Parallel Worlds: Spatial and Textual Representations of Information Structure in VR

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ABSTRACT

Navigation is central to information seeking in electronic worlds. Previous research on the physical world and virtual ones has considered the impact of environmental structure on navigation and learning. Such structure can be either spatial or textual. I propose an exploratory study to evaluate the effects of combining spatial and textual representations of information structure in different ways in VR. By observing users in several virtual worlds with similar information structures, I hope to extract guidelines for the use of spatial and textual representations in VR design.

INTRODUCTION

Navigation in virtual worlds is a relatively new phenomenon. Although some behavioral studies have considered user navigation in this context, most existing literature discusses navigation in the physical world or hypermedia. Relevant physical-world research has been done in the fields of cognitive anthropology, cognitive psychology, and urban design. Given the abstract nature of information domains, a deep tension arises between semantic and physical structures when the latter are used to represent the former (McKnight *et al.*, 1991). Semantic structures are those of language and meaning, while physical structures are those of architecture and the real world. These structures clearly have different properties. Accordingly, it is essential for the designers of virtual worlds to understand the tradeoffs between these types of structure, particularly for the important task of user navigation.

The CHI '97 workshop on navigation suggested that navigation has two components: locomotion (an activity at the physical or articulatory level) and wayfinding (an activity at the mental or semantic level). With regard to wayfinding in the physical world, architect Passini noted that this activity comprises three iterative stages: mental mapping, plan development, and plan execution (Passini, 1984). For mental mapping in the physical world, urban planner Lynch argued that certain structural elements in urban design can be used to enhance the legibility (or ease of mental mapping) of a city (Lynch, 1960). These design elements include landmarks, paths, districts, boundaries, and focal points. The ideas of Passini and Lynch can potentially be adapted for the design of virtual worlds.

In assessing design tradeoffs between textual and spatial representations of information structure, the first important issue is how users and designers perceive these trade-offs. It is important for research to establish some reference points in the design space, where users and designers can agree on the relative importance of particular representations.

The second important issue is the user's experience of the virtual world - was it satisfying? - and his success in learning the structure of the information domain. A positive user experience will probably correlate with successful navigation. Subjective user feedback, moreover, provides the researcher with information about the qualitative properties of the exploratory studyal worlds. Furthermore, information gathering in electronic worlds spans a range between tightly focussed searching and widely ranging exploration. Browsing, in the common usage of the term, perhaps occupies a position in the middle of this range. Search-engine technology and availability have provided effective solutions for most users' searching needs. But techniques to support effective browsing lag behind. In browsing tasks, informally speaking, a user seeks to determine the nature and structure of information available for some purpose. Accordingly, a user's success in learning domain structure during navigation is an important criterion for evaluating the success of a virtual world design.

Recent research on virtual world design has considered some of the issues discussed above. Waterworth has proposed a model for a public information space, called Information Islands, based on hierarchical geographical and urban metaphors (Waterworth, 1996). Initial trials were favorable, and this concept could be further developed through software prototyping and user experiments. Related work by Dieberger has demonstrated the navigational and semantic value of urban metaphors for information spaces (Dieberger, 1995). His research

has considered primarily textual interfaces to such spaces, and further work is required to generalize these findings to graphical environments. Recent research by Darken and Silbert has investigated navigation in large-scale virtual worlds (Darken and Silbert, 1996). Their work demonstrated the applicability of some real-world design principles to virtual worlds, as well as the necessity for global structure to support navigation. This research utilized large-scale geographical metaphors; related research in more densely structured virtual environments would extend these results.

CURRENT RESEARCH

My current research seeks to explore design trade-offs between textual and spatial representations of information structure that supports user navigation in virtual worlds. Specifically, how do people perceive and learn spatial and textual representations in VR? What are the implications for navigation and browsing, as well as virtual world design in general? An exploratory study is currently being designed to investigate these issues. The remainder of this paper will discuss the proposed study in greater detail, considering in particular the design of three parallel virtual worlds.

The study will be designed for immersive virtual reality. A set of approximately three virtual worlds will be designed. The worlds are intended to reflect key points along a continuum of design trade-offs between textual and spatial representations. Developed designs range from a geometric virtual city to a textual hierarchy browser. Even more extreme designs may be considered, such as a virtual city with no text (which would probably be unusable) and a textual interface in the style of the old online adventure games. (”You are in a dark cave. A light can be seen in the distance to the north. . . .”) In any case, the intermediate design points will likely prove the most interesting and useful. Worlds will be designed to present similar contents, probably a subset of a large, standard, hierarchical information structure. This information will be chosen for general interest to study subjects, specificity of detail, and computational tractability. A few hundred to a few thousand nodes will be included, so as to strike a balance between offering a large world for user exploration and completing VR development in a reasonable time.

The planned study will be informal and exploratory, seeking in-depth responses from a few subjects. (A formal experiment is envisioned as a follow-up.) During study sessions, each subject will navigate in several worlds. Navigational activities will be logged electronically, and subjects will be encouraged to think aloud. For each world, the subject will engage first in unstructured exploration to become familiar with the general environment. Subjects will then perform a sort of “scavenger hunt“. Following exploration of each world, subjects will complete a questionnaire and undergo a short interview about their experiences. The questionnaire may include questions about the number of Lynchian design elements recalled (e.g., how many distinct districts?), as an index of structural learning. I would thereby reuse design concepts, as did Lynch, as analytical tools to measure environmental quality. In addition, subjects will be asked to sketch a map of the salient features of the world. After subjects have explored all worlds, questions will be asked to gauge overall reactions. It is hoped that this ”multi-modal” data collection methodology - inspired by Lynch, and Darken and Silbert - will elicit varied and full responses from the subjects. In addition to capturing many aspects of the navigational experience, I hope to allow full expression for users with strong spatial or verbal preferences.

Results of the study will be analyzed to determine the perceived weight of textual versus spatial representations; the degree of user satisfaction with each virtual world; the effectiveness of each design for teaching structure; and the value of different design techniques for users with different preferences.

Waterworth has recently suggested that different levels of abstraction in navigational environments impose differing burdens on conscious information processing. In particular, cognition of structure from spatial features may be handled subconsciously, while cognition of the structure conveyed by textual features is probably handled consciously. These differences should result in corresponding changes in conscious capacity available for other activities during navigation. If so, such differences should be reflected in a user’s completion of informational tasks during navigation, as well as in his/her recall of environmental structure afterwards. Assessing performance and recall levels would thus measure the cognitive difficulty of navigating in virtual environments of differing abstraction.

With the previous considerations in mind, I hope to extrapolate VR design guidelines from my study. In particular, I hope to offer suggestions for the effective use of textual and spatial representations. The results of the current study should also indicate an appropriate direction for a future experiment in this area.

RESEARCH VR DESIGNS

As mentioned, the objective of this study is to compare user exploration and learning under different design conditions of spatial and textual representation. This objective may be realized through three intensities of spatial and textual representation in combination. Three parallel virtual worlds will thus be designed, with the same underlying data and maximally isomorphic design features. The first world will be an urban or regional landscape, which will use strong spatial representation and weak textual representation. The second world will be a similar environment with weaker (less prominent) spatial elements and stronger (more prominent)

textual elements. The third world will feature weak spatial representations and strong textual representations. This world's space will be abstract, serving only to indicate relationships with no absolute position or distance. For the sake of identification, these worlds will be called spatial, hybrid, and textual.

World 1

The first world is designed according to the information islands model proposed by John Waterworth. Data will be displayed at approximately five levels of hierarchy using geographical and urban metaphors: city, district, building, floor, and room. Additional hierarchy levels could be added through such metaphorical elements as continents and (room) walls. Lynchian design elements will be used to articulate space for mental mapping, as well as global structure as recommended by Darken and Silbert. A number of visual strategies can be used to represent structure in this way. Irregular forms and grouped colors could help to differentiate spatial regions. Geographical and urban metaphors are envisioned as relatively abstract, since the purpose of this research is not to explore the features of the metaphor, but rather to use it as a general spatial container. (This point will be emphasized in connection with virtual buildings below.) Directional lighting will be provided to enhance the user's sense of environmental orientation.

In this spatial world, cities and districts are envisioned as irregularly-shaped clusters of objects. (Figures 1 and 2 show design sketches from visual brainstorming.) Each cluster should have a distinctive feature such as color, shape, or style. Buildings are envisioned as varying shapes with a convex polygonal footprint and vertical walls. To avoid the navigational indirection of real-world transportation mechanisms such as stairways and elevators, users will be able to fly directly to locations of interest (throughout the world). Each floor will feature an exterior hallway around rooms in a central core. In this way, users will be able to navigate directly between levels of information hierarchy.

In order to allow the user a reasonable view of two or three levels simultaneously, world structures will appear opaque from a distance, but semi-transparent from close up. Users will thus be able to see relevant navigational options without being burdened by scanning multiple levels of hierarchy. Some description of the user's current location should always be visible.

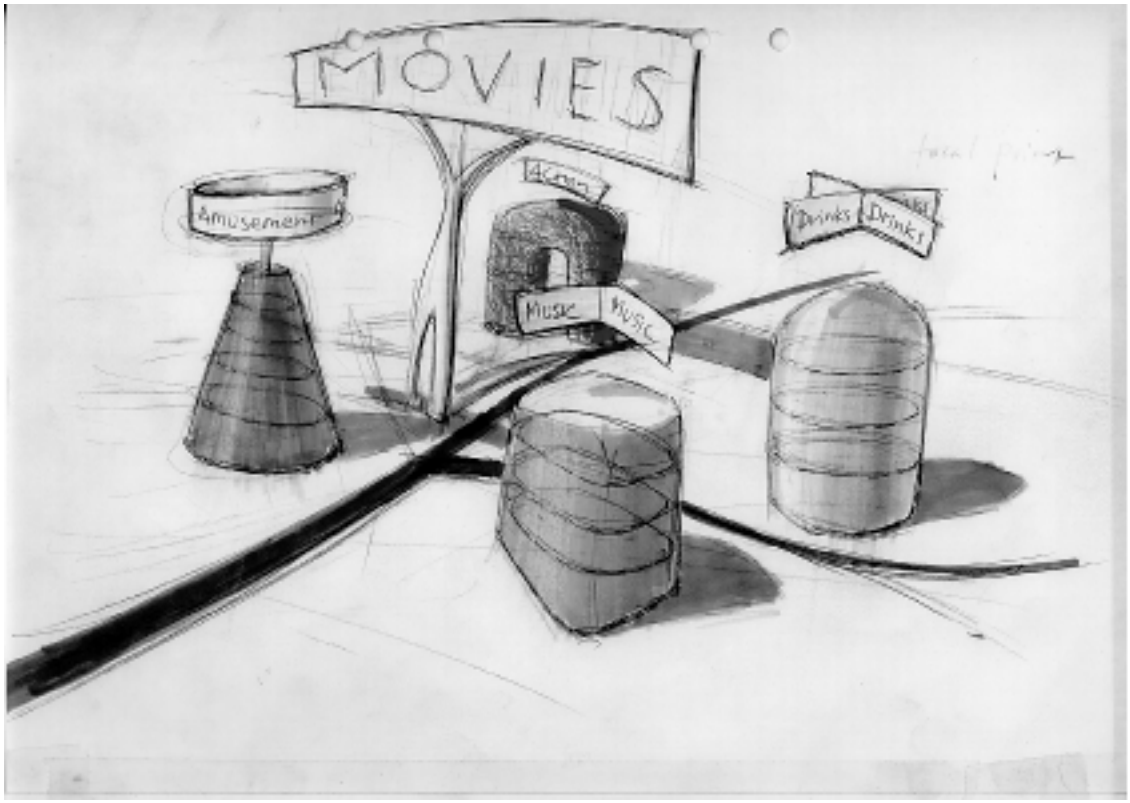

Figure 1. A district in a spatial world, with irregular buildings and navigational paths.

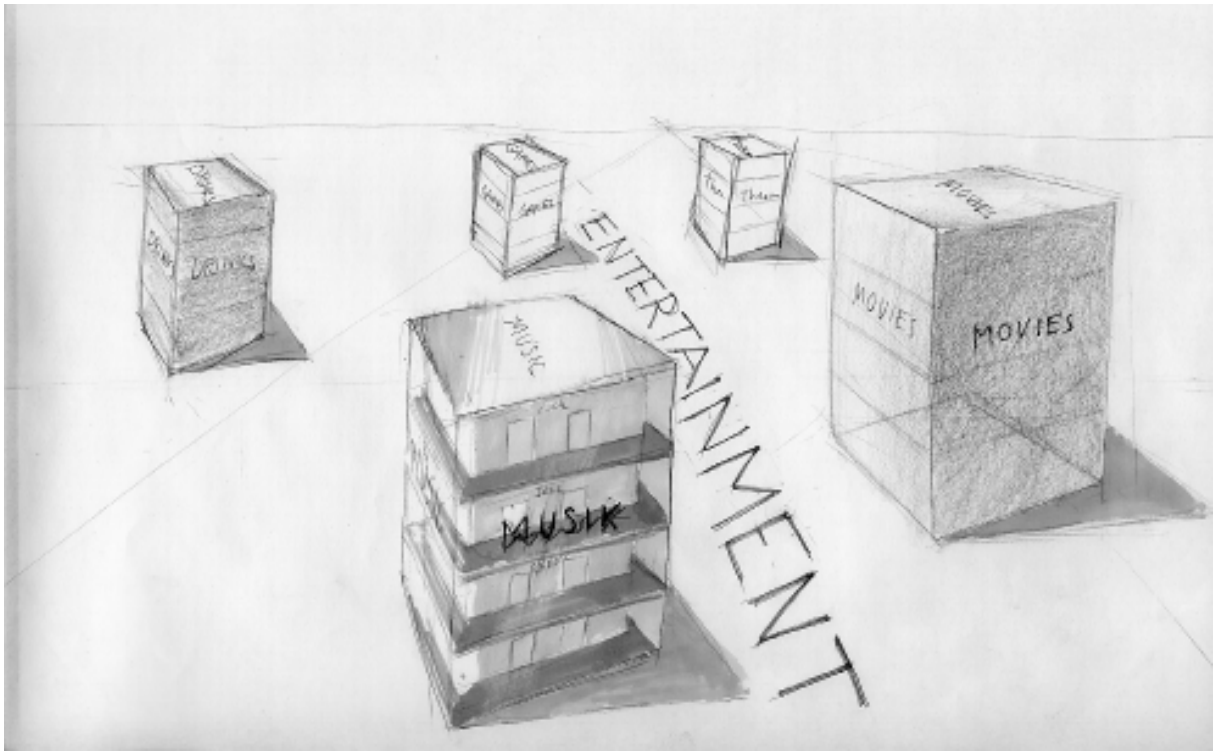

Figure 2. A district in a spatial world, with levels of hierarchy and semi-transparent objects (paths not shown).

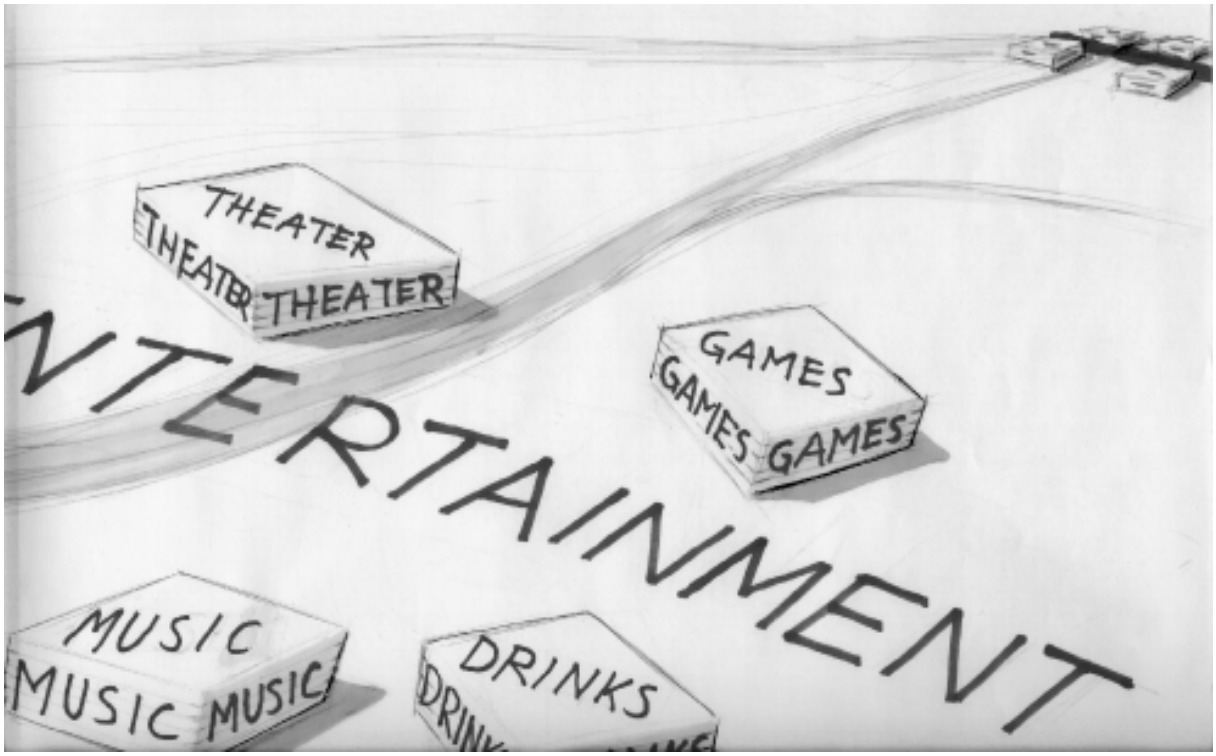

Figure 3. Two cities or districts in a hybrid world.

To convey semantics in this world, each object will be labeled with a small piece of text. The scale will be chosen to allow easy reading from close up, but no reading from a distance. In this way, objects will be shown on a scale resembling that in the physical world. While necessary to give meaning to this world, the labels will be deliberately small, so as to make them subordinate to the geometric representations. City and district labels will probably lie on the ground in cluster centers; building labels will be attached to exterior walls; and floor and room labels will be on interior walls.

World 2

Shifting the balance between spatial and textual representations, the hybrid world is envisioned as a transitional point between a virtual cityscape and a textual hierarchy browser. The world is intended to occupy a middle ground, in which the user's mode of perception may shift between textual and spatial, much as perception shifts in good optical illusions. The topography will match that of the spatial world, but spatial features have been reduced in visual intensity. Such objects will have weak gray colors, for example. The textual objects, by contrast, will be large and bold. They will occupy a large portion of object surfaces, and they will be shown in bold colors. (Figure 3 shows a design sketch from visual brainstorming.) This hybrid world will resemble SGI's File System Navigator (FSN) software: it will use simple geometric shapes and prominent textual labels to represent a hierarchical data structure. My study's textual world provides part of the design rationale for this hybrid world, and it will be discussed next.

World 3

The study's third world, a predominantly textual one, provides an environment in which the user will be able to browse an information hierarchy with minimal spatial features. Semantic cues are intended to predominate over spatial ones. Visually, the world resembles Earl Rennison's "Galaxy of News" (Rennison, 1994), though it behaves more like Apple's "Hot Sauce" prototype. Like Rennison's, the world will display pieces of text in a black 3D space. The user will move between hierarchy levels and nodes by navigating in this abstract space. As in Apple's world, the spatial relationships will be fixed, but without cues for absolute location or distance. In an effort to match the topography of the spatial and hybrid worlds as closely as possible (for good study design), text clusters will be displayed in spatial configurations matching those in other worlds. This deviation from convention is novel, but it is not expected to cause significant difficulty for users. (Figure 4 shows a design sketch from visual brainstorming.)

This world will use color and level-of-detail in ways analogous to the spatial and hybrid worlds as far as possible. Color should be used to group sibling nodes distinctively. Level-of-detail features will be used to limit the hierarchy's visibility to a couple of levels at a time. For example, the currently central topic could be shown in bold text, while the child topics could be displayed in progressively weaker colors. To minimize spatial cues, directional lighting will not be used in this world.

DISCUSSION AND CONCLUSIONS

While this study's worlds are basically designed as uniform and static, dynamic features could be added to assist user navigation. Such features include maps, dynamic paths, and navigational vehicles. Maps could be used to show the user's past, present, and future - that is, navigational history, current position and orientation, and suggested routes. Such routes could instead be shown as dynamic paths or colored "threads" in the environment, whose use could lighten the burden of route planning, allowing potentially more attention for mental mapping and route execution. Different cognitive balances of these activities could lead to differences in performance and recall levels. Navigational vehicles, proposed by John Waterworth (Waterworth, 1997), would offer a natural metaphor for providing additional software features, such as saved documents, interpersonal communication, and domain queries. Map and vehicle features are probably beyond the scope of the current study, but dynamic paths may be implemented.

Previous research has shown the importance of environmental structure for navigation and learning. Since most of this research has considered spatial and textual representations separately, it is particularly important to investigate their interactions. I have proposed an exploratory study in three parallel virtual worlds to study this area. Multiple methods will be used to gather data on users engaging in both general exploration and targeted browsing, which should generate useful information about users' experiences.

This research is expected to reveal strong individual preferences for textual or spatial representations. Such preferences have been demonstrated in the physical world, and they are likely to carry over to virtual ones as well.

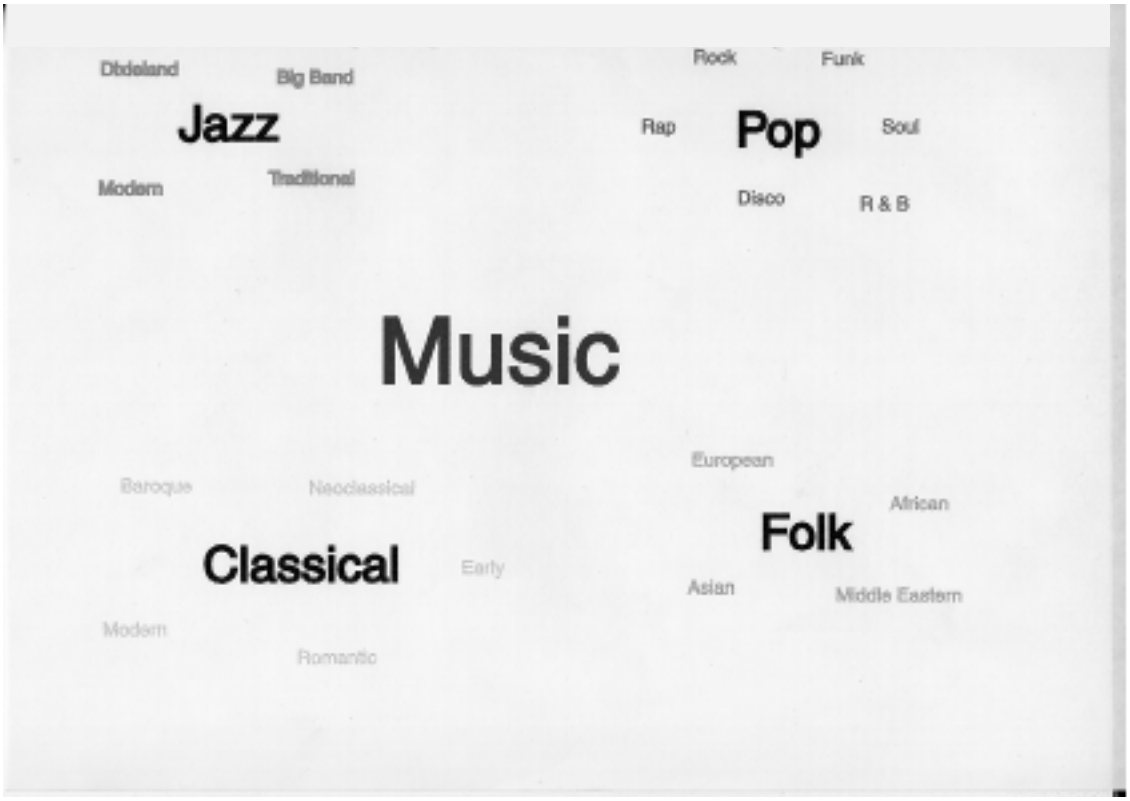

Figure 4. Clusters in a textual world.

Furthermore, I assume that textual and spatial representations manifest different types and levels of abstraction, which are useful in different ways. Physically realistic virtual worlds, with advanced hardware and software, should allow users to draw on extensive bodily experience in the physical world, reducing conscious processing and enhancing effectiveness for such activities as mental mapping and path following. Reciprocally, it is likely that good textual semantics allow users to reason intelligently about information worlds, thereby increasing their effectiveness and satisfaction with such activities as route planning and domain understanding.

The challenge for a VR designer, consequently, is to choose strategies for spatial and textual representations that are appropriate for particular users and tasks. This emphasis on user and task follows conventional HCI analysis and design techniques. My research is expected to yield useful guidelines in this direction.

Finally, I believe that the design of good cyberspace(s) is one of the major challenges of my era. This challenge has two parts. First, there is a need to design virtual worlds to support work and leisure activities in efficient and effective ways. Second, there is a corresponding need to support these activities in a pleasant and humane fashion. Now, navigation is central to the experience of any environment. Accordingly, by considering representations of information structure to support virtual navigation, I hope to contribute to the design of good virtual worlds. In such worlds, the trip will be a good one, and people will reach their destinations on time.

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