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MAPPING CYBERSPACE: VISUALISING, ANALYSING AND EXPLORING VIRTUAL WORLDS

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ABSTRACT

In the past years, with the development of computer networks such as the Internet and world wide web (WWW), cyberspace has been increasingly studied by researchers in various disciplines such as computer sciences, sociology, geography, and cartography as well. Cyberspace is mainly rooted in two computer technologies: network and virtual reality. Cybermaps, as special maps for cyberspace, have been used as a tool for understanding various aspects of cyberspace. As recognised, cyberspace as a virtual space can be distinguished from the earth we live on in many ways. Because of these distinctions, mapping it implies a big challenge for cartographers with their long tradition of mapping things in clear ways. This paper, by comparing it to traditional maps, addresses various cybermap issues such as visualising, analysing and exploring cyberspace from different aspects.

Introduction

The term cyberspace is increasingly used in our information technology age. It was initially coined by Gibson in his well-known science fiction novel *Neuromancer* [Gibson 1984]. Cyberspace is defined as a computer-generated landscape, i.e. the virtual space of a global computer network, linking all people, computers, and sources of various information in the world through which one could navigate. It has become a more and more dominant aspect of our society. Nowadays, academic research increasingly depends on cyberspace. Researchers use email in order to exchange information with colleagues world-wide, generate homepages for research reports, and for dissemination of their papers and projects. They even hold online conferences through Internet technology. A number of virtual universities is being set up. Moreover, our daily life is gradually shifting towards cyberspace, as it is increasingly used for shopping, entertainment, meetings, or chatting.

Cartography, hitherto regarded as a discipline for mapping the real world, is nowadays experiencing a big challenge to map cyberspace [Jiang and Ormeling 1997]. Most cartographic principles can be used as well for mapping cyberspace. Various cybermaps have been discussed regarding their uses for navigation, analysis or persuasion. However, cyberspace is rather different from the real world we live on. The earth is an irregular sphere, and mapping it requires flattening it to a two dimensional plane, with the help of map projections. In geographical space, direction, distance, area and scale are critical aspects. For cyberspace such a simple model as the globe does not exist, instead various different models of virtual space could be constructed. These differences provide a big challenge for mapping virtual space.

Traditional cartography is based on Euclidean geometry, because the correct representation of distances and angles is an important concern in such activities as navigation, exploration and land management. This traditional focus has been changed already somehow since the 1930s by the

emergence of topology and topological mapping. Here, the primary concern was not to render areas or object categories, but to focus on connectivity, i.e. on the fact whether or not locations (nodes) have been linked or not. The London Underground map is a good example of a topological map showing whether stations are connected by lines or not, and indicating interchange possibilities to move from one line to another.

Nowadays, the importance of the distance factor is decreasing due to the development of telecommunications and of the Internet as an information dissemination support. Instead of distance it is relations that become increasingly important for understanding network structures. This change in objective causes many differences between cybermaps and traditional maps. On the other hand, there are many resemblances between cyberspace and geographic space: both are very large and cannot be seen from a single vantage point.

This paper is oriented toward a general conceptual discussion of the contents of cybermaps. A distinction is made first between three views of cyberspace that can be discerned: one view considers cyberspace as a set of physical anchorages; the second concentrates on the topological relationships rather than physical locations and the third one regards cyberspace as an animated 3D virtual reality modelling language (VRML) model. Thus the first view leads to cybermaps with representations of the earth as a base map; the second view leads to maps of topological relationships and the third produces general purpose maps for virtual worlds. As opposed to direction and distance, it is aspects such as connectivity and integration that appear to be critical in mapping cyberspace.

Section 2 of this paper briefly reviews the cartographic approaches in mapping both physical and virtual spaces. It is followed by discussions on three kinds of cybermaps in section 3, 4 and 5, Finally section 6 presents a conclusion and assesses future work in mapping cyberspace from a cartographic perspective.

Space and Maps vs Cyberspace and Cybermaps

Space is probably one of the most essential and paradoxical concepts that human beings face. Space is always present in our everyday life, for instance, travelling all over the world, being in a country, a city, even in a building. Basically two kinds of space can be identified in terms of size of space from the point of view of perception: small space which can be seen from a single viewpoint and large space which is beyond human body perception and cannot be seen from a single vantage point. To understand and perceive large space, maps are often used to represent it on a small-scale paper plane. In other words, we need maps because space is too large to perceive, to understand, to

navigate and to explore. Maps provide a visualisation tools for understanding and perception of space. So traditional cartography is defined as "*the art, science and technology of making maps, together with their study as scientific documents and works of art. In this context, maps may be regarded as including all types of maps, plans, charts and sections, three-dimensional models and globes representing the earth or any celestial body at any scale*" [Meynen, 1973].

In this definition, both cartography as a discipline for mapping and maps are defined in rather restrictive terms. Two points deserve mentioning here. The first is that maps were initially meant for portraying the earth or (parts) of the earth and were later on developed for any celestial body. This constraint does not remain valid, as the notion of maps has been widely used for mapping brain or other micro organs [Hall, 1992]. It appears that cartography is also facing challenges to map virtual space, as is being discussed here. The second concern about the above definition is scale. Scale always comes with size, for instance, we need to represent a country or a city in reduced scale in order to fit a paper sheet. This may not be completely true for cyberspace. Cyberspace is large in the sense of its physical extent, on the other hand it is small in the sense that distance in cyberspace is non-existent. Through telepresense, people can be "together" despite geographical and/or temporal distance. When we state that cyberspace is small, it does not mean that we do not need a map for it. On the contrary, we need a map for it as its structure has become very complex so that it cannot be perceived in its entirety.

Cyberspace maintains many differences from geographic space. Firstly for the Internet, it can be regarded as both information infrastructure attached to the Earth and as information networks without any distance concept. Secondly, developed from the virtual reality technique, 3D VRML models with or without Internet connection constitute another sort of cyberspace within which one can go walking through or flying over with a mouse or special headset. From the traditional classification of maps into general reference maps and special purpose maps, it seems that the information infrastructure view of the Internet leads to cybermaps being classified as thematic maps. In this connection, many traditional thematic cartographic principles [e.g. Dent 1999] can be used in mapping this kind of cyberspace.

The information networks view of the Internet leads to network mapping, which has similar cartographic fundamentals. In Bertin's *semiology of graphics* (1983), one chapter has been contributed to the issue. Nowadays, it is considered quite acceptable to make available to the general public various schematic maps such as subway networks, the urban bus network and suburban railroad network. Travellers are also accustomed to exposure to documents showing the airline networks. In these schematic maps, real location and metric distance become less important compared to the topological relationships. Thinking about social networks, say, a genealogical tree,

each node has no sense whatsoever of physical location, neither has a link any physical meaning rather than that of showing a relationship.

It should be noted that in the above definition of cartography, three dimensional models and globes as special maps are in small scale, which means one can have a bird's eye view of the model. However, the 3D models we refer to here as cyberspace are those with huge size, so that while exploring it very often people feel getting lost in it.

Visualising Internet as a Space Anchored to the Real World

The Internet is a world-wide network of millions of computers communicating via an agreed upon set of Internet protocol. Because so many computers are networked together, the analogy "information superhighway" is often used. Physically speaking, all computers have their unique location on the earth, therefore Internet can be regarded as a space attached to the earth. Thus mapping Internet space would be mapping physical locations of computers distributed all over the world. This kind of cybermap can be thought of as a thematic map with a topographic map for a base map. Its mapping procedure follows the principle of traditional thematic mapping. In this connection, MIDS [1999] provides a huge amount of sample maps for the Internet. These cybermaps can be categorised according to themes as follows:

- Internet growth (rate),
- Internet weather forecast,
- Domain Name System (DNS),
- distribution of hosts, and
- information volume etc..

There are various aspects to be mapped as stated above. Internet addresses all have the name.domain format, e.g. www.casa.ucl.ac.uk. The last part of the address after the last period is called the 'top-level domain', which can be converted into corresponding geographic locations. In the mean time, the 'top-level domain' also indicates the type of group within which the address is located. In general there are two types of top-level domains: the older-style organisational domains (e.g. .com, .edu, .gov) and the newer geographical domains (e.g. .uk, .au). Domain Name System (DNS) is a distributed database which contains discrete 32 bit numerical addresses for every registered computer in the world, e.g. gauss.geog.fu-berlin.de = 160.45.60.50.

'Host' is the name of a specific machine within a larger domain. Usually domain and hosts have the same physical location. The second meaning of the word 'host' has to do with the way certain

computer systems have been set up. Some computers are made to support more than one user at the same time. These multi-user systems are often referred to as host computers.
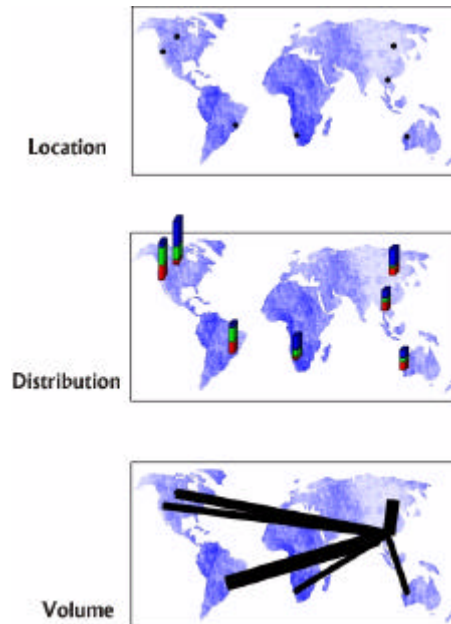

Figure 1: Visualising different aspects of cyberspace

Over the Internet, it is web servers that maintain detailed logs of every request made for information. Here every request is referred to as a hit. The number of hits reflects the frequency of usage of a specific web site. Both the number and distribution of hits can be mapped. When using the graphical grammar as proposed by Bertin [1983], location could be rendered by the dimensions of the mapping planes, the various domains (.gov, .edu, .com) could be differentiated between through the use of colours, and hosts and domains could be differentiated through differences in shape.

Figure 1 suggests a set of visualisations used in mapping cyberspace, with the Earth as a flat plane, actually it should be more realistically represented as part of globe. Mapping location, distribution and volume of the Internet according to geography is a major task for cyberspace. Various efforts have been made to visualising Internet in three dimensional and dynamic ways, which provides more intuitive communication and analytical tools for the Internet (figure 2, [Munzner et al. 1996]).
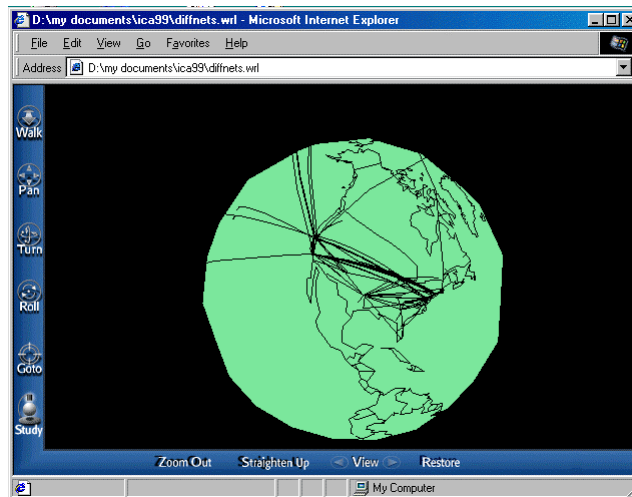
Figure 2: Visualising the global topology of the Mbone by the use of VRML model

In contrast to the Internet, Intranet, though based on the same technology, is restricted to relations within an organisation or enterprise. Except for the size of cyberspace, Internet and Intranet have no differences; Intranet can be regarded as a subset of Internet.

Analysing the Information Space of Internet

The Internet space can be qualified as a mathematical network with unit distance. For instance, researchers in Bell Laboratories are running a big project to collect routing data on the Internet [Cheswick 1999]. This mapping consists of frequent traceroute-style path probes, one to each registered Internet entity. From this, an Internet tree showing the paths to most of the nets on the Internet has been produced (figure 3). These paths change over time, as routes reconfigure and the Internet grows. They are preserving these data and plan to run the scans for a long time. The database can help analyse how the Internet grows.
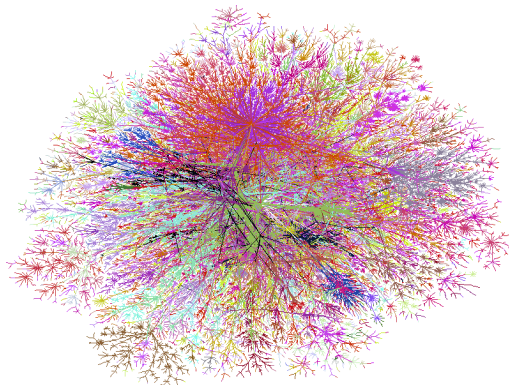

Figure 3: An Internet tree (Cheswick 1999)

In the Internet tree shown in figure 3, the map does not have a geographic nature; only links are shown in the cybermap. This is not only valid for the Internet, but for hypertext as well. The idea of hypertext originated from an early project 'memex', a tool linking any two items in large collections of information [Bush, 1945]. Bush's initial idea on memex has never been implemented, though. Engelbart [1963] developed the NLS (oNLine System) at Standford, that incorporated hyperlinks into a text database. Following these efforts, various projects have been developed during the 60s to the 80s. Hypertext technique has achieved a breakthrough since HyperCard has been put on the market. Nowadays, the Internet information sources (e.g. homepages) are all organised by hypertext techniques [Nielsen 1995].

Both the Internet structure, and the hypertext can be regarded as a complex network with considerable amounts of nodes and links. This complex structure can be generalised as a complex graph. By this term we mean a graph with millions of nodes and links. From an analytical point of view, some graph measures are important in understanding cyberspace. The most important ones would be: connectivity and integration. In order to describe these measures, let us assume some variables:

for any particular node in the graph, the shortest distance from the node is denoted by i, the number of nodes with the shortest distance i is denoted by N_i, the maximum shortest distance is denoted by k. Using the expression $\Im = \sum_{i=1}^{k} i \times N_i$, we can describe the following important measures:

$$\Im = \begin{cases} connectivity & iff \ i = 1 \\ local\ integration & iff \ 2 \leq i \leq k - \boldsymbol{d} \\ global\ integration & iff \ i = k \end{cases}$$

where $\boldsymbol{d}$ is a large enough constant variable, usually $k - \boldsymbol{d}$ is less than 10 depending on the size of graph.

So from the above formal definition, connectivity is the number of nodes that is directly connected to a node. Sometimes, connectivity can be called the number of immediate neighbours. Integration can be regarded as the number of neighbours within a few steps or full range of steps which leads to local and global integration respectively. These measures are taken from space syntax theory; interested readers may refer to relevant literature for more details [Hillier and Hanson 1984].

Both connectivity and integration measure the node's status in the graph as a whole, either at a local level or a global level. These measures present some important indicators for understanding cyberspace. For instance, connectivity shows how each node is connected to its immediate neighbours, and integration shows how each node is integrated or segregated. When visualised these properties or measures can be more easily understood. Figure 4 shows an example of these visualisations, where connectivity has four grades, integration has 5 grades, and links have 6 different grades.
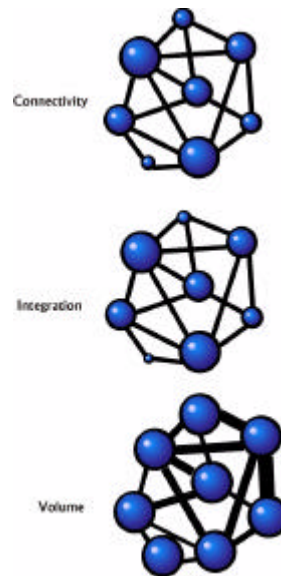

Figure 4: Visualisations of networks based on graph analysis measures

As Internet space can be qualified as a mathematical network with unit distance, it is not metric distance which is relevant here, but links and structures. That is why the concepts of integration and connectivity are so relevant here. So it would be important to map not absolute but relative locations, distributions. Traffic volumes would be relevant, as would be measures for connectivity and integration. It would not be relevant to map the distances covered by traffic flows, but rather the time or the time costs. Comparable to attempts to solve traffic congestion in the real world, traffic volume maps could help speed up Internet traffic. Time as a variable would be rather important, and animating Internet traffic flows offers itself as a solution to get more insight into the phenomena.

Over the years various attempts have been made to develop tools for displaying social networks [Freeman 1999]. Freeman suggested several ways to make a graph more intuitively evident, such as the use of different colours or shapes on the nodes in order to display properties of nodes and links, or the use of animation for time-dependent changes in network structure. It appears that visualisation of Internet can benefit from relevant research fields such as the visualisation of social networks and molecule structures.

Active Worlds: Exploring Virtual Worlds

As mentioned in the introduction, the emergence of cyberspace is partly due to the virtual reality technology. In this connection, Active Worlds is a good example of cyberspace developed from virtual reality. It consists of Active Worlds Browser, Active Worlds Universe, and Active Worlds Builder.

Active Worlds Browser allows us to access 3D VRML worlds where we can roam through different landscape, teleport from place to place and chat to other users. It uses a considerable amount of bandwidth and can be quite slow at times. When entering a world, one appears in the shape of an avatar, that is a 3D figurine. Most worlds have a selection of avatars for us to choose from. Other users can be seen as avatars as well, and one can chat with them via a test chat screen. Active Worlds actually is the combination of virtual reality and Internet technology, as 3D virtual worlds can be shared by multiple users through Internet communication. It seems very different from Netscape Browser, which initially was text oriented although now one can have images, animation and 3D VRML through appropriate plug-in extensions. Currently Active Worlds is available for Windows 95/NT only.

The Active Worlds Universe is a cyberspace which consists of numerous Active Worlds. Each virtual world is filled with human activities, once one enters them one can:

- *shop online in 3D virtual mall;*
- *explore over 300 worlds in real-time, 3D, high-color graphics;*
- *own land and build anything you like on your property;*
- *meet, chat with people and interact as a fully 3D, lifelike, animated figure;*
- *use objects just like hyperlinks to send mail and surf the web;*
- *play games, ride rides, solve puzzles, navigate mazes.*

[ActiveWorlds, 1999]

Active Worlds is also a 3D builder, with which one can build one's own 3D virtual world within it. It is rather similar to WWW, but is more graphics oriented than text oriented. Now the technique has been applied in various fields such as film making for decor building, virtual campus, virtual cities, etc.. AlphaWorld is the biggest virtual world within the Active Worlds Universe. It is an urbanised virtual world where each piece of land is owned by individually registered users (citizens of the virtual world). AlphaWorld appears to have evolved in much the same way as real world cities. Figure 5 shows an early stage of AlphaWorld, with a large area remaining undeveloped. As time goes by, this world has been further developed (see figure 6). This series is a set of morphological maps of the AlphaWorld**.**
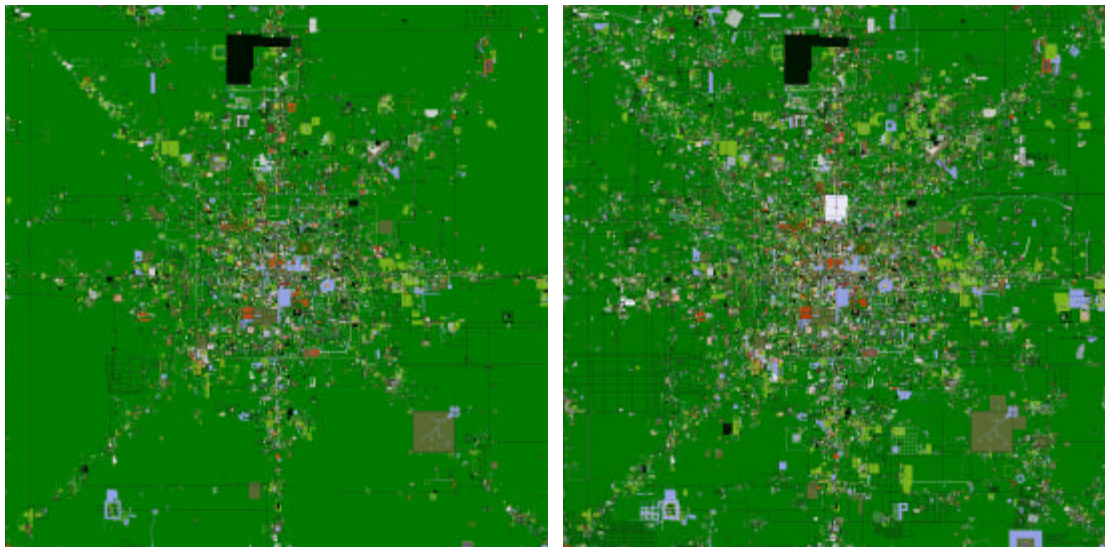
Figure 5, and 6: Morphological maps of AlphaWorlds (December 1996 and February 1998)

As AlphaWorlds is too big to perceive from a single vantage point, users still get lost in cyberspace. In order to help them get their bearings, they would need additional mapping tools. When users navigate in AlphaWorlds, for instance, a morphological birds eye view such as provided in figure 5 and 6 will not help them much. A common used scenario would be using cybermap with an active moving window to show the site currently being explored. Such a scenario helps avoid getting lost in it. Maps are thus essential to fulfil tasks such as navigation and orientation in cyberspace. The same scenario can be used for the exploration of information space.

Conclusion

This paper has discussed three kinds of map for cyberspace in the era of information technology. These three kinds of cybermap can be classified in functional terms as special purpose, general reference and network maps of cyberspace. Traditional cartography is facing a big challenge from both the impact of information technology on traditional map making and the need to map information technology space - cyberspace. It seems that visualisation techniques can have the same impact on both geographic space and cyberspace. Future work implies applying the principles discussed to some practical projects.

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