The appropriate use of space in interfaces varies greatly with system goals. Some systems use space to support the comprehension of structure; others use it to support navigation; and still others use space as a unique means to support expression through manipulation and modification. As a step towards the informed use of space in information systems, we will map some of the characteristics of spatial interfaces to the advantages they provide to the users.

We begin by describing the major roles of space in hypertext interfaces. Then we discuss some of the characteristics of spatial interfaces and map them to some of the affordances they provide to users. To ground this discussion of roles, characteristics, and affordances, we compare our use of space in Aquanet [Marshall et al. 91], VIKI [Marshall et al. 94], and the Hyper-Object Substrate (HOS) [Shipman and McCall 94]. Finally, as an example of how spatial interfaces can be used to support hypertext-derived activities, we describe the connection between VIKI and World Wide Web (WWW) [Berners-Lee 92] and the functionality provided by VIKI’s spatial model for WWW users.

Role of Space in Hypertext Interfaces

Space plays at least three general roles in hypertext systems: It is the means for presenting visualizations of structure; it supports navigation through complex hypertexts; and it provides users a medium for expression (or the system a means for acquiring knowledge, depending on your perspective).

Computed visualizations of intrinsic or pre-existing structure. One of the earliest uses of spatial interfaces in hypertext systems is found in facilities for visualizing complex interconnected structure. For example, NoteCards included a computed browser card which enabled users to browse (and later, edit) a network of cards and links as a drawn graph [Halasz et al. 87]. Other systems use automatically generated spatial displays to show content-based node relationships; for example, Hypergrids provides a graphic depiction of similarity metrics [Madigan et al. 94]. The goals of this type of spatial interface are comparable to those of tools like the Information Visualizer [Robertson et al. 93], and more generally, to work in scientific visualization. In hypertext, spatial visualizations generally support comprehension of structure in-the-large.

Navigation. Space can also provide improved feedback for navigation. For example, virtual worlds present navigable 3D representations of hyperspace where navigation takes place in a manner analogous to navigation in a physical space. Infinitely scalable spaces like Pad provide similar navigational capabilities, but use zooming as a major means of navigation [Perlin and Fox 93]. In general, the use of space aids navigation by helping users establish a local context, find information, remember where they have been via landmarks, and comprehend traversal between contexts.
Acquisition/Representation/Expression. A third use of space is in supporting user expression and system acquisition of knowledge. Space in this case forms the backdrop for manipulation and provides a means for expressing ambiguity and other information difficult to express textually. For example, VIKI allows the development of idiosyncratic relations and composites to be realized spatially prior to any textual or formal representation of the relationships or their meanings.

Because space can play a variety of interface roles and be realized in different metaphors, it is critically important to understand what people are doing through the interface. This in turn allows us, as system developers, to match properties and affordances of different kinds of spaces to the users’ activities. We can decide, for example, whether a card, page, plane, or space-based metaphor is more appropriate; whether we should implement scrolling or zooming; whether automatic layout is a visualization aid or an attractive nuisance, and so forth. In the next section we take a more detailed look at characteristics and affordances of spaces.

**Properties of Different Types of Spaces**

We can examine the spatial properties from three different perspectives. First, we can look at the characteristics of the space itself: what kind of space is the interface portraying? Second, we can look at the relationship between the hypertext, an abstract data model involving information objects and structures, and its manifestation in the space: how is the hypertext presented? Finally, we can look at the interaction characteristics of the space: how do users interact with the hypertext through the space?

Important characteristics of a space include (but are not limited to) dimensionality, whether it is cartesian or not, and whether it is continuous or not. Spaces range from two dimensional (objects and structures presented on a plane), through two-and-a-half dimensional (objects may overlap in ways meaningful to the user and represented in the system), to full three dimensional representations (where hypertext objects are have locations that are a function of x, y, and z). Most spaces used in hypertext interfaces are cartesian, but some include curvilinear types of spaces and views (e.g. fisheye views). We can also observe some contrast between discrete-valued coordinate spaces (spaces that use gridding) and spaces that where position values are constrained only in a pragmatic sense by the resolution of the presentation device. Some hypertext systems include discontinuous spaces. For example, in VIKI, spaces are embedded hierarchically in other spaces; objects must “jump” from one space to another as they cross borders into subspaces.

The relationship between the hypertext as an abstract structural model and the space reveals another set of properties. We can contrast intrinsic and extrinsic relationships -- is there a single function which describes the intrinsic mapping of any structure onto the space? If this is true, then automatic layout is possible; if it is true over time, then layout may be animated. We can also contrast implicit and explicit portrayals -- is structure, for example, represented graphically (as in the case of lines standing for links), or can it be left implicit? Finally, we can distinguish between spaces that use direct references to the objects they portray (that is, node contents are portrayed in the space as is the case with Pad) and spaces that use visual markers as indirect references to objects, allowing the same content to be referred to from multiple contexts.
Interaction characteristics are the final source of properties that we will explore; they describe how a user is expected to conceive of the space. Many of these characteristics depend on whether the developers have constrained the interface design to follow the features of physical space. How close of an analogy is made? How much of the interface is familiar? How much is abstract? In Virtual Reality-based and cartographic-like spaces (e.g. Pad), users are made to feel like they are “in the space.” Other less literal, more metaphorical, renderings place users as external observers of the space (as is the case in, for example, a desktop metaphor). This tension between literal and metaphorical spaces in turn suggests a variety of ways to describe movement within them like flying, scrolling, jumping, or zooming.

Often there is a tension between the properties of a spatial interface and the kinds of activities it may support. For example, a spatial interface that supports visualization and comprehension of structure through functions that map hypertextual structure onto a space (i.e. automatic layout) may not be very strong in its ability to support ad hoc expression or structural ambiguities. The well-defined mapping function precludes this. Similarly, an automatic layout feature introduces a trade-off between support for memory (by landmark) and support for comprehension (by visualization), since a user’s sense of landmarks and physical features of a hypertext can be destroyed through computed relayout.

It is also clear that some models of space make navigational access quite a bit more intuitive through their close adherence to physical properties of space, while others make access quicker, but less obvious -- interface space no longer behaves according to analogy, so navigation techniques must be learned.

Then too, although direct reference is easier for users to understand (since there is a one-to-one correspondence between hypertextual objects and their graphical manifestation), it does not support multiple simultaneous perspectives onto a single hypertextual object. Indirect reference is necessary to support this more complex, less intuitive, capability.

The characteristics and trade-offs we mention here are not meant to be exhaustive; they are intended as illustrations, foils against which developers discuss design decisions. In the end, the use of space in interfaces must take these and other trade-offs into account; a thorough understanding of expected user activities is the only real means of resolving many of them.

Applications

As we have seen, characteristics and affordances interact. As examples of this we will look at three hypertext systems: Aquanet, VIKI, and HOS. Aquanet and VIKI are browser-based hypertexts where indirect references to objects are arranged in two dimensional planes. HOS is a page-oriented hypertext where links take users between two dimensional pages. All three systems had similar representational aims (user expression of semi-formal knowledge), although they had slightly different emphases: Aquanet emphasizes graphical knowledge representation; VIKI emphasizes ad-hoc expression and representation; and HOS emphasizes incremental formalization of knowledge. Figure 1 shows examples of uses of these systems. We will use these systems as a foil for the argument that spatial characteristics and user activities (and system design) interact.
First, let’s look at an example of the interaction between spatial topology and means of navigation. Spatial topology differs among these systems in the number and organization of spaces which compose a complete information set (or hyperdocument). Aquanet provides a single, continuous 2D plane, while VIKI provides for a hierarchy of discontinuous 2D planes (planes are embedded in other planes) and HOS provides for any number of separate (and therefore discontinuous) 2D planes. These organizations of space lead to different means of navigation. Aquanet’s single, continuous 2D plane leads to scrolling as being the primary traversal mechanism. VIKI’s hierarchy of spaces leads to “enter and exit” navigation like that found in Boxer [diSessa and Adelson 86]. Finally, the separate 2D planes of HOS lead to the point and click navigation that is so common in hypertext systems.

Let’s also look at an example of the interaction between the space-hypertext relationship and how information is represented. Aquanet’s richly expressive relationship mechanism leads to explicit portrayal of semantic relationships between objects through both drawn connections (like arrows) and constraints (like the adjoining display of objects). VIKI’s choice of inferred composites for

**Figure 1:** (a) An Aquanet discussion, (b) a VIKI collection hierarchy, and (c) some HOS pages.
relations removes the need for graphical representations of relationships besides those generated by users through spatial positioning of objects. HOS, with its knowledge-based system heritage, includes relations, but they are only displayed through a property sheet and have no graphical representation.

### Table 1: Comparison of the use of space in Aquanet, VIKI, and HOS

<table>
<thead>
<tr>
<th></th>
<th>Aquanet</th>
<th>VIKI</th>
<th>HOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>single 2D</td>
<td>hierarchy of 2D spaces</td>
<td>separate 2D pages</td>
<td></td>
</tr>
<tr>
<td>scrolling</td>
<td>scroll &amp; enter/exit navigation</td>
<td>point &amp; click navigation</td>
<td></td>
</tr>
<tr>
<td>graphical</td>
<td>no explicit relations</td>
<td>attribute-based relations</td>
<td></td>
</tr>
</tbody>
</table>

### Extending Existing Hypertext Systems using Spatial Constructs

Spatial constructs can be used in their various roles to extend existing hypertext systems. An analysis of the systems’ intentions can suggest appropriate ways of incorporating spatially-based mechanisms. To illustrate this, we briefly discuss current and potential uses of space with the World-Wide Web.

A hypertext that’s purely navigational, but which is an information provider like the Web, can be extended to include the expressive qualities provided by a spatial interface. Our integration of the Mosaic viewer into VIKI so that World-Wide Web pages can be manipulated and interpreted is an example of this strategy. Users can more readily organize their own “hotlist” of Web pages using a spatial interface.

Similarly, comprehension of navigational graph-based hypertext like the Web can be enhanced through visualization techniques along the lines of those offered by the Information Visualizer’s Cone Trees. It’s easy to see that such an integration would greatly increase a reader’s ability to take in a complex structure through a well-constructed visualization.

Once the information has been given spatial qualities, PAD-like zooming navigation can give readers more context and perspective than a traditional point and click hypertext interface.

### Summary

The first step in creating a spatial interface to information is to understand what people are doing with the information. We have described how space can be used to aid in expression, visualization, and navigation. Once the role of space in the system is understood, properties and affordances can be chosen to match the users’ activities. Our own choices of spatial properties and affordances in Aquanet, VIKI, and HOS point out the interrelation and trade-offs of different characteristics and the potential for space to enhance the expressiveness, visualization, and navigation characteristics of existing hypermedia systems.
References


