$^{VR}/_{search}$:
An Architectural Approach to Cyberspace

Andrew Vande Moere, Herman Neuckermans & Ann Heylighen
K.U.Leuven, Belgium

ABSTRACT: *This paper focuses on one single aspect of the relationship between cyberspace and architecture: the domain of information visualisation. This field embraces many different approaches to represent data-derived information in a three-dimensional way. One of them, Benediktine Cyberspace, is discussed in more detail. First, the role and importance of visualisation techniques are situated within the context of the information revolution. Second, the cyberspatial principles of Michael Benedikt are described, and finally investigated in a concrete computer application called* $^{VR}/_{search}$. *This should illustrate both the three-dimensional consequences as well as the still visionary character of Benedikt's ideas.*

1. Introduction

This paper focuses on one particular aspect of the relationship between cyberspace and architecture: the domain of information visualisation. More specifically, we would like to pursue the future possibilities architecture could create when the phenomenon of cyberspace is understood as a primarily informational tool. Many authors are convinced that this 'space' possesses some valid rules and principles that should be followed by its designers. However, few of them dare to theorise these rules and write them down. In this respect, the principles Michael Benedikt proposed are more than challenging, especially from the point of view that the future of architecture will be partially built in the virtual realm.

Today already, cyberspace inspires research projects in science, art, business, and architecture. For Benedikt, the 'cyberspace program' should start experimentally, by creating 'crude' and 'fragile' cyberspaces with a limited number of users, from which the most essential lessons should be learned. He foresees this process taking decades of time, meanwhile stimulating spin-offs in various areas of computing, like hardware, software, telecom, and interface design. Furthermore, thousands of engineers, programmers, designers, and managers will work to make this visionary cyberspace a fact of reality, by investigating its potential to increase the productivity of many companies and agencies. "Because the design, institution, and management of cyberspace will be a task of immense scale and complexity, it can simply be argued that '*it is never too soon to begin*' "(Benedikt 1991:189).

Taking this advice, we have developed a simple Virtual Reality (VR) application called $^{VR}/_{search}$ in order to investigate the three-dimensional consequences of his cyberspace ideas and principles. Before describing this application, the first part of this paper will situate the role and importance of visualisation techniques within the broader context of the information revolution, after which part two will discuss the principles underlying Benediktine cyberspace. Finally, part three will explore the concrete software application based on Benedikt's ideas.

2. The Information Revolution

"*The information sector of our economy is enormous – including mass media (newspapers, magazines, books, online services, movies, radio, and television), information systems, educational institutions, and more. No industry or enterprise is untouched by the persuasive influence of the information revolution. Understanding this revolution requires an examination of the determinants and sources of the value of information and the impact of that value on the organisational infrastructure of business and commerce"*(Whittle 1996:306).

2.1 Cyberspace as an Information Tool

David Whittle is convinced that the right information (on the right time) can have an enormous value and consequently a high price. In this view, information is anything but a commodity, as its value varies from person to person and its price often has little to do with its value. But since the supply of networked information drastically exceeds the actual demand, and the cost of sharing is very low, the price quickly approaches about zero.

For today, the information available on the Internet is characterised by immediacy and a sheer breadth and scope. This electronic network can deliver any digital good imaginable thanks to numerous databases of all kinds. However, Whittle points to some important disadvantages when the Internet is used as a commercial tool, such as difficulty of access, bandwidth constraints, wide disparity in information quality and applicability, and lack of real security (Whittle 1996:309).

2.2 The Value of Online Information

To clarify the role and characteristics of cyberspace as information delivery mechanism, Whittle has recognised six different key factors (Whittle 1996:310-317). The first one is *convenience*. Netsurfing is more convenient for quick access to a huge amount of knowledge, while printed media are better fit for portability, content, and permanence. *Granularity* stands for the size of information chunks that the consumer still considers valuable. Unlike traditional, physically limited media, cyberspace promises targeting and delivery technologies a huge step forward by drastically increasing the granularity. This should result in a more efficient information flow, while the time and effort spent for gathering it will either decrease or become more productive. However, advantages of convenience and granularity should not be lost in lack of *quality* and *suitability*. In cyberspace, often only raw material is found, while reviewed, useful, stimulated and well reasoned writings would offer an 'added value'. Moreover, in spite of the filtering capabilities of so-called search engines, there still is a remarkable inefficiency in finding the 'right' information for a well-defined target. A fifth factor is *accessibility*, i.e. the ease with which information can be obtained and understood. Dramatic as its growth and potential may be, the Internet will not be part of everyday life until it becomes as accessible as say cable TV. Furthermore, questions about the universal access of cyberspace arise, as not all social classes have the opportunity to ‘go online’. Finally, *scarcity* affects the economic value of information. As an increasing amount of information will be available at lower cost, people will become more educated, which is considered of great value in any society.

2.3 3D Information Visualisation

2.3.1 Information Quantity

Computer networks, like the World Wide Web (WWW), are growing in a rapid, almost exponential manner. Coupled with the increasing processing power and storage capacity of contemporary computers and their decreasing price for the general public, this expansion cannot but end in an ‘information big-bang’. Yet, perhaps *information* is not the right word to use. Critical researchers, Ziuaddin Sardar for instance, paint the current situation of the Internet as follows: “The net, in fact, provides us with a grotesque soup of information: statistics, data and chatter from the military, academia, research institutions, purveyors of pornography, addicts of Western pop music and culture, right-wings extremists, lunatics who go on about aliens, paedophiles and all those contemplating sex with a donkey. A great deal of this stuff is obscene; much of it is local; most of it is deafening noise” (Sardar 1996:24).

In this chaotic, increasingly purely commercial 'soup', the amount of *data* may have grown, yet the amount of *information* certainly has not. Meanwhile, the problems of finding relevant information have shifted thoroughly. At first, information was difficult to access or search, which has already changed since the emergence of search *agents* and *engines*. However, like most ordinary software, agents and engines tend to overthrow any possible context in which information is asked. Thus, the problem no longer lies in getting information as such, but rather in picking the right record out of more than hundred similar items.

Researchers are investigating various tools and techniques to offer the user comfortable and economical solutions to this problem. Algorithms and methods for intelligent data evaluation are being developed to automate information filtering, i.e. to recognise what elements and records the user finds relevant. On the other hand, visualisation techniques shift the task of retrieving relevant data to the user-side. These techniques profit from the user's cognitive, perceptual, and intuitive skills to find interesting data that may be missed by search algorithms, for instance because they are not directly relevant to the query. Before some principles of 'architecturally' inspired approaches in this area will be investigated, it seems useful to give a quick overview of the existing 3D information visualisation techniques.

2.3.2 Visualisation Techniques

The growth of specially designed graphic user interfaces (GUIs) started at Xerox Palo Alto Research Centre (PARC) in 1971 (Woolley 1992:147). The idea was to present the computer’s resources graphically, so that the user could literally *explore* and *discover* its possibilities. Within the world of cyberspace, GUI-technologies enable the user to experience control (‘*cyber-*‘) as a projection of self from the own centre, the own will, to a field of activity, which can be characterised as *space*. This space is real because of its independence of the potential user. It is even more real because of its ability to respond and interact. In this view, the major challenge of the computer industry is not to deliver better and faster hardware, but to develop a completely different concept of a *real* user interface, one that recognises the presence and needs of the user not only by the keyboard. Part of this research concentrates on the communication level of this task, e.g. speech recognition (Neuckermans et al. 1998) and other artificial agents to derive user preferences from specific experiences. Yet, much work is still invested in visualising all kinds of information in a more intuitive and human-friendly way.

Most of these efforts focus on the possibilities of three-dimensional representation techniques, which can be roughly classified in three categories (Gloor 1996; Young 1996). So called *presentation techniques* mainly concentrate on the appearance, accessibility, and usability of the data, which should result in a user-friendly and intuitive interface. *Dynamic techniques* enrich the visualisation with behaviour and dynamic properties, which respond automatically to specific data changes or user actions. Finally, *mapping techniques* use some aspect, property, or value of the data-elements to produce a mapping onto objects within the visualisation.

Benediktine Space belongs to this third category. However, before discussing this technique in more detail, it might be useful to stress the original relation of information visualisation with cyberspace. Today, visualisation techniques still largely depend of the applied technology. Nevertheless, visionary thoughts foresee them to become the core of what cyberspace is about: offering a tight union between the user and his virtual representation as a true state of *human-machine 'symbiosis'* (Benedikt 1991; Gibson 1984; Novak 1991). In their view, these future environments will become 'really' accessible, as the user interface ultimately disappears and users are immersed in the universe of information.

3. Benediktine Space

3.1 Mapping

In the realm of electronic cyberspace, the concept of *mapping* is a strong and already widespread technique. A stream of bits, initially formless, is shaped by a representation scheme, and information emerges through the interaction of data with the representation. Generally some predefined mapping algorithm must be followed, which translates abstract data into a recognisable representation and into a specific location of that object within the information terrain. The resulting spatial configuration is interpretable, as properties of data items can be inferred from the relative position and unique presentation of the objects.

Among the various mapping techniques, four different approaches can be recognised: Hyper-Structures (e.g. the WWW), Human Centred Approaches (e.g. Cities and Rooms), Statistical Clustering (e.g. search engines) and Benediktine Space (Young 1996). Within the scope of this paper, only the latter will be further explained.

3.2 Michael Benedikt's Principles

The term ‘Benediktine space’ can be traced back to Michael Benedikt’s research on the structure of cyberspace. He has investigated the possibilities to map object attributes onto intrinsic and extrinsic spatial values, based on the two principles of *exclusion* and *maximal exclusion*. Benedikt thoroughly explains these principles, which are meant for the so-called cyberspace architects of the future, in his book *Cyberspace: First Steps* (Benedikt 1991:119-224).

In Benediktine cyberspace, both the space as well as the geometry carry meaning. In other words, this cyberspace is built in such a way that spatial metaphors - like up or down, left or right, closeness or distance - all have some informational and interpretable significance. To accomplish such virtual realm, Benedikt defines seven principles in relation to those of physical space, and classifies them under four, essentially topological rubrics: *dimensionality*, *continuity*, *limits*, and *density*.

Dimensionality

The first rubric describes the possibilities to visualise more than three dimensions in an immersive, virtual world. If a set of N different measurements must be represented, two different approaches can be followed to describe the *state* of the system. First, the designer can simply decide which three dimensions to work with and drop the others, which results in many different non-complete representations of the system. Second, certain dimensions, called *extrinsic*, can be assigned to perform ‘co-ordinate duty’, while the others, called *intrinsic*, determine the *character* of a point in the co-ordinate space. Thus, unlike an Euclidean point, a point-object might *have* a colour, shape, weight, size, spin, etc. - all intrinsic qualities that are logically independent of its position in space. In this way, any N-dimensional state of a system can be represented in the data space of point-objects having n spatio-temporally locating, extrinsic dimensions and m intrinsic ones.

$$N = n + m \qquad (N > 0,\ 0 < n \leq 4)$$

This technique gives way to the conception of *animated* actions. Since intrinsic dimension data only exist at address points, an object's size and shape can possibly change as it moves, thereby revealing the data embedded within each address of the data space. Note that there is some freedom to choose the partition and combination of m intrinsic and n extrinsic dimensions. Provided that no information is lost, all combinations are mathematically, yet not necessarily functionally, equivalent. It is far from evident to create a three-dimensional view containing mapped data that the user understands immediately, and in this sense, a ‘good’ choice is considered to contain *more* information.

According to Benedikt, object size is not always a good variable. An extremely large item can crowd out other objects, while simultaneously sub-features of the shape (corners, edges etc.) might be misinterpreted as having some significance.

Moreover, not all surfaces of an object are visible all the time. However, by simply *zooming in* the user can solve many of these problems. The enlarged object becomes isolated from the overall context, while some intrinsic dimensions expand in inner detail and behave in a more extrinsic way. An alternative is the technique of *unfolding.* When an object unfolds, its intrinsic dimensions open up to form a new co-ordinate system, and thus a new three-dimensional space.

In order to describe the relation between any two objects in this data space, Benedikt gives three definitions. Two objects are said to be *identical* if they have the same values for the same intrinsic dimensions; *similar* if they have different values for the same intrinsic dimensions; and *different* if they do not have the same intrinsic dimensions. Obviously, problems arise when two non-identical objects have, at some time, the same extrinsic dimensions. In that case, the ***Principle of Exclusion***, commonly understood as “*you cannot have two things in the same place at the same time*”, clearly states that this is forbidden.

This first principle has already been denied by the other 'architectural' voice in the same book, Marcos Novak. He states that, although two objects cannot occupy simultaneously the same space in physical space, this does not necessary hold for cyberspace. He motivates this statement with two arguments: “to allow a poetic merging of objects into evocative composites, and secondly, to keep the implementation of cyberspaces as simple as possible”(Novak 1991:239). Not the programmer, but the *cyberspace desk* that visualises the two objects should take care of this problem. In fact, its characteristic task will be to resolve conflicting situations according to its computational capabilities and the representations chosen.

The ***Principle of Maximal Exclusion (PME)*** is meant to help a cyberspace designer decide on the dimensional partition of the offered data. This second fundamental principle states that "*Given any N-dimensional state or phenomenon, and all the values (actual and possible) on those N dimensions, a designer has to choose that set of extrinsic dimensions that will minimise the number of violations of the Principle of Exclusion*" (Benedikt 1991). Both PE and PME are considered very effective when, in the future, cyberspace will increase in complexity and content. Each controllable aspect of the world (e.g. its overall size, the amount of dimensions, and mapped information) is then able to increase until the new situation and the visible representation have found a new equilibrium.

Continuity

The X, Y, Z (and T) axes of any ordinary rectangular co-ordinate system are understood as *real number lines*: they must be infinitely divisible and monotonic, and support ordinary arithmetic operations. This number-line character generally forms the intuitive and functional basis of any representational mapping technique. Yet, in order to determine the values of the mapped co-ordinates of an object, the available data first must be ordered so that they can be treated as spatially interpretable number-line dimensions. Ordering techniques, e.g. *alphabetical*, *geographical* and *chronological* classifications, should be used skilfully, if the cyberspace designer wants to create a comfortable, active, and navigable three-dimensional data space.

Limits

“Will cyberspace have edges to blackness, walls of final data? Or will it be endless? If the latter, how? … Might it be possible to present cyberspace phenomenally as a four-dimensional sphere, where striking out in any (three-dimensional), direction brings one eventually back to where one started?” (Benedikt 1991:152). Benedikt himself proposes to conceive cyberspace as an *abstractly glued two-torus*. This is a rather difficult term to describe the fact that: first, the vertical dimension is open-ended, and Second, any continuous movement in the horizontal plane ultimately returns to the initial start position. The user, however, never sees the torus itself, but perceives instead a terrestrial geometry of a plain, a horizon, and a sky.

Density

How much space is there in space? In order to clarify and quantify this particular problem, Benedikt defines space_o (*space-over*), the space of varying amount, and space_u (*space-under or space-uniformly*), which is a certain underlying, absolute and homogenous space. The density of a three-dimensional ‘space-in-space’ can then be written as: $D^{(3)} = \text{space}_o / \text{space}_u$.

When cyberspace would become more and more complex, the range of scales at which users can operate could be increased, so that the *density* of information per volume unit of (cyber)space would expand as well. Increasing density, however, cannot be accomplished without technical difficulties, as nearly all experienced VR users will have noticed before. Any dense virtual environment is surrounded by some strange phenomenon that could effectively be described as a ’*reverse gravity field’*. When approaching a group of complex objects, the user's motion gradually slows down. Of course, this can be ascribed to the finite computational speed, which depends on the *rate* of a new-frame display, the level of *detail* displayed, and the ‘increase of *information*‘ with each frame. When maximal smoothness and imitation of nature is required, an appropriate technique is *adaptive refinement*. This means that the level of detail of an approached object automatically and gradually increases. However, making this technique the norm would violate the ***Principle of Indifference (PI)***, stating that "*the felt realness of any world depends on the degree of its indifference to the presence of a particular ‘user’ and on its resistance to his/her desire*" (Benedikt 1991:160).

This third principle is primarily based on the observation of situations in reality, where mysterious complexity often is characterised by ignorance and indifference of the perceiver's actions. This characteristic is commonly known as ‘life goes on whether or not you are there’. It is, in fact, one of the powers of everyday reality, in which people become curious about certain developments and must adapt to the flow of data, transactions, and situations. Ultimately, it argues for the *independent existence* of virtual worlds as in the thoughts of William Gibson, where the user is finally able to believe the relevance and continuity of witnessed actions and events (Gibson 1984). However, this principle should be applied with care. The real challenge is to design cyberspaces both indifferent and responsive, both beyond and for the individual.

However, limiting the amount of new object info per frame could provide a consistent realm where ‘phenomenal immensity follows information density’, and where certain *laws of information* begin to create new spatio-temporal physics. The latter is stated in the ***Principle of Scale***: *"The maximum (space$_0$) velocity of user motion in cyberspace is an inverse, monotonic function of the complexity of the world visible to him"* (Benedikt 1991:162). Benedikt compares this principle with a traditional Japanese garden, in which miniaturised elements only reveal their detail from very close. Partial views direct the provision of new information, while various spatial elements (bridges, stones, obstructions, etc.) slow down the movement of the viewer. Nevertheless, the user still feels powerful, as the motion itself affects what can be seen.

The Remaining Principles

According to the ***Principle of Transit (PT)***, "*travel between two points in cyberspace should occur phenomenally through all intervening points, no matter how fast, and should incur costs to the traveller proportional to some measure of distance*" (Benedikt 1991:168). The concept of ‘cost’ in this context is open to various interpretations (e.g. loss of resolution, of range of view, of smoothness of motion, etc.), yet seems reasonably identified with the notion of time. In this case, the Principle of Transit may seem unnecessary, as one of the main advantages of network computing is the almost instant access to every file, document, and program one is interested in. However, Benedikt offers four different arguments for the validity of this principle.

First, *access is never really instant.* Delays in searching and locating information could be made proportional to a determinate ‘distance’ in cyberspace, and evenly used to experience the route between. Second, *navigating around file structures, selecting paths, accessing different and distant computers, and so on constitutes a good deal of the pleasure of computing.* Benedikt clearly wants to preserve the orienting, 'world-building' tendency of human beings, as well as the fundamental concepts of distance and velocity, in favour of abstract structures such as menus, hierarchies and graphs. Third, *being in transit for significant periods of time in relatively public areas can be considered as useful.* In between tasks - both spatially and temporally - a person is open to 'accident' and 'incident'. Benedikt refers to coincidental meetings in hallways or airports as essential in forming interpersonal networks. Finally, *the process of progressive revelation inherent in closing distance between self and object, and the narrative of travel are important.* Destinations would all be ‘certain’, and otherwise notions like time and history or the unfolding of situations would collapse, thus becoming the sole rights of the physical world.

Benedikt distinguishes between two types of data. *Navigation data* stands for information that orients the user in time and space, in location and direction, by means of addresses, instructions, or warnings. In fact, it organises users in spatio-temporal terms. *Destination data*, on the other hand, is information that *satisfies* users by answering some question or promise. The answer can take the form of a text, an image, a face to speak to, a piece of music or code, a diagram, etc. Navigation and destination data always appear together, and even can transform into one another. The amount of each category varies in time and with the user’s actions. Continuously choosing items on a menu-driven interface, for example, generally decreases the display of navigation data, until only destination data fills the screen.

The ***Principle of Personal Visibility (PVV)*** states that "*(1) Individual users in/of cyberspace should be visible, in some non-trivial form, and at all times, to all other users in the vicinity, and (2) individual users may choose for their own reasons whether or not, and to what extent, to see/display any or all of the other users in the vicinity*" (Benedikt 1991:177). Although this principle seems to threaten the notion of privacy, Benedikt maintains the contrary, as he envisions a minimum of visibility. Small coloured spheres, for instance, might represent persons in cyberspace, indicating nothing but their position, movement, and of course *presence*. No restrictions are mentioned as to the channel for interpersonal contact, such as voice, video, text, gesture, VR-touch, etc. In this minimal presence, user-identity is not essential, and anonymity thus acceptable. A good part of the information available in cyberspace then becomes apparent *in* people, and even *is* people.

According to the ***Principle of Commonality***, "*Virtual places should be 'objective' in a circumscribed way for a defined community of users*" (Benedikt 1991:180). In other words, all users in a certain domain and at a given time should see and hear largely the same things, or at least subsets of them. Obstructions (shadows, for example) may differ in separate views of two viewers. It is also allowed to introduce other features, depending on the feeling, experience, and knowledge brought into the situation. For instance, one user might sit in a leather chair that is for another user an ordinary wooden bench. In short, the worlds of two users A and B must only be subsets of an overall domain D. What is experienced by both users is called *common* and makes up the intersection of their respective worlds.

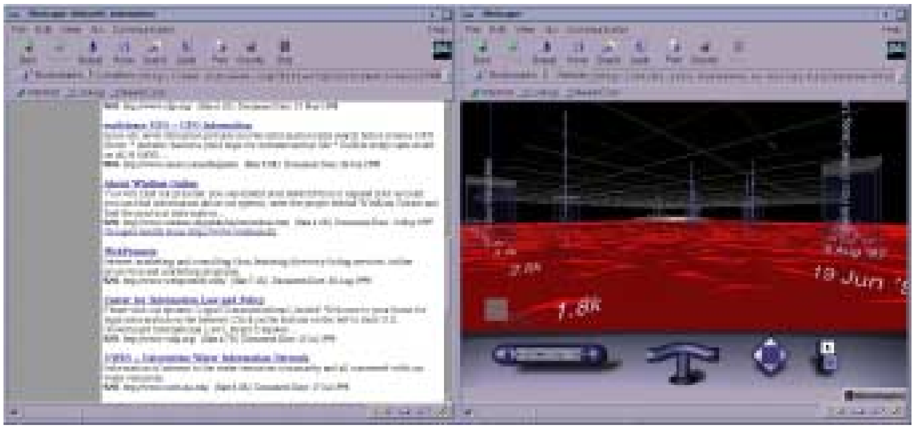


Figure 1. Two visualisations of the same information: on the left the standard result page of the search engine Infoseek, on the right the 3-dimensional world of $^{VR}/_{search}$

4. The $^{VR}/_{search}$ Program

Having discussed Benedikt's ideas and principles, we will now describe a VR application called $^{VR}/_{search}$ that demonstrates some aspects and problems of designing a simple Benediktine environment. The program has been developed within the scope of a graduate's thesis (Vande Moere 1998), and is meant to three-dimensionally visualise information resulting from an Internet search engine. This representation employs the intuitive cognitive capabilities of the user who seeks the most suitable link for his individual requirements. We assume that the user wants immediate access to parts of the data (e.g. title, size, date, number of ordering, and relevance of the provided links) and will use this information during decision making. In this application, a surface is laid out on which links are represented by box-like objects, onto which the necessary data are mapped. After a short overview of the main *programming tools* used, paragraph two will explain the process of *mapping*.

4.1 Programming Tools

$^{VR}/_{search}$ has been implemented within a UNIX environment and runs on a Silicon Graphics O2 machine. The program uses the principles of *CGI* (Common Gateway Interface) to run an application on a server after the user (client) has entered a query through a HTML-form on a web page. A *Perl* (Practical Extension and Report Language) program on the server reads the input values and submits them to a search engine, in this case *Infoseek*. It retrieves the returned results and starts scanning the text of the provided HTML-page. During this scan, useable information is stored in variables that are passed to related values in a *VRML 2.0* (Virtual Reality Modelling Language) file. Only after all this is accomplished and the whole structure is assembled, the VRML-file containing the requested values in the form of heights, co-ordinates, texts, etc. is sent back to the user. On this client side of the connection, a browser, in this case *Netscape Comunicator 4.04* equipped with *Cosmoplayer 1.0*, recognises and interprets the type of file as a VRML-content, and finally displays the three-dimensional world.

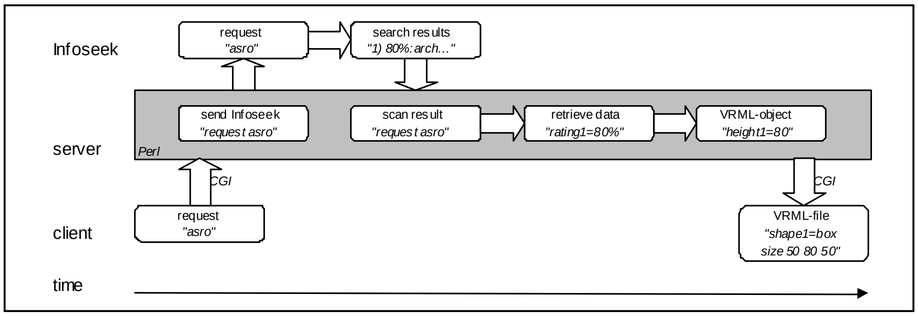
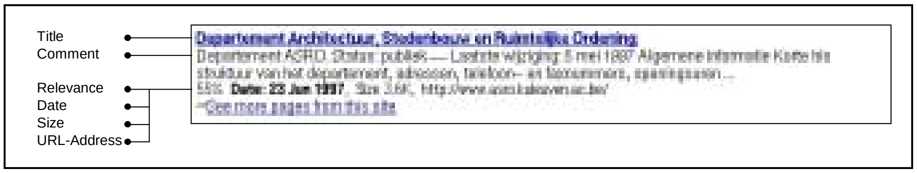


Figure 2. Sequence of techniques $^{VR}/_{search}$ *applies after a user enters the term 'asro'.*



Departement Architectuur, Stedenbouw en Ruimtelijke Ordening
Departement ASRO. Status: publiek — Laatste wijziging: 5 mei 1997 Algemene informatie Korte his
structuur van het departement, adressen, telefoon- en faxnummers, openingsuren...
55% **Date: 23 Jun 1997**, Size 3.6K, http://www.asro.kuleuven.ac.be/
–See more pages from this site

Figure 3. Dimensions in $^{VR}/_{search}$ *that can be retrieved out of a typical search result*

4.2 Benediktine Mapping in $^{VR}/_{search}$

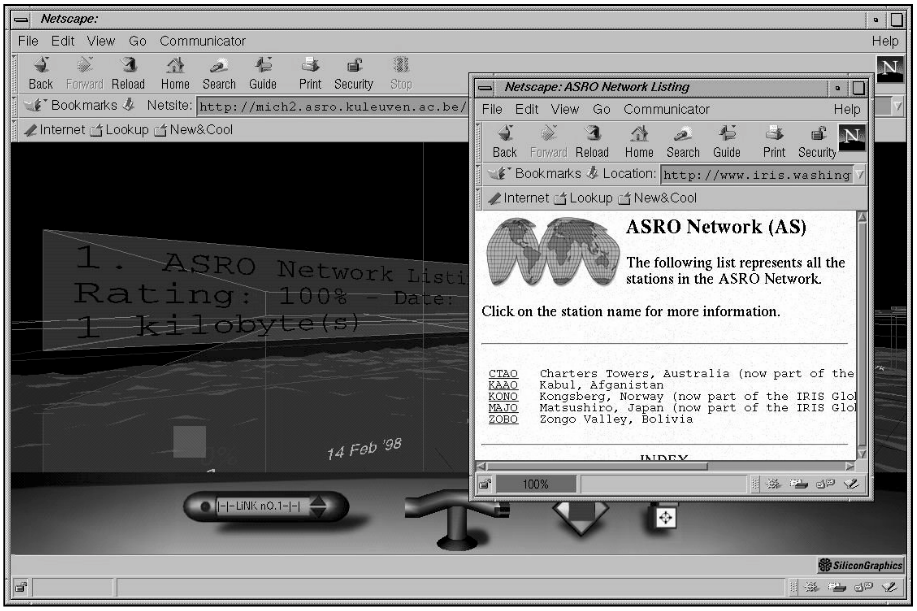
In order to explain the mapping in $^{VR}/_{search}$, we will now compare its concepts to the rubrics and principles underlying Benediktine Cyberspace.

Dimensionality

In $^{VR}/_{search}$, the *size* and the *date* of a web page provided by the search engine act as extrinsic dimensions, and thus determine the X- respectively Z-co-ordinate of any presented three-dimensional object. The main intrinsic dimension is the *relevance* or *rating* of a provided link, which defines the height (Y-dimension) of any link object. Other (intrinsic) text-based variables are the *title* of the link, its *abstract* or *comment*, the *number* by which the links are ordered, and the *URL-address* of the link. In addition, the *date* and *size* of the web page are used again, but now interpreted as readable text-strings instead of real values. These variables can also be understood as potential intrinsic dimensions, as they determine the overall view and character of the object as well. For instance, the lengths of the vertically placed titles allow for additional visual interpretation (similarity, effectiveness, etc.) if the user considers this issue important, and are particularly well fit to find similar links on different servers. Such links have the same size and title, yet slightly shifted dates.

The ***Principle of Exclusion*** is not implemented for the same reason Novak already mentioned. There is no way to equip VRML-objects with a programmable sensor that triggers the proximity of other objects so as to perform certain actions. Specialised newsgroups, however, foresee this feature in one of the next versions of VRML. Since the program contradicts the first principle, it directly conflicts with the ***Principle of Maximal Exclusion*** as well. The question arises whether the visualisation would carry more significant and interpretable information if we had chosen one of the following approaches, which do obey the PME. First, the *number* by which the search engine orders the links could be used as extrinsic dimension, but is in fact already partly incorporated in the order of the relevance percentages. Second, the values of the extrinsic dimensions could be sorted and, instead of linearly interpolated, placed onto the fixed squares of a grid. Overlapping would be impossible as each row and column would possess one single object. However, relationships like closeness, proximity, etc. would be lost, and replaced by arbitrary and interchanging connections that are difficult to perceive.

In the current version of $^{VR}/_{search}$ clicking the top part of a link-object can be interpreted as a form of 'unfolding', as it causes a new browser-window to appear. This window contains the requested webpage or even a virtual world, represented and 'possessed' by the clicked link-object.



ASRO Network (AS)

The following list represents all the stations in the ASRO Network.

Click on the station name for more information.

```
CTAO   Charters Towers, Australia (now part of the
KAAO   Kabul, Afganistan
KONO   Kongsberg, Norway (now part of the IRIS Glol
MAJO   Matsushiro, Japan (now part of the IRIS Glol
ZOBO   Zongo Valley, Bolivia
```

Figure 4. The top part of the link-object is ‘clicked’ by the user: the requested website appears in a new browser window, ready for approval by the user. The link-object then gradually changes its colour, making visible the occurrence of this user-action.

Continuity

As already mentioned, the values of *file size* and *file date* determine the two-dimensional co-ordinates of each link-object. First, the maximum (co-ordinate 100) and minimum (co-ordinate 0) size and date values of the collection are sought, after which the remaining are interpolated between these two extremes. In this way, sizes and dates are ordered by chronology and magnitude respectively. This results in logical spatial relationships between the locations of the objects, instead of the arbitrary ones if values would be mapped onto a fixed regular grid (co-ordinates 0-10-20-30-…).

Limits

VRML is fundamentally specified to represent an infinite space. This means that any traveller is able to move everywhere and thus endlessly without any standard pre-programmed restriction of the application. On the other hand, programmable nodes can be introduced to represent a (never reachable) background above an abstract ground-surface, which in fact also constitutes the horizon. The data-space built by the $^{VR}/_{search}$-program, however, is understood as representing a very small part of the unimaginable collection of possible Internet-links. Hence, users are free to wander infinitely far and away from the visualisation. Furthermore, the underlying surface is conceived as slightly larger than the floating data-grids onto which the link-objects are placed. Although this feature is not implemented yet, the program is designed in such a way that additional search-requests can be represented as well, next to or within the initial visualisation. As a result, a whole landscape of data-grids could arise, with each surface representing a subject or a user's personal interest.

Density

As to the ***Principle of Indifference***, $^{VR}/_{search}$-users are able to request any desired combination of search items, and thus to determine individually the resulting world. Yet, submitting one input does not necessarily produce one single defined world, as the links obtained by the search engine change over time. In the world itself, minor or continuous actions occur without any triggering of the user, offering an effect of independence. On the other hand, the user is capable to partially control the world by means of the dynamic user-interface. Moreover, he can move a horizontal plane in the environment that visualises the world's vertical dimension. Hereby, the relationship between the height and the relevance is clarified by visibly slicing the link-object.

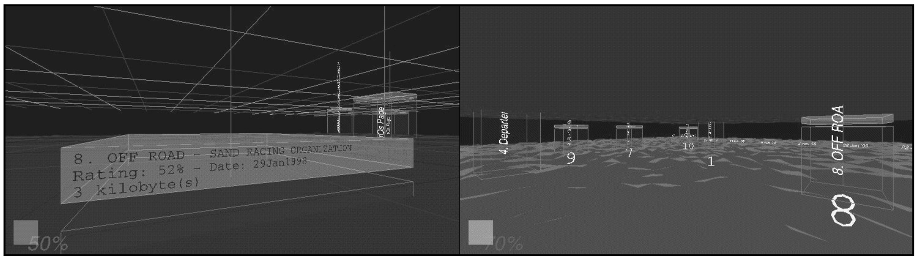


Figure 5. Left: a dark surface cuts the link-object. This view offers the user an idea of the relevance of this object (which is obviously higher than the corresponding value in the lower left corner of the screen, 50%). On the right, the user moves underneath the surface, and discovers that link *8* ***and*** *9* ***have a lower relevance than the actual value on which the surface is set (70%), while link*** *1* ***is more relevant.***

Concerning the ***Principle of Scale***, we took some precautions to avoid the appearance of too many moving objects, complex textures, proximity-sensors, touch-buttons, and other elements at the same time, which would require an enormous amount of computing time. For instance, the user-interface, which contains several sensors, is only existent (and thus computable) in the programmed scene structure when the user has touched a certain button. Furthermore, the link-objects only reveal detailed information when the user approaches them close enough to perceive it. Meanwhile other informational elements that become too large to be understood correctly disappear from the user's view. This technique is implemented for two reasons: it decreases the number of objects to be calculated by the computer, and avoids any oversupply or overlapping of data perceived by the user. On the other hand, we preferred to use standard VRML-nodes (e.g. Box, Sphere, ElevationGrid, IndexedLine, etc.) to complex geometries that can only be generated via uneconomic, large data-files derived from generally non-intelligent data-translators.

The Remaining Principles

In $^{\mathrm{VR}}/_{\mathrm{search}}$, *navigation data* are implemented as follows: a clickable legend on the ground surface clarifies the X- and Z-axis, so that the co-ordinates (and thus the size and date) of any object-link can be roughly estimated. Furthermore, text informs the user about the vertical position of the adaptable horizontal plane, which allows reading the height, i.e. the relevance of the object-link from these relationships. The ground surface was introduced because users seemed to have problems with orientation and cognitive estimation of distances in a completely black and empty space. When the user approaches an object-link closely enough, or when he moves his pointer over the object, detailed information appears on its surface respectively on the VRML-interface. These *destination data* are then available to be judged by the user's requirements.

As the $^{\mathrm{VR}}/_{\mathrm{search}}$-program is completely built up by VRML-objects, it is also bound to its restrictions, for example, instabilities of the programming language, and the impossibility to share a VRML-world by multiple users in the available standard. However, this field of research is developing at a rapid race and some commercial applications already exist to overcome these problems. Implementing the ***Principle of Personal Visibility*** thus will probably be a technical issue for the next VRML-specification.

Afterthought

Benedikt obviously imagines a peaceful and commonly shared cyberspace in which all users possess the same protocols. He seems to believe in all the positive chances that future cyberspaces will offer both its users and designers. Remarkably, however, he continuously avoids mentioning most drawbacks that would result if his principles would be integrally implemented. By consequence, probably not all Benedikt's recommendations will be realised in the cyberspaces of the future, as most of them need a common controlling protocol that everyone agrees upon. For instance, it may be valuable to investigate the positive and negative consequences when other cyberspace travellers would use different principles in this vast and shared realm. Nevertheless, his insights remain extremely interesting, mainly because he is one of the firsts who dared to write down the initial cyberspace designing rules in a very straight manner.

5. Summary and Conclusion

The field of information visualisation embraces many different approaches and original ideas to represent information in a three-dimensional way. One of them, the Benediktine approach, has been discussed in detail, and explored in a concrete application called $^{VR}/_{search}$. If architecture would be further applied in this field, the new materials of the cyberspace architect obviously would consist of code, bandwidth, and other electronic tools. In this respect, $^{VR}/_{search}$ was an important argument to prove both Benedikt's cyberspatial principles as well as the still rather visionary character of his statements. For instance, as the computational speed gradually and considerably increased during the development of the program, we almost reached the first, and perhaps most important, design constraint: that of usability of the application when applying today's technical developments.

The Future

"Architects of the twenty-first century will shape, arrange, and connect spaces (both real and virtual) to satisfy human needs. They will still care about the qualities of visual and ambient environment. They will still seek commodity, firmness, and delight. But commodity will be as much a matter of software functions and interface design as it is of floor plans and construction materials. Firmness will entail not only the physical integrity of structural systems, but also the logical integrity of computer systems. And delight? Delight will have unimagined new dimensions" (Mitchell 1995:105).

Acknowledgements

The authors would like to thank all who have contributed to the thesis on which this paper is based. Special thanks go to Prof. Gerhard Schmitt from the ETH Zürich for his hospitality, stimulation, and support. *Very* special thanks go to Prof. Maia Engeli, also from the ETHZ, who turned this work into an invaluable instructive experience.

References

Benedikt, M. 1991, Cyberspace: Some Proposals in *Cyberspace: First Steps,* edited by Benedikt M., MIT Press, London, pp. 119-224

Gibson, W. 1984, *Neuromancer*, HarperCollins Publishers, London

Gloor, P. 1996, *Elements of Hypermedia Design: Techniques for Navigation and Visualisation in Cyberspace*, Birckhäuser, Berlin

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

Negopronte, N. 1995, *Being Digital*, Hodder & Stoughton, London

Neuckermans, H., De Ridder, T. and Geebelen, B. 1998, Speech-Driven Computer-Aided Design in *CAADRIA '98, Proceedings of the Third Conference on Computer-Aided Architectural Design Research in Asia*, edited by Sasada T. and Yamaguchi S., pp. 309-315

Novak, M. 1991, Liquid Architectures in Cyberspace in *Cyberspace: First Steps,* edited by Benedikt M., MIT Press, London, pp. 225-254

Sardar, Z. 1996, alt.civilisations.faq: Cyberspace as the Darker side of the West in *Cyberfutures: Culture and Politics on the Information Superhighway*, edited by Sardar, Z. & Ravetz, J.R., Pluto Press, London, pp. 1-13

Vande Moere, A. 1998, *The language of Cyberspace: an Architectural Approach*, graduate's thesis, K.U.Leuven, Dept. of Architecture, Urban Design and Planning, Leuven

Whittle, D.B. 1996, *Cyberspace: The Human Dimension*, W.H. Freeman Co., New York

Woolley, B. 1992, *Virtual Worlds: a Journey in Hype and Hyperreality*, Blackwell Publishers, Oxford

Young, P. 1996, *Three Dimensional Information Visualisation* (also published in Computer Science Technical Report, No. 12/96), http://www.dur.ac.uk/~dcs3py/pages/work/documents/lit—survey/IV-Survey/

1) ir.arch. **Andrew Vande Moere**
Dept. CAAD & Architecture
Swiss Federal University of Technology Zurich
ETH-Zurich, Switzerland
E-mail: moere@arch.ethz.ch

2) Prof. Dr. ir.arch. **Herman Neuckermans**,
Dept. of Architecture, Urban Design and Planning
Faculty of Engineering
Catholic University of Leuven, Belgium
E-mail: herman.neuckermans@asro.kuleuven.ac.be

3) ir.arch. **Ann Heylighen**
Research assistant of the Fund for Scientific Research Flanders
Dept. of Architecture, Urban Design and Planning
Faculty of Engineering
Catholic University of Leuven, Belgium
E-mail: ann.heylighen@asro.kuleuven.ac.be