Abstract
This paper focuses on the use of elaborated computer visualization techniques to support multi-user browsing within a digital collection of library books and subject categories. First, a short description about the research project is given, and the two different interfaces of the developed application, called ‘Explore Interface’ and ‘Browse Interface’ are described. Then, some of the theoretical issues and practical use of the interfaces are presented. Finally, the experiences gathered from this research project and their impact on possible future working directions are summarized.

1. Introduction
The phenomenon of cyberspace still inspires research projects in science, art, business, and architecture. For Michael Benedikt (1991) the so-called ‘cyberspace program’ should start experimentally, by creating ‘crude’ and ‘fragile’ cyberspaces with a limited number of users, from which the most essential lessons can be learned. He foresees this process taking decades of time, meanwhile stimulating spin-offs in various areas of computing and engaging research people with different kinds of experiences and education. All with one goal: to make the visionary cyberspace a fact of reality, “Because the design, institution, and management of cyberspace will be a task of immense scale and complexity, it can be simply be argued that it is never to soon to begin” [1].

In the spirit of Benedikt's thoughts, this paper focuses on the use of elaborated computer visualization techniques to support the process of multi-user browsing within a digital collection of library books and subject categories. The concept of researching a certain area of interest, by browsing through a collection of knowledge-based, spatial paths within a three-dimensional shared information space, was the starting point of this research project. Furthermore, the intrinsic qualities of two different digital user-interfaces were explored. Specifically, the proposed application should enrich the use of a primarily hierarchical cataloging system and simultaneously give the users additional opportunities to discover and share knowledge with others in an intuitive way. With the awareness that efficient data exchange and interdisciplinary information retrieval play an increasingly important role, the “Virtual Library - Paths to Knowledge” project proposes an experimental way to trace, visually represent, and share our global knowledge in a unique way. The presented application was created as a part of the exhibition for the 'Library of the Future' event, held at the ETH Library between December 1999 and March 2000.

2. Project Description

2.1. Considerations
The means of sharing information and knowledge between the users of the digital library as well as the particular way users interact with a strict classification system became important starting points for developing the interfaces for a data-intensive virtual library system.

We started our research by observing how daily users interact with physical collections of documents and by focusing on the implications of physical document location on the process of perceptive information browsing. We concluded that sophisticated, decimal classification systems are too abstract to help guide common library visitors in browsing through the huge collection of subjects. When access to the physical collection is permitted, the easiest way to locate a group of interesting documents is by indicating the physical area where this particular range of collection is located. While interacting with the collection of documents, a patron (physical library user) may examine the covers, browse through the titles (this task is determined by the size and shape of the lettering), or become interested in a document with a familiar publisher's logo, even if it does not belong
to the area of the initial interest. Notably, this procedure enables patrons to become easily inspired by other documents in the immediate proximity of the initially searched book. Important factors in this decision making process are the typical ordering by subjects, which is reflected in the physical locations of the books, and their unique physical appearance. For example, heavily used and worn out documents (such as hard copy documents) can be particularly intriguing, as their fairly distinguishable physical look can indicate a certain seminal value of the document. Books that include many user annotations can be of an interest too, demonstrating the potential of common interests among the users of the library.

2.2. Aim

As previous work in the area of information visualization has shown [5, 9, 11, 13], the structural use of dynamic imagery and animated events enriches the human ability for interconnecting experiences, organizing information, and sharing the current state of the information with other users.

The visualization system called Vineta [6], developed by the University of Nottingham, demonstrates the capability to represent a large number of dimensions, retrieved from a certain collection of documents, by applying sophisticated visualization metaphors.

In the specific area of user interfaces design for digital libraries, the importance of the concept of ‘direct manipulation’ was shown in the concrete example of the Visible Human Project [7].

A further interesting project that deals with the visualization of a collection of interconnected books is called VR-VIBE [2]. This fully three-dimensional environment enables users, represented as animated avatars, to navigate freely through the presented data structure while selecting documents, performing queries, applying certain filters or requesting additional information.

The aim of our Virtual Library project however, was to concentrate on the area of creating a digital counterpart for the physical and spatial qualities of the library, and to enrich a collective exploration of the documents in an online digital collection. Furthermore, we used the concept of three-dimensional information mapping in an attempt to communicate informational values towards the user in a cognitive way. Finally, it should be remarked that these interfaces were especially designed and carefully developed to give users an opportunity to make unusual and inspiring choices by allowing them to operate almost exclusively on the visual level.

2.3. Application

The Virtual Library application envisions an alternative way to visualize and explore a digital library catalog. This project, experimental in nature, demonstrates the rendering of the mathematically ordered data into meaningful spatial visualizations by ‘mapping’ that data onto a three-dimensional virtual space. The abstract interpretation concept being used is based on a numerical classification standard of the refined hierarchies among subjects. This representation mechanism makes it possible to transform parts of the large library database into a system of comprehensible values, so that interesting and unconventional exploration metaphors can be applied.

Practically, the concept of 'knowledge paths' was applied upon a small, re-engineered catalogued collection of newly-arrived books (about 3000 entries), which we retrieved from the ETH Library. By applying different filtering algorithms, we were able to build a meaningful database of interrelated books by using only the book titles and their corresponding decimal system numbers. It should be noted that the use of keywords was completely neglected, and were therefore not available for the user as means of querying the gathered data. During the library exhibition event, two distinctive interfaces were designed and displayed on two separate computers, positioned in opposite corners of the provided area.

Figure 1. LINE, Library for the Information Era, visualizations of the knowledge paths generated by the users of the library. (outside and inside view)
Notably, the decision for creating two separate interfaces was not merely a result of the physical exhibition layout but represented an additional conceptual part of the project itself.

3. Application

3.1. Paths of Knowledge

The process of revising and classifying our gathered knowledge plays an important role for many reasons. Essentially, it gives us an opportunity to have a global look at our heritage and discover new interesting areas for future inventions.

In the Information Era of today, in which the global amount of data grows exponentially and the processing hardware becomes continuously more available, this process occurs even faster and with much broader scope. New disciplines have already been created, researched, and documented, based on some completely new ideas and needs generated from this collection of meanings. In this sense, tracing and visualizing user activities and data processing within data-intensive catalogue systems could be a significant source of meaningful information [9]. For this goal, the concept of ‘Paths of Knowledge’, based upon a research project called LINE (Library for the Information Era) [4] is proposed as a new kind of a three-dimensional data-carrying visualization metaphor that would allow tracing, sharing and enriching the user activities within a certain data collection. Ultimately, these developed geometries grow on the edges of currently defined disciplines, focusing on new interdisciplinary research areas that have already become crucial for scientific progress.

Conceptually, Paths of Knowledge are collectors that accumulate products and methods of investigation. It would be interesting to see these methods (or patterns of their usage) being traced in the future to formulate unique ways of organizing information in general. Such defined paths can also be seen as continuous spatial traces that record the latest moves in interdisciplinary science and art fields, while allowing for the discovery of possible connections among them. It should be noted though, that since they record vast amounts of individual investigation results, their effectiveness intrinsically depends on the skills of their creators. In this project, we consider these Paths of Knowledge to be spatial metaphors that visualize the activities occurring inside the applied library classification system or ‘boundary object’ [3]. Conceptually, these ‘paths’ represent the accumulated experience of library users, enabling users to ‘visit’ the data-worlds of others. By using such conceptual traces, users collectively build an open-knowledge base for further development, sharing the information about certain subject areas and forming methods or patterns of research.

3. Explore Interface

3.1. Personalizing the Classification System

One of the most efficient ways to browse within an electronic library catalogue is to select a predefined, hierarchical thematic category like ‘Arts’, ‘Arts-Architecture’, ‘Art -> Architecture -> History’ or a set of keywords describing the desired subject (architecture, history, …). The library classification system, as any instance of classification, is created to accommodate many communities of practice and satisfy the informational requirements of each of them [3]. We decided to challenge the power of the classification system and let the users of our experimental application fracture the existing scheme, letting them create their personal classification categories while looking for documents with interdisciplinary character. As a result of the interdisciplinary character of scientific literature available in the ETH university library, a considerable number of books in the database possessed a multiple category assignment. This means, for instance, that a certain book about famous churches in Rome can be a simultaneous member of several classification hierarchies, such as ‘Architecture-History’, ‘Construction Engineering-Conservations of Historic Buildings’, ‘Tourism-Travel Guides’ or ‘National Italian Misfortunes-Catastrophes’. It should be noted that this specific phenomenon triggered the chosen design of the Explore Interface, as it enables the users to specify their personal interrelated subject collections.

3.2. Visualization of textual information

The applied classification system is presented as a hierarchical list of disciplines or categories presented in a keyword-like language. Some of the categories are very descriptive and represent almost a long sentence. Navigation and user manipulation with such interface elements requires a significant amount of time, as textual descriptions need longer attention time to decode and understand than, for instance, iconic representations. Since the text has to be decoded through reading, it needs to be represented clearly on the screen and displayed by contrasting it with the overall background, as well as have a proper size [12]. Presentation of the hierarchical lists involves an aesthetical and ecological approach, which

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1 “The Universal Decimal Classification (UDC) is an international scheme which endeavors to cover all areas of knowledge. Its origins lie in the Dewey Decimal Classification (DDC) which was adapted towards the end of the 19th century by Paul Otlet and Henri LaFontaine in an attempt to create a universal bibliography. […] The scheme consists of 60,000 classes (divisions and sub divisions) as well as a number of auxiliary tables to describe countries, etc.” Link was visited on Nov. 2000. http://www.ukoln.ac.uk/metadata/desire/classification/class_3.htm
means that visual elements have to be used scarcely but effectively, to give the user a sufficient level of interface functionality and comprehension. This point of view is supported by James Wise (et al.) who says that: “The bottle neck in the human processing and understanding of information in large amounts of text can be overcome if the text is spatialized in a manner that takes advantage of common powers of perception.”[16].

One of the issues in using text as an active element within the interface involves deployed rendering technology. Practically, the visual interface is built using the VRML2.0 (Virtual Reality Modeling Language) language. It can be noted that the VRML-world text displayed on a computer screen does not appear to be smooth or anti-aliased. Consequently, there is a certain distinguishable critical value of size and color properties of text elements that makes them easily readable.

Another interesting characteristic of this interface is the considerable amount of screen space that users are provided with for manipulating the elements. It was chosen not to construct a display that appears to be crowded with textual information, as this would have implicated a lack of organizational data structure and therefore would have adversely affected the user-friendliness of the interface. Instead, the different classification hierarchies were structured as lists and presented as animated pull-down menus. These specially designed animation events reveal the sub-categories, and at the same time emphasize the idea of two conceptual axes of the interface.

3.3 Animation events

Animation is a powerful, functional component for data intensive user interfaces. By shifting the user's task from cognitive to perceptual activity, it frees up his cognitive processing capacity for application tasks [8]. Assigning different animation events to the same object of the interface helps to communicate to the user the state of the activity he is involved in [5].

Animation also helps us to convey the illusion of a temporal-spatial notation for the history of the user's interaction with the interface. It is especially helpful in the case of interfaces, which work with qualities of both two-dimensional and three-dimensional worlds. Both interfaces presented in this paper have carefully designed animation event sets that support the user-friendly interaction with the information appearing on the screen. The ‘animation set’ of the Explore Interface consists of three independent ‘animation events’. These events work on directions drawn by Cartesians axes. Within the plane of the screen, a vertical axis represents a direction of the animation event, which reveals the sub-categories and is a part of the pull-down menu function. The ‘depth’ axis, located perpendicular to the plane of the screen, has been chosen to direct the event that communicates the history of the user choices while browsing.

Two animation events have been assigned to the selection frame. This is an outcome of a functional characteristic of the selection frame, which serves as an element informing the user about both his future and already performed actions. The decision to proceed with the selection of collected disciplines, or going ‘forward’ triggers the appearance of a new selection frame.

The animation associated with this action is designed to minimize the effect of a sudden disappearance of one element and appearance of a new one on the interface. The old frame disappears by giving the user an illusion of ‘stepping through’ it. In the meantime, the new frame evolves from a point to a horizontal line to a rectangular selection frame. The vertical axis serves as the rotation axis for the selection frame.

The frame rotates when the user decides to take one step back, to revise or refine his previous actions. The selection frame rotates 180 degrees, demonstrating the spatial quality of the current procedure. This activity conceptually ‘makes’ the space for the elements from the previous selections as they reappear. As a result, they co-exist with the elements from the current selection and are still slightly visible in the background of the screen.
Figure 3. View of the Explore Interface with a dynamic horizontal rotation of the selection frame after the user chooses to go back in the history of decisions.

3.4 Interface Description

The Explore Interface offers the possibility to browse through the different top- and sub-categories of the library collection in a simple, text-based view. The spatial position of categories within interface is generated randomly. Animated pull-down menus enable the user to explore or select directly related subcategories of a certain subject field, simultaneously avoiding unnecessary text clustering. Inside this open interface screen, users are able to select multiple categories of their choice by simply clicking, dragging and dropping the appropriate connotations inside a central selection frame. A rapid and easily distinguishable color change of the chosen text tags gives the user immediate feedback of his actions. After this selection process is over, and thus two or more categories are chosen, the interface makes it possible to view the ‘deeper’ categories by clicking on the ‘+’ or ‘-’ symbol on the menu bar. After such a user decision, the program starts to navigate through the previous user-selection and displays a more detailed data view of the chosen query. Subsequently, all selected themes become more specific and a small set of relevant books enters the newly presented view. Now the user is able to perform the same actions again but this time with an option to select the just appeared books. This procedure can be repeated in both conceptual directions to narrow or widen the categorization level or change the number of chosen items. It should be noted that if the plus sign is pressed, the interface ‘flies’ almost literally forwards, turning the depth (the axis perpendicular to the screen) into a metaphorical, virtual time axis. Conceptually, this action will shift the interface one level lower in the hierarchical library database structure, to search for the related decimal sub-categories.

At the same time, relevant books of the categories that were chosen are also searched by the system and enter the interface for further user evaluation. Subsequently, clicking the minus sign will retract the interface backwards on the time-axis, enabling the user to see a full-view of the previous menu choices while simultaneously showing the last interface in the blurred background. The intuitive and direct notion of this time axis proved to be useful to orient the user in the personalized decision process.

Figure 4. Functional features within the Explore Interface.
Interestingly enough, the whole interface including the interaction paradigms was built in a three-dimensional virtual world, which enabled an easy and direct translation of the envisioned visualization metaphors by the application programmers. Although intrinsically three-dimensional, it should be noted that to avoid eventual complications, all user navigation possibilities inside this three-dimensional world were solely controlled by the application and taken away from the user. Additionally, the fact that the VRML programming language was used enables the deployment of this interface on the Internet, on any browser provided with the appropriate plug-in². The data processing and filtering algorithms were programmed in the PHP language, after the data was retrieved from a mySQL database on an Apache server.

² In spite of our continuous efforts, it should be remarked that the actual application only runs with the SGI CosmoPlayer browser plug-in, due to the extensive use of VRML Proto objects inside the program. The online version has been tested on IRIX, Microsoft Windows and Macintosh operating systems, with Netscape and Internet Explorer browsers.

4. Browse Interface

4.1. Visual expressionism

Working with three-dimensional interfaces requires a lot of attentiveness from the user, although it can provoke a powerful and engaging experience. VRML based, animated worlds can be created which, when presented as a sequence of images on the screen, can be powerful enough to inspire and change our thinking patterns. It can also steer the user to follow thinking patterns proposed by the interface designers or the user community.

As information architects, we aimed at creating interfaces that represent as close as possible 'aesthetically successful' forms. As formulated by Weber [15], there are two principal criteria for determining perceptual appropriateness and aesthetic value. Firstly, an object (in our example, an interface) should possess an order that can express its perceptual organization (perceptual wholeness, completeness of its internal organization). Secondly, a component is characterized as the object's ability to stimulate perceptual interest by "possessing a minimum of structure yet not so much relative complexity" [15]. Following these criteria in both interfaces, we located an identical static bar (placed in a prominent place) to carry out the main functions of the interface and allow for the exploration, browsing and exiting the interface. Additionally, both interfaces have elements that support the visual quality of the space.
In the Explore Interface, this role is taken by the dynamic selection frame and in the Browse Interface by the texturemapped channel. These elements were designed to add an ambiguous and intriguing element to the browsing experience. We observed that the user navigation patterns throughout the library space were not only based on the textual information presented on the screen or the 'historical' position within the explored channel, but also on the visual characteristics of the composition presented through the interface. Users either followed paths that were located in a visually dense neighborhood of other paths, or on the contrary, picked up those visually separated from others. Visually, the channel in which the user is traveling through is texturemapped, with an image of high and medium-high contrast. Also, most of the users randomly selecting a path most likely chose those superimposed on high contrasted parts of the textured channel.

### 4.2. Information Mapping

In Benediktine Cyberspace [17], both space and geometry carry some meaning. This means that the virtual world is built in a way that some spatial metaphors, such as going up or down, left or right, and proximity or distance, have all some sort of informational and interpretable values [1]. In the realm of cyberspace, the concept of mapping is a strong and already widespread technique. Conceptually, a stream of bits, initially formless, is shaped by a certain representation scheme, and information emerges through the unique interaction of data with the representation. Generally, some predefined mapping algorithm must be followed, which translate abstract data into a recognizable representation and into a specific location of that object within the information terrain.

The application called VR/search, an online three-dimensional search engine [14], was an extensive experiment into the direction of three-dimensional information mapping.

This application proved, among other aspects, some of the intrinsic problems associated with the direct translation of data when a certain strict predefined representation is used. On the other hand, much could still be expected when a more poetic and hidden approach would be followed by the ‘information architect’ when interpreting incoming values into a certain visualization. In this line of thinking, the Explore Interface tries to prove that not every translation from data into form has to be immediately understandable for the user to be regarded as useful or valuable. As more attention went towards the aesthetics, speed and user-friendliness, this approach proved to be at least equally useful.

### 4.3. Interface Description

The second interface visualizes the individual search paths of different users as a collection of three-dimensional lines, trapped inside a semi-transparent navigation channel. When the user logs on, his or her personal decision track will be traced and highlighted. Simultaneously, through the pre-defined mapping scheme, the sequence of decisions made by numerous users is turned into meandering lines, since their directions relate to the unique combination of the selected subjects. In fact, every single line displays and demonstrates the decisions of the other users. When clicked, these lines are capable of transforming into a spatial ‘Channel of Knowledge’, changing into a full tunnel view and thus revealing the lines that cross this channel. The personal channel of the user is marked white and it is always possible to jump back to it by simply selecting it.
Additionally, the height and width of the channel correspond with the number of books and the conceptual size of the chosen categories. Clicking on the ‘+’ or ‘-’ signs enables a straightforward navigation through the Path of Knowledge, in the direction of the metaphorical time line. Consequently, clicking the plus sign brings the user ‘deeper’ into a more detailed view of both the decision making process and the hierarchical library classification system. By means of simple forward or backward navigation through such a channel, the titles of associated books chosen according to the hierarchy level appear as dynamic slogans in virtual space. As a positive characteristic, the personal interpretation of this visualization paradigm can be potentially very broad and personal. The straightness of lines can reveal the determination of a certain user, while groups of persons with partly equal interests probably generate close bundles of paths.

By researching the density and general direction of the lines, librarians are able to easily perceive shifts in readers’ interests according to time or university department. Interested visitors can intuitively learn from past decisions of other users. In short, all kinds of users can gain a deeper understanding of hidden, previously unknown relationships intrinsically created by themselves. Intuitive mapping concepts help individuals gain access to the visualized information of their past search attempts and broaden their view into related, relevant subjects.

5. Interface Evaluation

The evaluation of the interfaces presented here has resulted from the observation carried out during the exhibition, and from interviews with users in a computer-lab environment. Note that our test users were working on faster computers than those available during the exhibition itself, and that the exhibition users were only able to gather information about the application through a small icon-based explanation paper stuck onto the computer displays, which provided graphical representation of the necessary user actions.
Following observations were made during the exhibition itself:

1) As initially expected, around 80% of users were prepared for a 'Windows'-like environment and were quite surprised by the presented types of interfaces. However, through ‘playing’ around with the mouse and clicking on the elements (e.g. different book categories within the Explore Interface, and the ‘plus’ and ‘minus' buttons in Browse Interface) users won confidence in triggering animation events, ‘opening’ and ‘closing’ categories in the Explore Interface or moving back and forward in the channel of the Browse Interface.

2) The possibility for dragging elements within the Exploring Interface was encountered and used after the text elements (categories) had been clicked on and right before any ‘symbol-looking’ elements were executed. Once users became confident with the dragging actions, they immediately started organizing the book categories spatially on the ‘stage’. Additionally almost all users evaluating our interfaces in the computer lab agreed that this feature is helpful and they would even like to see it more often in other applications. This feature also clearly enabled the intuitive connections of the keywords that were displayed in close distance to one another.

3) Using the Browse Interface very often began by triggering the ‘going forward’ function (clicking on ‘plus’ button). Notably, the ‘going backward’ function was chosen only in emergency situations (like reaching the end of the tunnel) or by frequent users of our application. The evaluation conducted in our computer lab was performed on five subjects of multinational origin and different levels of computer literacy. Since the interface was designed for use within the exhibition environment where help mostly was not available, subjects were only shortly informed about the goal and functionality of the application. After interacting with the interfaces for about five to seven minutes, users could ask questions and also respond to the general questions asked by the interviewers. Within the Exploring Interface, confusion was often caused by initial misunderstanding of the meaning of the plus, minus and ‘x’ symbols. For instance, the minus symbol was understood as an element representing a delete function and as such it was used with certain caution. In addition, users seemed to like the presence of animation events triggered after the selection was completed. It gave
them the feeling of making the decisions along the spatially positioned path and actually helped them understand the continuity between the Explore and Browse interfaces.

While using the Browse Interface users almost immediately started to travel along the channel using both ‘plus’ and ‘minus’ buttons. They also recognized almost instantaneously the titles of the books they had been selecting in the previous interface. This part of the user experience was noted as quite engaging and inspiring. While users enjoyed the visual quality of the interface, they could not guess what the lines were representing. However, having recognized that the selection of a line results in ‘jumping’ into the channel, the concept of traveling along the paths of other users became clear. Still, switching back to users’ own channel presented a challenge, since they had to look within the interface for the white line symbolizing the actual ‘home’ channel. This was considered to be a drawback.

To conclude, most of the interviewed subjects pointed out that sound events accompanying the interface would have increased the quality of spatial interaction with both interfaces.

6. Experiences and future work

Many restrictions were introduced into the project as a result of the strict development time that was provided toward the deadline of the exhibition and the limited graphical computer hardware that was used for the application’s presentation. Furthermore, it could be discussed whether or not the interfaces are as intuitive as we originally predicted. Problems might have occurred when people were faced with rather unfamiliar, ‘not-WIMP-like’ interface and the required drag-and-drop actions. It was also perceived that most users had limited experience in working with real-time three-dimensional representations, which resulted in additional confusion. Further sophisticated features could be developed, such as an information retrieval service that would enable users to retrieve book titles and other data of interesting Paths of Knowledge through their personal email accounts, or an awareness system that recognizes and reacts upon entries of individual users. Additional analysis and filtering tools could also provide inexperienced users with information they would never detect themselves. Also, many new conceptual and practical consequences could be envisioned when this Virtual Library application would be programmed for fully immersive or even supercomputer hardware systems. Nevertheless, it should be noted as that these issues could be tackled during the course of our further research.

7. Acknowledgements

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8. References


Links:
1. ETH-Bibliothek, http://www.ethbib.ethz.ch/index_e.html