.casa.ucl.ac.uk/bjiang.htm	bjiang	OK	http	text/html	2343	1	7	28/08/97 09:24:33
mailto:asmith@geog.ucl.ac.uk	asmith@geog.ucl.ac.uk	Unread	mailto	N/A	N/A	3	0	N/A
mailto:nshiode@geog.ucl.ac.uk	nshiode@geog.ucl.ac.uk	Unread	mailto	N/A	N/A	1	0	N/A
[illegible]	[illegible]	Unread	mailto	N/A	N/A	1	0	N/A

Figure 23.7 Mapping computer storage: Astra SiteManager.

At a basic level, then, mapping can be divided into one of four categories:

1 real world/material (conventional mapping),
2 real world/immaterial (metaphorical mapping),
3 VR/spatial (conventional mapping),
4 VR/non-spatial (metaphorical mapping).

Each of these four categories can be further sub-divided by mapping form, which can take one of four forms: static, animated, interactive and dynamic. Static mappings are the equivalent of traditional cartographic maps in that they are snap-shots in time. They differ, however, in that they vary in visualization technique, for example extending to three dimensions. Animated mappings portray a sequence of static maps in sequence to provide a time-series. Interactive mappings move beyond static mappings to create mappings that the user can move through and interrogate from different viewpoints (essentially 2.5D+ virtual models). Whilst the 'map' itself is static, the user becomes dynamic. Dynamic mappings are where the mapping automatically updates as the information used in its construction is updated. These forms of mapping can be combined so that a map can be static and interactive or dynamic and interactive.

This process of categorisation could continue. For example, it is possible to categorise the maps on the basis of function following Jiang and Ormeling (1997). We feel, however, that to continue our topology would be confusing, unhelpful and relatively pointless given that we think that the essential differences are captured by the topology outlined above.

Key issues

In this section we detail some of the key issues that need to be considered in relation to VR and its mapping. Some issues are omitted because they are dealt with in Chapter 20. These include: real/virtual, embodiment/disembodiment, place/placelessness, public/private.

Data quality

Geographic visualizations are only as accurate as the data used to underpin the representation. Therefore, a key question for those seeking to construct mappings of VR spaces is access to accurate information. Given the fast-growing and dynamic nature of both aspects of cyberplace and cyberspace, this issue becomes of critical importance. Online spaces such as textual and visual MUDs are in constant flux. We ourselves have encountered many dead-ends and re-routings because data and the links between them no longer existed or had changed address. Mappings will increasingly be important for understanding the connections between VR spaces and geographic spaces, and in comprehending and navigating through VR spaces, but without suitable high-quality data to underpin their construction they will be next to useless.

Naïve versus expert users

As the work of cognitive cartographers (e.g. Lloyd, 1997; MacEachren, 1995) has illustrated, maps, whilst effective at condensing and revealing complex relations, are themselves sophisticated models. For example, Liben (1991) has noted that most maps are not 'transparent' but are complex models of spatial information that require individuals to possess specific skills to process. This implies that a novice will not learn from a professionally-produced map unless they know how the map represents an area. This also applies to the mappings of VR spaces, particularly in the case of 3D interactive mappings, and metaphorical mappings. Care needs to be exercised in relation to the design of mappings so that the target audience can understand and use the information portrayed. As far as we are aware, whilst there has been some work on the legibility and design of visual virtual worlds (e.g. Darken and Sibert, 1995) and hypertext (e.g. Bachiochi *et al.*, n.d.; Kim and Hirtle, 1995; Nielsen, 1990), there has been little or no work on the legibility of VR mappings.

Representation

Geographic visualizations are spatial representations. They aim to represent, in a consistent manner, some particular phenomenon. An age-old question therefore relates to the extent to which geographic visualizations adequately represent data. Mappings necessarily depict a selective distortion of that which they seek to portray, they generalise and classify. Would the use of a different transformation, of generalising and classifying, reveal totally different relations? Harpold (1999), for example, noted that strategies of aggregation in the use of Internet demographic maps hides variation within units. Furthermore, he suggested that mappings of cyberplace reproduce particular hegemonic messages because of the ways in which they adopt traditional cartographic map units (e.g. political boundaries) in which to display data. As noted, debates concerning representation often centre around issues such as accuracy, precision, verisimilitude and mimesis. For data with no geographic referent or materiality, however, by what standard are these factors judged? When the data and mapping become synonymous, how do issues of representation apply? Here, VR spaces may become meaningless outside of their representation. The need for standards to be set and for issues of representation to be addressed, then, is of paramount importance.

Power of mapping

As Harley (1989) and others (e.g. Woods, 1993) have argued in relation to traditional cartography, maps are not objective, neutral artefacts. Mapping is a process of creating, rather than revealing, knowledge since in the process of creation decisions are made about what to include, how the map will look, what the map is seeking to communicate (MacEachren, 1995). Maps are never merely descriptive – they are heuristic devices that seek to communicate particular messages. Maps are imbued with the values and judgements of the individuals who construct them and they are undeniably a reflection of the culture in which those individuals live. As such, maps are situated within broader historical contexts and, according to Harpold (1999), they reflect hegemonic purposes through the use of historically- and politically-inflected metageographies (sign systems that organise knowledge into visual systems that we take for granted). Mappings of VR spaces are similarly the products of those that coded their constructing algorithms. They are mappings designed for particular purposes. Because they allow other users to create their own knowledge through application to their own data, these algorithms can also be empowering. In a sense, the monopoly power of the professional cartographer is severely undermined. These issues of power must be appreciated in the construction of mappings of VR spaces.

Conclusion

In this chapter we have discussed the mapping, both conventional and metaphorical, of VR spaces. Our discussion is, by our own admission, partial. The mapping of VR spaces is a recent occurrence. It has generally been conducted by information and computer scientists, with little knowledge of geographic visualization, and who construct the 'maps' for specific practical purposes. The wider implications of mapping in relation to both conceptions of space and the real world is little theorised. We have tried to give a flavour of the spatial aspects of VR spaces, how these spaces are being mapped, and some key issues that need to be considered in relation to mapping them, in order to provide context from which a more detailed analysis can occur. We would advocate two parallel and interconnected strands of research to be conducted. The first would focus on conceptualising space within VR and using these conceptions to devise effective forms of geographic visualization. The second would be a critical analysis of the process of mapping and the links between VR spaces and geographic spaces. In this way, the mapping of VR spaces can be contextualised and understood, and some of the issues such as representation, data quality and usage examined.

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References

Adams, P. 1998. Network topologies and virtual place. *Annals of the Association of American Geographers*, 88, 1, 88–106.

Bachiochi, D., Berstene, M., Chouinard, E., Conlan, N., Danchak, M., Furey, T., Neligon, C. and Way, D. 1997. *Usability Studies And Designing Navigational Aids For the World Wide Web*, in the Proceedings of the 6th WWW Conference, 511–17.

Batty, M. 1997. Virtual geography. *Futures*, 29, 4/5, 337–52.

Batty, M., Dodge, M., Doyle, S. and Smith, A. 1998. Modelling virtual environments. In Longley, P.A., Brooks, S.M., McDonnell, R. and Macmillan, B. (eds) *Geocomputation: A Primer*. Chichester, UK: Wiley.

Benedikt, M., 1991. *Cyberspace: First Steps*. Cambridge, MA: MIT Press.

Card, S.K., Mackinlay, J.D. and Shneiderman, B. (eds). 1999. *Readings in Information Visualization: Using Vision to Think*. San Francisco: Morgan Kaufmann Publishers, Inc.

Castells, M. 1996. *The Rise of the Network Society*. Oxford: Blackwell Publishers.

Crampton, J.W. 1999. *Map as Texts, Maps as Visualizations*. Department of

Geography and Earth Science, George Mason University, USA. <http://geog.gmu.edu/gess/people/jwc.html>.

Darken, R.P. and Sibert, J.L. 1995. Navigating large virtual spaces. *International Journal of Human–Computer Interaction*, 8, 1, 49–71. http://www.seas.gwu.edu/faculty/sibert/darken/publications/Navigating_IJHCI95/navigating.html.

Dieberger, A. 1996. Browsing the WWW by interacting with a textual virtual environment – a framework for experimenting with navigational metaphors. *Proceedings of ACM Hypertext '96*, Washington DC, March 1996, pp. 170–9.

Dodge, M. 1997. A cybermap atlas: envisioning the Internet. In Staple, G.C. (ed.) *TeleGeography 97/98: Global Communications Traffic Statistics & Commentary*. Washington DC: TeleGeography Inc.

Dodge, M. 1999. *An Atlas of Cyberspaces*. Centre for Advanced Spatial Analysis, University College London. <http://www.cybergeography.org/atlas/>.

Gershon, N. and Eick, S.G. 1995. Visualization's new track: making sense of information. *IEEE Spectrum*, November 1995, 32, 1, 38–56.

Gibson, W. 1987. *Mona Lisa Overdrive*. New York: Harper Collins.

Hall, S.S. 1992. *Mapping the Next Millennium*. New York: Vintage Books.

Harley, J.B. 1989. Deconstructing the map. *Cartographica*, 26, 1–20.

Harpold, T. 1999. Dark continents: critique of Internet metageographies. *Postmodern Culture*, January 1999, 9, 2. <http://www.lcc.gatech.edu/~harpold/papers/dark_continents/index.html>.

Holtzman, S.R. 1994. *Digital Mantras: The Languages of Abstract and Virtual Worlds*. Cambridge, MA: MIT Press.

Jiang, B. and Ormeling, F.J. 1997. Cybermap: the map for cyberspace. *The Cartographic Journal*, 34, 2, 111–16.

Kim, H. and Hirtle, S.C. 1995. Spatial metaphors and disorientation in hypertext browsing. *Behaviour and Information Technology*, 14, 239–50.

Lamm, S.E., Reed, D.A. and Scullin, W.H. 1996. Real-time geographic visualization of World Wide Web traffic. *Proceedings of Fifth International World Wide Web Conference*, 6–10th May 1996, Paris, France.

Liben, L.S. 1991. Environmental cognition through direct and representational experiences: a life-span perspective. In Gärling, T. and Evans, G.W. (eds) *Environment, Cognition and Action – An Integrated Approach*. New York: Plenum Press, pp. 245–76.

Lloyd, R. (1997) *Spatial Cognition: Geographic Environments*. Dordecht: Kluwer.

MacEachren, A. 1995. *How Maps Work: Representation, Visualization, and Design*. New York: Guilford.

Memarzia, K. 1997. *Towards the Definition and Applications of Digital Architecture*. School of Architectural Studies, University of Sheffield. http://www.shef.ac.uk/students/ar/ara92km/thesis/.

Mitchell, W.J. 1995. *City of Bits: Space, Place and the Infobahn*. Cambridge, MA: MIT Press.

Morse, M. 1997. Nature Morte: Landscape and narrative in virtual environments. In Moses, M. and Macleod, D. (eds) Immersed in Technology: art and virtual environments. Cambridge: MIT Press, pp. 195–232.

Munzner, T., Hoffman, E., Claffy, K. and Fenner, B. 1996. Visualizing the global topology of the MBone. In Gershon, N. and Eick, S.G. (eds) *Proceedings of the 1996 IEEE Symposium on Information Visualization*, 28–29th October 1996. San Francisco: IEEE Computer Society Press, pp. 85–92.

Nielsen, J. 1990. *Hypertext & Hypermedia*. San Diego: Academic Press.

Novak, M. 1991. Liquid architectures in cyberspace. In Benedikt, M. (ed.) *Cyberspace: First Steps*. Cambridge, MA.: MIT Press, pp. 225–54.

Richardson, A.E., Montello, D.R. and Hegarty, M. 1999. Spatial knowledge acquisition from maps, and from navigation in real and virtual environments. *Memory and Cognition*, 27, 741–50.

Ruddle, R.A., Payne, S.J. and Jones, D.M. 1997. Navigating buildings in 'desk-top' virtual environments: experimental investigations using extended navigational experience. *Journal of Experimental Psychology – Applied*, 3, 2, 143–59.

Satalich, G.A. 1995. *Navigation and Wayfinding in Virtual Reality: Finding Proper Tools and Cues to Enhance Navigation Awareness*. University of Washington, HIT Lab. http://www.hitl.washington.edu/publications/satalich/home.html.

Stalder, F. 1998. The logic of networks: social landscapes vis-à-vis the space of flows. *Ctheory, Review 46*. http://www.ctheory.com/.

Staple, G. 1995. Notes on mapping the Net: from tribal space to corporate space. *Telegeography*.

Tlauka, M. and Wilson, P.N. 1996. Orientation-free representations from navigating through a computer simulated environment. *Environment and Behavior*, 28, 647–64.

Turner, P. and Turner, S. 1997. Distance estimation in minimal virtual environments. *Proceedings of UK VRSIG 97*. http://www.brunel.ac.uk/~empgrrb/VRSIG97/proceed/030/30.htm.

Witmer, B.G., Bailey, J.H., Knerr, B.W. and Parsons, K.C. 1996. Virtual spaces and real-world places: transfer of route knowledge. *International Journal of Human–Computer Studies*, 45, 413–28.

Wood, D. 1992. *The Power of Maps*. New York: Guilford.