Paper for Varenius Meeting - Measuring and Representing Accessibility in the Information Age

Accessibility to Information within the Internet: How can it be Measured and Mapped?

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Introduction

One definition of the Internet is:

> *"a collection of resources that can be reached from those networks"*
> (Krol & Hoffman 1993, page 1)

This definition by Krol & Hoffman provides the starting point for my conceptualisation of accessibility in the Information Age. I will examine how one can begin to measure and visualise the aspects of accessibility to resources *within* the Internet. I start my discussion with the assumption that a person has physical access to the Internet, via a networked computer. I also take a broad view of accessibility, going beyond formal mathematical models to consider wider issues.

There are many important dimensions to accessibility beyond simple Internet connectivity which need to be considered and in some manner measured and mapped. Once you have, what could be termed, 'physical' access to the Internet, how accessible are the information resources, people and electronic places available online? For example, a person sitting at their networked Windows98 PC, clicks on the Internet Explorer icon which will connect them to the Net and by default load the Microsoft homepage, but then what? As the Microsoft mantra says, "*where do you want to go today?*". What resources are accessible within the Internet and how do you reach them? Web sites, people and other electronic places are not obviously accessible when you start "surfing", information structures are largely invisible from a distance and can only be located with precise directions.

It is also important to consider how these dimensions of accessibility can be represented, particularly given the abstract nature of information spaces, which often do not have natural spatial structures, and the somewhat ethereal nature of searching, browsing and communicating in Cyberspace. These representations need to be dynamic and interactive, as well as being readily available whilst navigating the Internet (December 1995, Dodge 1998b).

The scope of geographical accessibility needs to be expanded to encompass notions of *information accessibility*. The growing importance of the Internet, and its layered services, for receiving and distributing all manner of information and for personal interaction will require us to consider how concepts of accessibility are played out within these electronic spaces. Gaining access, in a timely fashion, to the right information resources, be that a Web page, an email, a video clip, a chat room or a particular place in a virtual world, is problematic for a number of human and technical reasons.

The Web may well facilitate easy access to vast arrays of information from servers around the world, but this does not mean one can find useful, current, reliable and affordable information at the right time. As Pirolli *et al* comment, "*The apparent ease with which users can click from page to page on the World-Wide Web belies the real difficulty of understanding the what and where of available information*" (Pirolli et al 1996, page 1). The Web is a vast array of information, but the ratio of noise to useful information can be very high. The problems of information retrieval through searching and browsing this massive space are becoming important for conceptualising accessibility in the Information Age. There is an increasing awareness of the problem of 'information overload', with "*a tsunami of data crashing onto the beaches of the civilized world*" (Wurman 1997, page 15). Accessibility to too much information is potentially as significant an issue as accessibility to too little information. Excessive information impedes its assimilation and therefore does little to improve knowledge and understanding. A great deal of effort is being directed by researchers in a range of disciplines to cope with the problem of information retrieval and information overload through filtering, structuring, analysing and visualising information to aid the limited human capacity to search for, absorb and comprehend information (Berghel 1997, ASIS 1998). Much of this research is relevant to broadening the scope of geographic accessibility to encompass information spaces of the global Internet.

In this paper I shall consider how we can develop the theme of information accessibility within the Internet by closer examination of the issues measurement and representation in two information spaces - Web space and virtual worlds. To begin I will look at the different information spaces of the Internet and then examine some of the fundamental issues in information accessibility.

Information Spaces of the Internet

It is important to be aware that the Internet contains a number of distinct services, which are often thought of as different "spaces", with differing virtual landscapes. The different spaces support different types of information exchange and levels of social interaction. Therefore, they are likely to require differing measures of accessibility and forms of graphic representation to be able to model their true nature. At a fundamental level, the different information spaces are caused by different network protocols used by software tools to communicate over the Internet, which give rise to the different form and functions apparent to the end-user. **Figure 1** shows a sketch map produced by John December showing the principle information spaces and some of the connections between them. The map provides a good way of thinking about the information spaces of the Internet as distinct and self-contained domains, but with fluid, complex boundaries and many interconnections and overlaps. The map was drawn at the end of 1994 and the nature of the Internet has changed markedly since then, with certain spaces dying off (WAIS and Gopher) and the inexorable and exponential growth of Web space. For many end-users the Web, and the browser interface, is the key information space, although email is still the most widely used information service on the Internet (ITU 1997, Clemente 1998). Other important information spaces within the global Internet that have evolved and grown since December drew his map include multi-user chat environments and virtual worlds. Also, the rise of large private networks and Intranets are creating important information spaces, but they are largely unseen from the outside and so are difficult to quantify and map. More recent work on conceptualising the form and structure of different information spaces includes Michael Batty's examination of "Virtual Geography" (Batty 1997), Paul Adams's work on "Network Topologies and Virtual Place" (Adams 1998), Manuel Castells's "Space of Flows" (Castells 1996) and Brian Gaines's research on the human-factors of Internet information spaces (Gaines 1997).

Issues in Information Accessibility

There are a number of important issues that need to be factored into future models of accessibility to information in the Internet. I will discuss the following:

- network performance,
- size of the information spaces,
- information 'findability' and persistence,
- information structure, design and user behaviour.

A common joke is that the WWW really stands for the world-wide *wait* because of the poor and unpredictable performance of the Internet, particularly perceived by the Web user waiting for a page to download. It could be argued that distance is dead on the Internet because it does not matter where the information is located geographically that I am trying to access. Instead, what really matters is where the site is located in temporal space. Time replaces distance in access to interactive information spaces. A slow response time from a Web site that is physically nearby means that it will be perceived as being more remote and inaccessible than a fast site that is thousands of miles away on another continent. Limited human patience with interactive computer interfaces means that response time is critical and even delays of a few seconds can prove so frustrating that people simply give up and try to locate an alternative source closer in temporal space. If network performance degrades below certain thresholds, some information spaces on the Internet become effectively infinitely distant because people will not bother to wait. The delays caused by network performance also have financial implications for those people paying by the minute for their access to the Internet. The complexity and self-organising nature of the underlying Internet infrastructure make it difficult to determine where performance problems that effect information accessibility are located in the network. They can be at any point in the chain from the users computer through the network links and nodes, to the target server. Examining Internet traffic reveals the incredible complexity of routes that data travels through the network, often traversing fifteen or more nodes and crossing infrastructure owned and operated by competing ISPs and telecoms companies. It is possible to explore Internet traffic routing using utilities called traceroutes (Rickard 1996) and you may be surprised at just how complicated things are "under the hood" so to speak, in some ways it is amazing that it performs as well as it does! To take an example, my Web site is located at a commercial hosting service that is geographically about a kilometre and half from my office in UCL and yet the traceroute reveals that traffic takes 12 hops (different network nodes) to travel this distance. Whereas traffic to the mirror site that is physically located in Washington DC, around 3,700 km from UCL, only takes slightly longer at 14 hops. In terms of measuring accessibility through the routing topology of the Internet these two Web site locations are pretty much equally distant from UCL. However, in terms of response time from these two sites, there are some interesting variations. The site in London usually equally responsive throughout the day, however the temporal accessibility to the mirror site in Washington depends on the time of day as the response degrades noticeably in the afternoon when the mass of North American Internet users wake up and logon. It is well known that for European Web surfers the performance of the Web degrades in the afternoon when America wakes up. Clearly measuring accessibility to global information resources like the Internet and the Web requires the time dimension to be fully integrated.

At the network performance level, information accessibility would be measured by three key parameters, (1) *delays*, known as network latency, (2) *deliverability*, the problem of data packets being lost in transit and having to be resent, and (3) *availability* of the network and servers assessed by the amount of 'down-time'. Much of the research into the performance of Internet infrastructure is highly technical, however there is some research particularly relevant to the issue of geographical accessibility. This includes the work of John Quarterman who undertakes real-time monitoring of Internet performance (Quarterman *et al* 1994), by calculating round trip travel times of traffic to several thousand sample nodes in the global Internet from his base in Texas. The results are presented in what he terms Internet Weather Reports (IWR) as animated maps, and **figure 2** shows a couple of frames from a map of California (Quarterman 1997, see also http://www.mids.org/weather/). Quarterman claims that his analysis shows that there has been a thirty percent improvement in mean Internet latencies since he started monitoring in 1994. There is also the study by Keynote Systems / Boardwatch into Internet backbone performance in the USA. This involves large scale testing of the performance of 10 different networks from 27 different sample points in different cities (Rickard 1997). Shane Murnion is also undertaking interesting research examining information flows from UK academic Web servers in relation to Internet latency to sixty-six countries (Murnion & Healey 1998). His findings show the existence of a distance decay effect in Web server audiences with increasing latency.

Another key issue for reconfiguring accessibility measures for the information age is to develop scaleable models to cope with the size, diversity and dynamic nature of Internet information spaces. Pinning down definitive figures on the size of Internet information spaces from the cyber-hype and Net boosterism can be difficult, but it is big and, more significantly, it is the fastest growing medium of information and communication in history (ITU 1997, Clemente 1998)[1]. Recent statistics show there were an estimated 36.7 million Internet hosts (Network Wizards 1998) and approximately 147 million Internet users world-wide (NUA 1998) in the summer of 1998. In terms of the information resources potentially accessibility on the Web, recent estimates are that the 2.8 million sites contain around 300 million pages (Bharat & Broder 1998, Lawrence & Giles 1998). More importantly, these studies also reveal how incomplete the databases of even the largest search engines are, only indexing at best a third of the Web pages. The Web pages people are seeking may exist, but if they are not in the search engine indexes they are invisible and, therefore, inaccessible because people will never find them. Even if they are in the index they may come so far down the list of search results returned that most users will never see them, making them effectively inaccessible. This could be termed the ‘findability’ factor and is crucial in realistically modelling information accessibility.

Search engines have become the key access points - known as portals in the current terminology - to information spaces on the Internet. They are rich indexes of socially constructed information and as such offer a potentially useful database for geographical research. The potential is beginning to be realised, for example in research into the reproduction of the concepts of place online (Alderman & Good 1997, Jackson & Purcell 1997, Alderman 1998, Henkel 1998, Norris 1998).

Another serious issue with modelling information accessibility is the problem of persistence, or rather lack of it, on the Internet. The Internet and the Web are changing every day, with information resources, sites and virtual places appearing and disappearing. A flick of a switch or a press of key can cause whole parts of an information space to simply disappear without a trace. Structures in

Cyberspace are much less permanent than those of the real-world. Can accessibility measures cope with this?

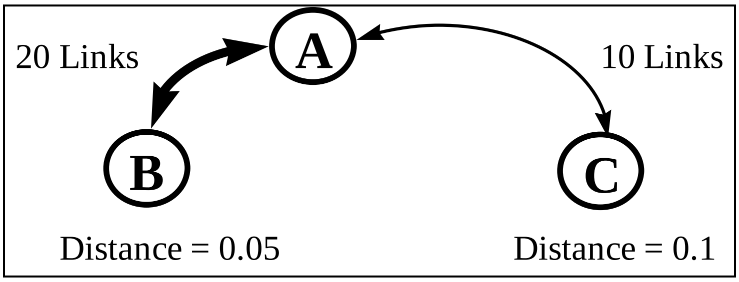
The actual design of the information space can have an impact on its accessibility. Like real-world cities and buildings, poorly designed Web sites and pages are rendered inaccessible to certain groups of users. The virtual world of information certainly suffers from the same degree of bad architecture as does the material world (Wurman 1997). We have all seen Web sites with poor choice of fonts, colours or frames for example that make them practically unusable. The need for accessible design is especially important for blind and partially-sighted people who surf with text-only software. There was a recent high profile case reported in the UK where the newly re-vamped Web site for Number 10 Downing Street was so badly designed that it was said to be "*staggeringly inaccessible*" (Jellinek 1998). Work is ongoing to improve the 'physical' design and accessibility of Web sites, co-ordinated through the Web Accessibility Initiative (http://www.w3.org/WAI/) of the World-Wide Web Consortium (W3C). However, the problem is difficult to resolve as many Web site writers are keen to use the very latest technologies which can easily make their sites inaccessible to many average users. A survey of UK Web sites last year found that only 30% of pages were completely accessible to all users (Beckett 1997).

To develop new models of information accessibility we need to know about the content and structure of information spaces and how users behave in them. There is some useful work trying to answer these questions, but our quantitative knowledge of Cyberspace is far from complete, particularly compared to our knowledge of real-world spaces. There are several reasons for this, firstly the sheer newness of some of the information spaces and also their invisibility to the conventional monitoring and census-taking methods developed for the material world (Batty 1990). Governments have not, until very recently anyway, realised the significance of the information spaces and so have made no attempts to gather statistics on them. However, there are a number of interesting academic studies that have begun to fill in the blanks. In terms of the contents of the Web there is the work of Bray (1996), Woodruff *et al* (1996) and Fagrell & Sørensen (1997). The structure of the information spaces, in particular the Web has been examine; see the exemplary work of James E. Pitkow (Pirolli, Pitkow & Rao 1996, Pitkow 1998) and also Bray (1996). Lastly, researcher are beginning to analyse and model how users behave in Cyberspace, see the work by Huberman *et al* (1998) who have devised a "law of surfing" to describe user behaviour.

Accessibility Between Web Site

I am researching the spatial structure of the Web by analysing the hyperlinks between sites, with my colleague Naru Shiode (Dodge 1998a). The data on how Web sites are linked together can be used to model accessibility for this particular information space. In our preliminary investigation we analysed a small, manageable subset of the Web, the site of the major universities and colleges in the United Kingdom, some 122 nodes. We used the AltaVista search engine (http://www.altavista.com/) to gather statistics on the size of each Web site (in terms of the number of pages) and the number of hyperlinks between them. To determine links between sites we had to submit 14,884 separate queries to AltaVista, using the query syntax `+url:<site1>.ac.uk +link:<site2>.ac.uk`. The results showed that the 122 sites contained over one million Web pages and over 450,000 hyperlinks (although the vast majority were internal links within individual sites).

The data on the connectivity between sites was analysed to determine the most accessible Web site. To do this, the distance from each university to every other one was calculated. In the Web, virtual distance is calculated as inversely proportional to the number of hyperlink connections between two points. In the example, site B is much closer in virtual distance terms to site A than is C. The Web sites that had the lowest average distance, i.e. was closest to all the others, was designated the central, most accessible site.



The virtual distances between all 122 sites were measured and stored as a large graph where the edge lengths were assigned the distance value. The graph was analysed to find the shortest path distance from each university to every other one using the Dijstra algorithm. The mean of these shortest path distances was calculated for each Web site and then normalised by dividing by the number of Web pages to take account of the influence of variations in Web site size. The resulting ranking showed that the University of Oxford's Web site (http://www.ox.ac.uk) had the smallest, normalised, mean shortest path distance to all other site, hence it was declared as the most accessible Web site. The graph of virtual distance was then used to measure the shortest path distance from Oxford to each university and this value was used as a metric of accessibility in Web space and was called the *WebX distance*.

To begin to understand the structure and differential accessibility of academic Web sites as measured by the WebX distance it was necessary to visualise the position of sites in relation to Oxford. To achieve we used radar type map called a *Web Scan.* In the Web Scan, Oxford becomes the central point of gravity, around which planetary Web sites rotate, their orbital distances being equal to their WebX distance. **Figure 3** shows a Web Scan for the most accessible Web sites, those closest to Oxford. What is immediately striking are the two giant sites very close to the Oxford centre point. These are the University of Cambridge (http://www.cam.ac.uk/) and University of Edinburgh (http://www.ed.ac.uk/), which have large Web sites and are very closely interconnected. Cambridge has a WebX distance of 10 and Edinburgh is only slightly further out at 13. Imperial College (http://www.ic.ac.uk/) comes next with a WebX distance of 26, double that of the second place site. Further out from the top three, there is cluster of site around the 40 WebX mark. These are Heriot-Watt University, the universities of Leeds, Glasgow, Southampton, Queen Mary & Westfield College and my own institution University College London (http://www.ucl.ac.uk/). All these universities are well connected, accessible in the academic Web. UCL has a WebX score of 42, placing it in seventh place away from Oxford, a respectable place given its historic place in the development of Cyberspace in the UK, as it was first organisation in Britain connected to ARPANET, the Internet's forerunner, back in 1973. There is then a slight gap until the next Web sites are encountered including large metropolitan universities such as Birmingham, Liverpool, Bristol, Sheffield and Manchester and as well smaller provincial institutions like York and Stirling. Interestingly, the University of Manchester (http://www.man.ac.uk/) recently celebrated a anniversary significant to development of Cyberspace, the 50th birthday of modern digital computing. In June 1948 scientists at the University built "The Baby" the world's first stored program computer. Finally, right on the edge of this scan is the University of Durham (http://www.dur.ac.uk/) with a WebX score of exactly one hundred. Further results are presented in Dodge (1998a).

Accessibility in Virtual Worlds

Virtual worlds are a form of information space on the Internet that provides a simulated environment in which multiple users can interact with each other in real-time. Crucially, the users have a bodily representation in the space as an avatar and the simulated environment is graphically rendered in 2-d, 2.5-d or full 3-d. A number of virtual worlds from competing companies have emerged on the Internet since mid-1995 (Rossney 1996, Damer 1998). They are used by many thousands of people who have constructed new forms of social interaction and a distinct sense of community and cultural identity to suit the unique characteristics of these spaces (Rossney 1996, Donath 1997, Schroeder

1997, Damer 1998, Rafaeli, Sudweeks & McLaughlin 1998). In many respects the users can be said to inhabit these worlds and have developed a real sense of place.

Virtual worlds have pre-defined and programmed geographical dimensions, architectural structures and rules of avatar movement, they are truly information *spaces*. They provide a fascinating new realm, arguably at the cutting-edge of the Information Age, in which to explore the meaning of geographical accessibility. The spatial nature of virtual reality and Internet virtual worlds has, so far, received little attention from academic geographers, notable exceptions being Hillis (1996) and Taylor (1997).

One of the most popular, technologically advanced, and geographically interesting virtual worlds is called Active Worlds, owned by Circle of Fire Studios, Inc (http://www.activeworlds.com/). Their flagship world is called AlphaWorld and it is one of the oldest (it opened in the summer of 1995) and most developed virtual worlds on the Internet. **Figure 4** shows a screen-shot of a typical view of AlphaWorld with its realistic 3-d environment and users represented by avatars. I have been exploring the physical and social geography of AlphaWorld with my colleague Andy Smith. This has been made easier because, uniquely, it has been mapped in remarkable detail and also has a rich recorded history. **Figure 5** shows two maps of the city growing at the centre of AlphaWorld at two snap-shots in time, December 1996 and February 1998 (Vilett 1998). A technical innovation, unique amongst Internet virtual worlds, is that registered citizens of AlphaWorld are able to claim plots of vacant land and build a homestead to their own design. This has had profound consequences to nature of urban development in the world facilitating spontaneous and organic growth. The geographical extent of AlphaWorld is huge, covering some 429,000 km^2, larger than California, so it can easily contain the virtual building boom in which nearly thirty people built 27 million objects in the world (Vevo 1998). Most of the development has taken place in the centre of the world, around what the locals call Ground Zero, located at 0,0 in the Cartesian co-ordinate space of this world. A sprawling city has grown outwards from Ground Zero in a totally unplanned way. To give you an idea of the scale of the city, the maps of it (figure 5) cover an area of four hundred square kilometres.

The morphology of urban growth, revealed by the maps, provides useful information on the nature of geographical accessibility in this virtual world and on the impact of changes to the conventional laws of physics for human movement. In AlphaWorld there are no cars, trains or planes so people are reliant on teleportation to travel any distance. Teleportation in AlphaWorld work just like in scifi movies, your avatar is instantaneously transported to the specified location with the accompaniment of a “beaming” sound effect! Teleportation has seriously warped the nature of geographical distance and accessibility as any location in the 429,000 km^2 expanse can be reached instantaneously from any other point in the world with no costs in terms of time or money. Consequently, every point in AlphaWorld is equally accessible. This is truly the death of distance (Couclelis 1996, Cairncross 1997). Teleportation is available to the user at any time as a menu in the browser, they just have to type in the co-ordinates of their desired destination and then they are whisked there in a second.

Distance may be dead in AlphaWorld, but the importance of location is alive and well. When people are choosing a location to visit or, more importantly, a place to build their homestead they want a good location. A good location is determined by two factors, firstly being as close as possible to Ground Zero, the centre of the world and secondly having a location with memorable co-ordinates. Human nature, particularly when interacting with computers, means that people tend to select regular numbers for co-ordinate pairs, such as 10,10, when teleporting. This has given rise to the star-shaped pattern of the urban growth with radial spokes of development emanating from the city centre along principle compass axes. The spokes are clearly evident in the December 1996 map, although in the second map, taken just over a year later, they have become less pronounced as fill-in development has taken place.

The ability to teleport is a powerful feature, but interestingly it was not made available to users when AlphaWorld was first launched. It has only been progressively introduced for fear of its affects on the world. As the AlphaWorld newspaper, the New World Times, reported in November 1995:

> *“Teleportation! Yes Teleportation! The one most common request of AlphaWorld citizens has been teleportation… With teleportation more of AlphaWorld will become readily accessible. … There is still some concern that teleportation will ruin the simulation of reality in AlphaWorld. In order to keep this simulation within bounds, teleportation will be implemented in a somewhat limited fashion. A “Grand Central Telestation” located at or near Ground Zero will enable citizens to teleport to key location, from which they can travel more easily to their destinations of choice.”* (New World Times, Issue #4, page 2, http://vrnews.synergycorp.com/nwt/)

AlphaWorld also warps conventional spatial rules at a local scale which have an impact on geographical accessibility. Firstly, you are able to fly, unaided, above and even below the ground. To achieve this one simply presses the + and - keys to effortless float up and down. It is also possible to walk through any walls and structures by holding down the shift key, which has the effect of making all objects immaterial to your avatar. These two god-like ‘powers’ have had a significant impact on the architectural design of buildings in AlphaWorld (Damer 1997). Visibility in AlphaWorld is also artificially constrained because it is only possible to see a maximum of 120 metres in any direction. This is due to the limits of graphics hardware and software on PCs to render a larger 3-d landscape in real-time. However, the effect on the space is really quite unnerving, like walking around in an opaque bubble 120 metres across and it takes some getting used to. The problem is that streets and buildings appear to end, with a sharp cut-off line. This impacts on local accessibility because it is hard to orientate and navigate with no fixed landmarks and distant vistas.

Conclusions

In this paper I have been concerned with the idea of *information accessibility* within the virtual spaces of the global Internet. Two particular information spaces have been examined, the Web and Virtual Worlds. One approach to measuring and mapping the relative accessibility of Web sites is to use the structure of hyperlinks between them to calculate measures of virtual distance. Virtual worlds provide a fascinating challenge to the conventions of geographic accessibility. Although the worlds have a tangible, simulated geographic environment which has many of the spatial characteristics of the real-world, they can also warp the physical conventions of distance and travel. AlphaWorld is a particularly nice example to explore because it warps the notion of geographic distance by allowing users to teleport, and yet still exhibits the fact that certain locations are preferable over other because of their centrality or desirable address (in terms of nice, memorable co-ordinates). If, as some predict, these kinds of immersive, 3-d, VR-type environments became prevalent as the next generation of information interface, then it will be vital to understand how accessibility effects the way people navigate and find places in the virtual worlds.

In the Information Age the importance of access to information spaces, such as the Web or places in a virtual world, will increasingly take precedence over access to physical facilities in the real-world. As a personal example, I can say that access to Amazon.Com is more important to me than access to the real book shop, only a few hundred yards from UCL. Although it is still nice to spend a spare half an hour away from the computer browsing real shelves of books! Being able to quantify and visualise accessibility to virtual information spaces like Amazon will be an important challenge in extending the notions of geographic accessibility to encompass Cyberspace.

Notes

1. Although the Internet is large information space, it is still small in absolute volume terms compared to other information domains, particularly broadcast television. See the paper by Lesk (1998) for a fascinating examination of the sizes of different information domains.

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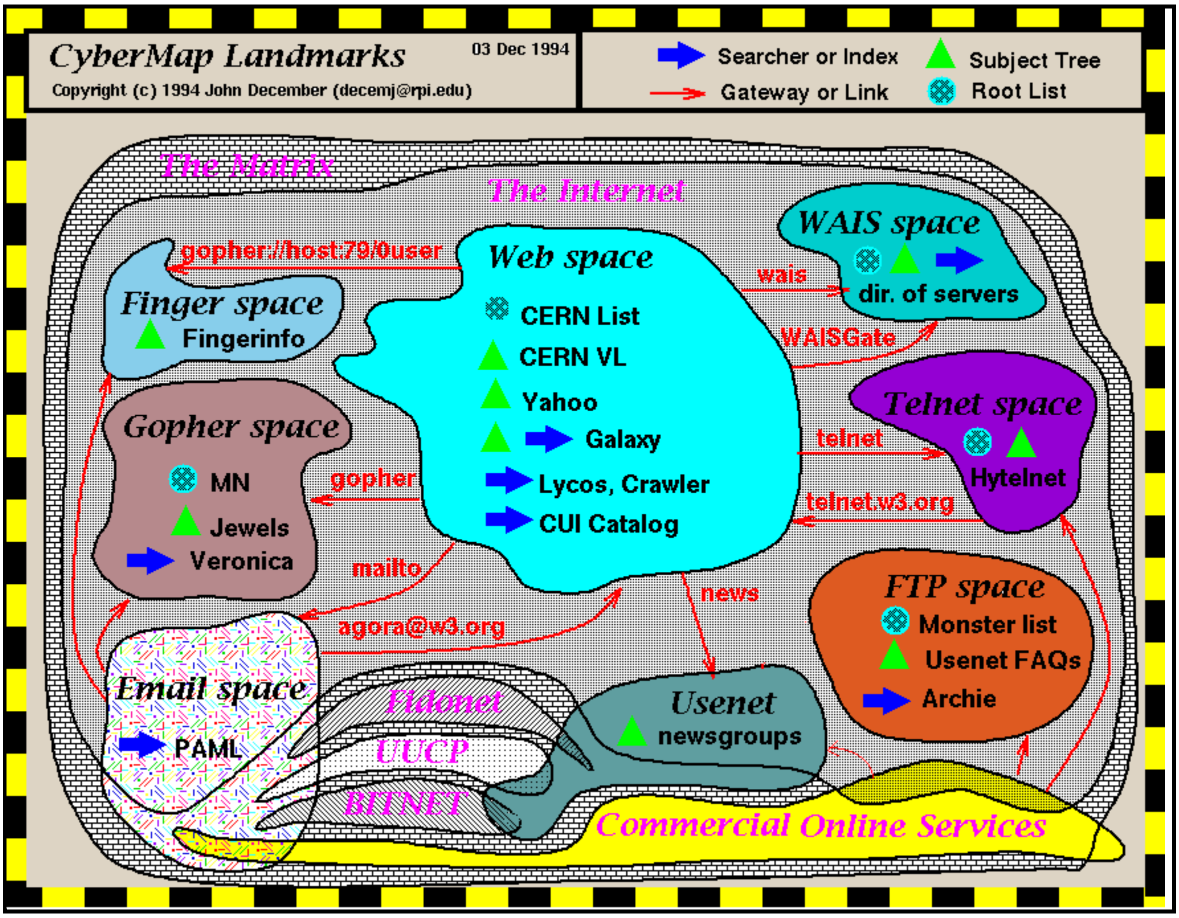

Figure 1 : Information spaces of the Internet - circa 1994 (Source: December 1995).

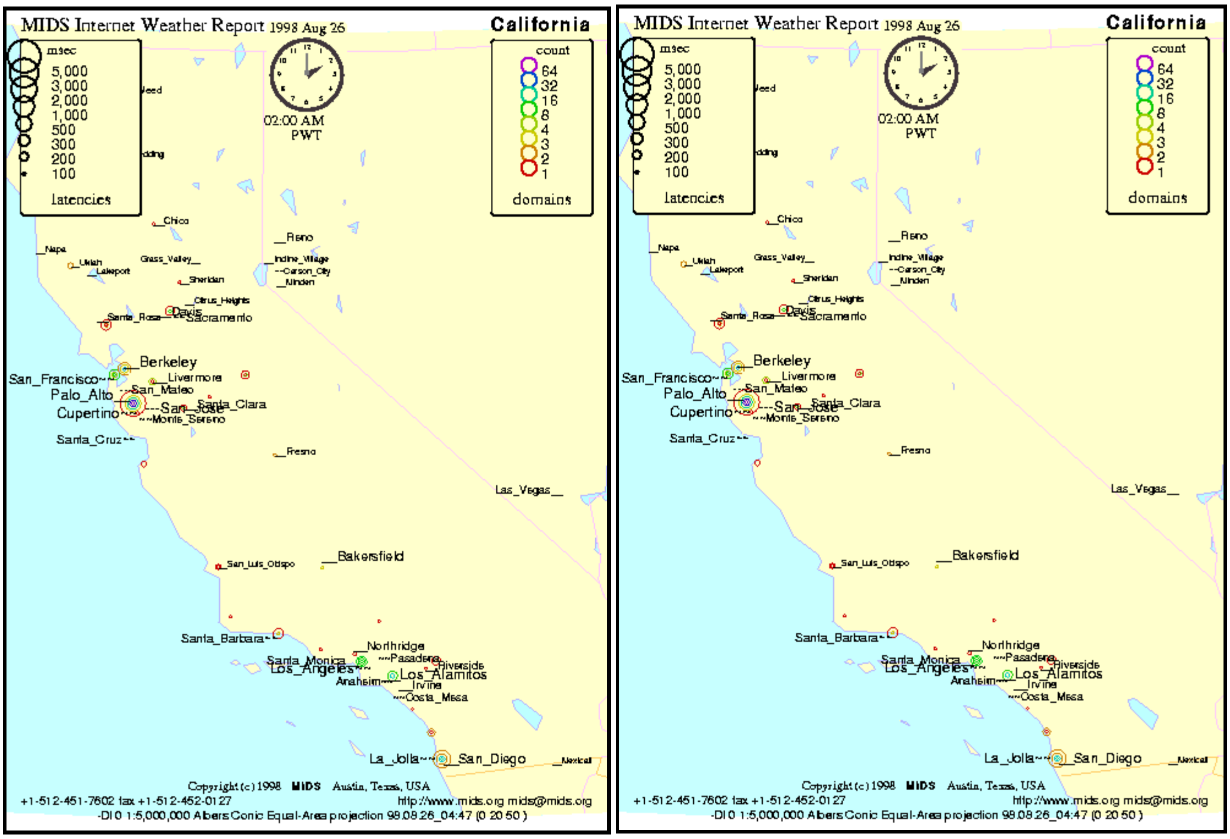

Figure 2 : Internet Weather Report (IWR) for California (Source: http://www.mids.org/).

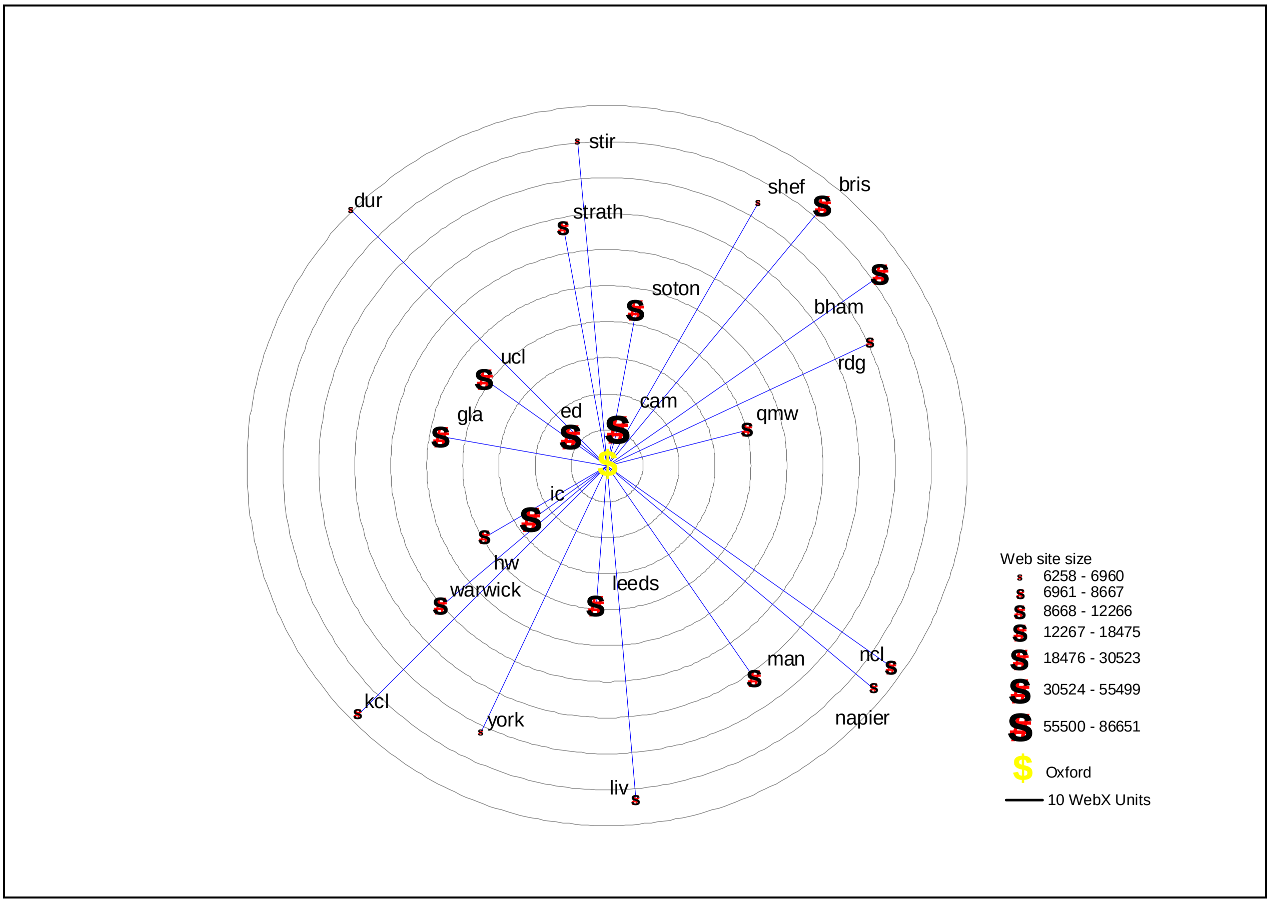

Figure 3 : Web Scan showing the most accessible Web sites of UK universities.

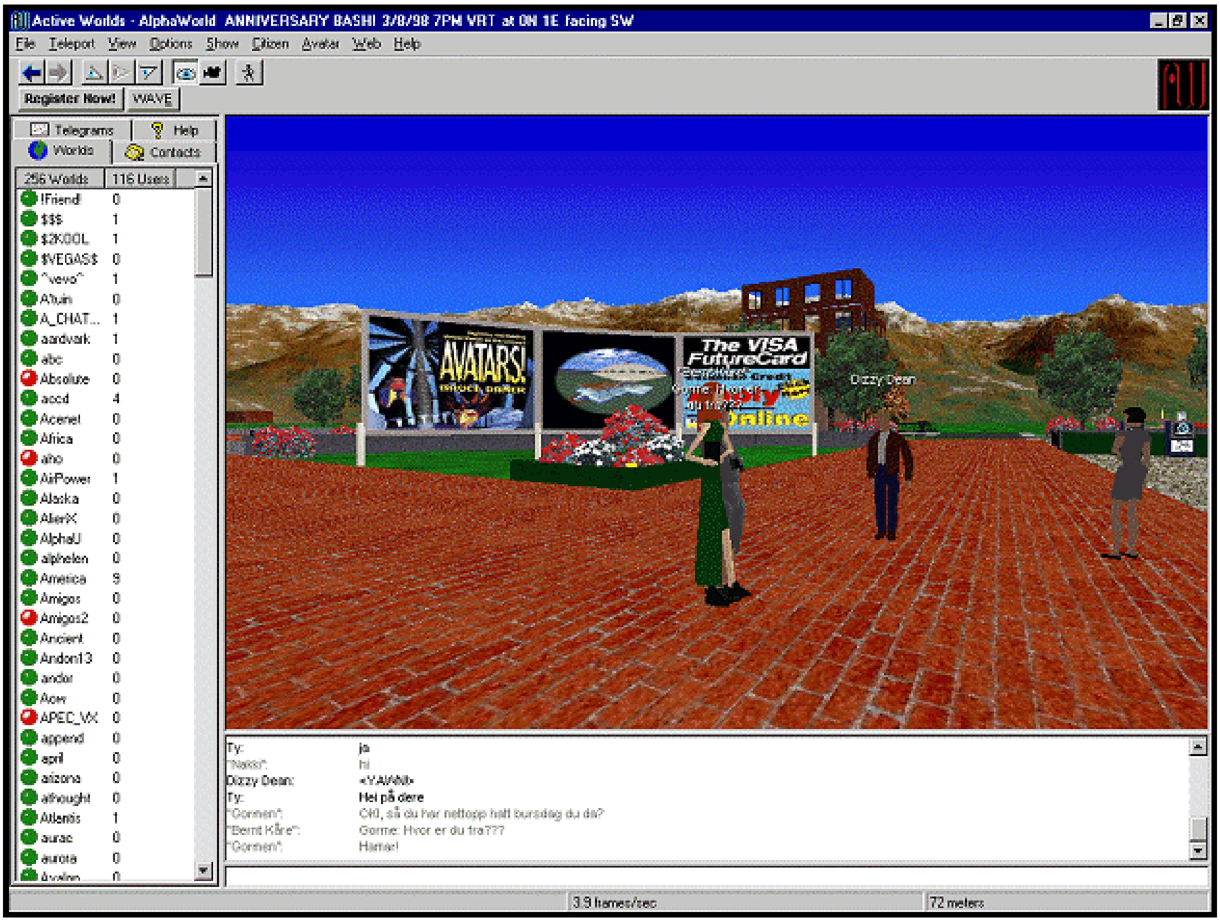

Figure 4 : Screen-shot of AlphaWorld's 3-d environment and user avatars.

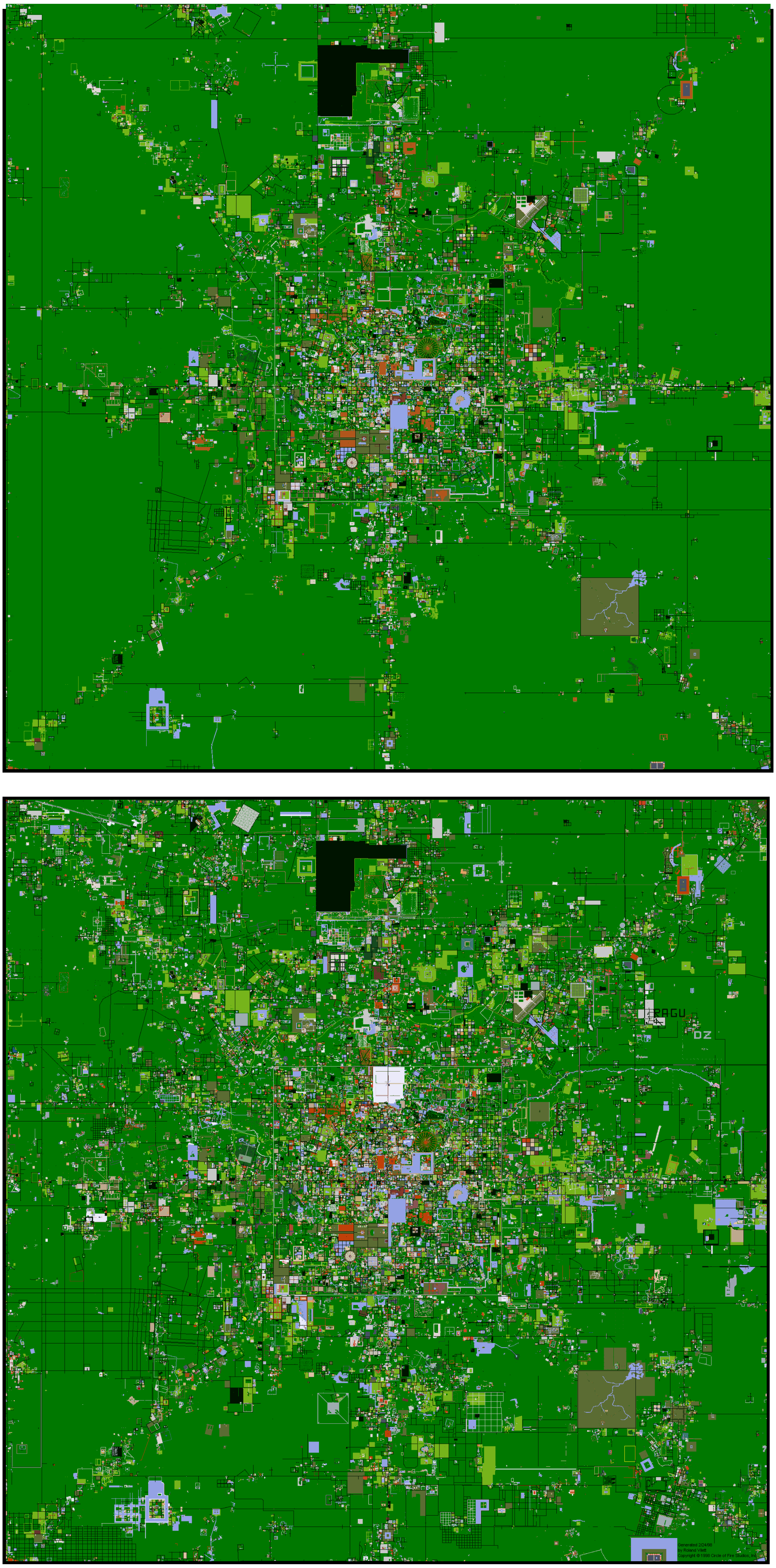

Figure 5 : Maps of the centre of AlphaWorld in December 1996 and February 1998 (Source: Vilett 1998).