The Information Visualizer: A 3D User Interface for Information Retrieval

J. D. Mackinlay, G. G. Robertson and S. K. Card

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Jock D. Mackinlay, George G. Robertson, and Stuart K. Card

Xerox Palo Alto Research Center
3333 Coyote Hill Road
Palo Alto, CA 94304
415-494-4335, mackinlay.parc@xerox.com

Abstract

Advances in computer technology have created new possibilities for information retrieval systems in which user interfaces could play a more central role. Our analysis of the problem suggests that what is needed from the user's point of view is not so much information retrieval itself, but rather, the amplification of information-based work processes. User interfaces enabled by this technology may be able to amplify work by modifying the cost structure of information used in work. As a consequence, we have attempted to go beyond the usual notion of an information retrieval systems to develop an "Information Workspace" that encompasses the cost structure of information from secondary storage to immediate use. As an implementation of the concept, we describe an experimental system, called the Information Visualizer, and its rationale. The system is based on the use of (1) 3D/Rooms for increasing the capacity of immediate storage available to the user, (2) an animated scheduler-based user interface interaction architecture, called the Cognitive Coprocessor, for coupling the user to information agents, and (3) information visualization for interacting with the information structure. The system and its rationale are described.

KEYWORDS: Information retieval, interface metaphors, information visualization, animation, desktop metaphor, UI theory, 3D graphics, interactive graphics

Introduction

Information retrieval has often been studied as if it were a self-contained problem (e.g. the library automation problem). Yet from the user's point of view, information retrieval is almost always part of some larger process of information use. What is really needed isn't so much information retrieval itself, but rather the amplification of information-based work processes–that is, methods and machines that would allow people to bring to bear on a task of interest more information more quickly than otherwise possible.

Emerging technologies for 3D visualization and interactive animation have created new possibilities for information retrieval systems in which user interfaces could play a more central role, particularly when the structure of the information can be visualized. In particular, we have developed an experimental system, called the Information Visualizer, that is based on the use of (1) 3D/Rooms for increasing the capacity of immediate storage available to the user, (2) an animated scheduler-based user interface interaction architecture, called the Cognitive Coprocessor, for coupling the user to information agents, and (3) information visualizations for interacting with information structure. This document provides a summary of a talk given at AVI'92 on the design rationale for the Information Visualizer (see Table 1). Three CHI'91 papers contain a much more detailed discussion of the system and its rationale [2, 3, 6]. The Information Visualizer research represents a technology exploration motivated by a systems research paradigm that moves iteratively from analysis to goals to artifacts and back to analysis. This iterative process strives to create abstractions and characterizations that can be used during design.

The Cost Structure of Information

In the office, sources of information can take different forms–from paper documents to machines to people. However, each piece of information has a *cost* associated with finding and accessing it. Abstractly, an office at a particular moment for a particular task can be characterized by a cost structure of the information in it. What is usually meant by an organized office is one with a cost structure arranged so as to lower the cost of the information-based work processes performed within it. Our analysis of these cost structures revealed a number of observations that were used to formulate the system goals for the Information Visualizer.

The cost structures of information include the cost of access, interaction and assimilation relative to some information processing task (see Table 1). Access costs are often improved when a system is structured hierachically relative to such tasks. This is particularly true because the ratio between

Table 1: The Design Rationale for the Information Visualizer

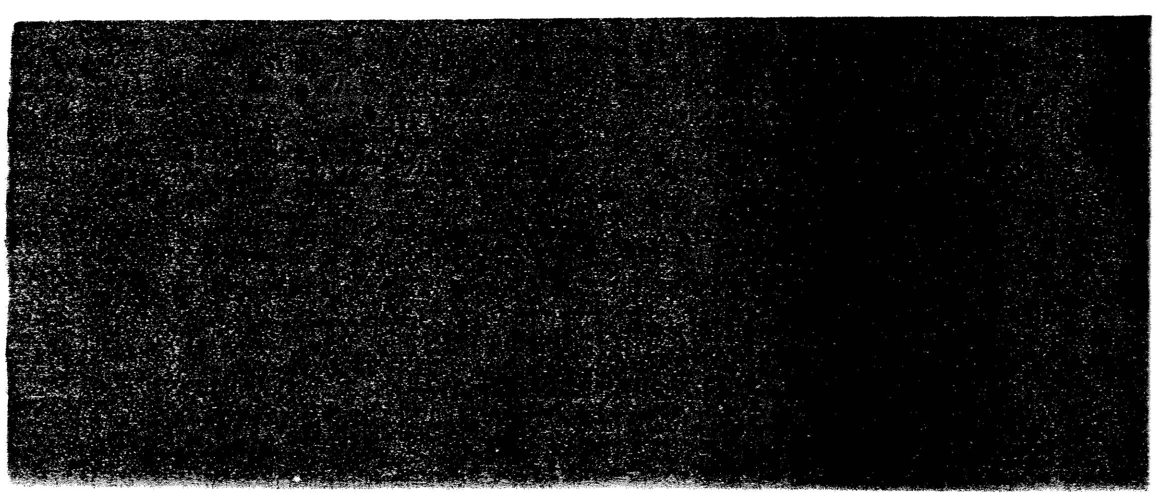
Problem: Aid Information Access and Processing				
Analysis and Observations (Cost Structure of Info.)	**System Goals** (Information Workspace)	**UI Artifact** 3D/Rooms	Cognitive Coprocessor	Information Visualizer
Access Cost	**Improved Storage**			
Hierachy	More immediate storage			
High Cost Ratios	Larger	Yes		
Locality of Ref.	Denser	Yes	Yes	Yes
Ref. Clustering	Cheaper access to secondary			Yes
Interaction Costs	**Highly-coupled Systems**			
Max Info/Cost	Iterative retrieval			
	Faster cycle		Yes	
	Fewer cycles			Yes
	Impedence match		Yes	
Assimilation Costs	**Information Visualization**			
Abstraction	Hierachical structure			Yes
	Linear structure			Yes

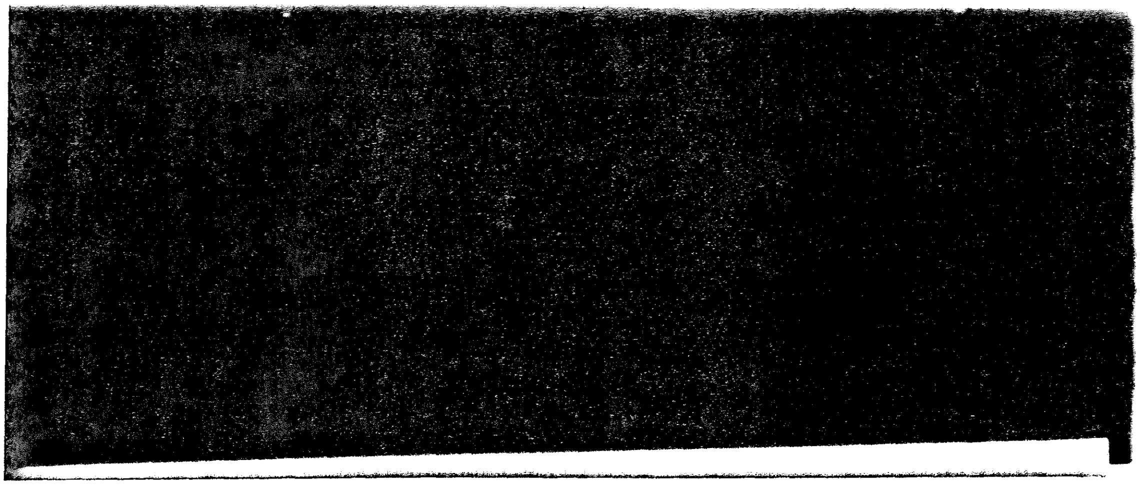
the cost of information ready to hand and the cost of information not immediately available may be quite high, even orders of magnitude. For example, RAM access typically is five orders of magnitute faster than disk, which is two orders faster than optical drives. Access costs are also affected by patterns of use that are common as people work. One common pattern is Locality of Reference, where people tend over small time intervals to concentrate their references to information in a subset of the corpus called the working set. Another common pattern is Reference Clustering, where people tend to establish Locality of Reference in one cluster, then jump to another cluster. Access naturally leads to interaction with its associated cost. Many information processing systems address interaction costs by maximizing (or minimizing) the quantity of information processed relative to some processing cost constraint. For example, the visual system tends to encode points of greatest curvature because these carry the most information [4]. Finally, even if information can be found, there is often too much of it to process directly. Thus, assimilation costs can be improved by having lower levels of an information processing system simplify and organize information through abstraction and selective omission.

Information Workspaces

If we want to move beyond information retrieval, narrowly conceived, to address the amplication of information-based work processes, we are led to try to develop user interfaces oriented towards managing the cost structure of information-based work. This, in turn, leads us to be concerned not just with the retrieval of information from a distant source, but also with the accessing of that information once it is retrieved and in use. The goal then is to develop an *Information Workspace*, a special environment in which the cost structure of the needed materials is tuned to the requirements of the work process using them.

The Information Visualizer is our experimental system that embodies this concept. The Information Visualizer has three major components (see Table 1): (1) *3D/Rooms*, a 3D version of the Rooms system [1]. This component effectively increases the capacity of Immediate Storage to improve access costs. Locality of Reference and Clustering are addressed by using Rooms to make the Immediate Storage larger by having multiple desktops. The effect of 3D/Rooms (and the associated Cognitive Coprocessor architecture) is to make the Immediate Storage not only larger, but also *denser*. (2) The *Cognitive Coprocessor* [5], an animation-oriented user interface architecture. This component increases the rate of user-system interaction and information transfer to improve interaction costs. Two time constants are particularly important. The first is the *perceptual processing time constant*, which is around 0.1 sec-





onds per frame, to maintain the illusion of an animated view of a virtual world. The second is the *immediate response time constant*, which is around a second. During a second, an animation can occur without interupting effective work time. Animation supports object constancy, which shifts work from the cognitive system to human perception, (3) *Information Visualizations*, which serve as structure-oriented browsers into sets of information. This component increases the level of abstraction to improve assimilation costs. Information Visualization is analogous to Scientific Visualization except that it focuses on abstract information rather than intellectually large data collections. Visualization makes the structure of information visible to the user, which can reduce assimilation costs. The Information Visualizer contains visualizations for various types of structures, including the visualizations for hierachical and linear structure that are described in the next two sections.

Cone/Cam Trees: Visualizations of Hierachical Information

Cone Trees are visualizations that layout hierachies uniformly in three dimensions. Hierachies are presented in 3D to maximize effective use of available screen space and enable visualization of the whole structure. Hierachies tend to be broad and shallow, which typically result in 2D layouts that either have very small details or require scrolling. Cone Trees, on the other hand, have a well-behaved aspect ratio. Cards are used to represent nodes. The card at the top of the hierachy is placed near the ceiling of a virtual room and it is the apex of a cone that has the root's children cards placed evenly spaced along the base. Each child card that is not a leaf is the apex of a cone. The aspect ratio of the tree is fixed to fit the rooms, with cone base diameters for each level reduced in progressions to assure fit. The *Cam Tree* is a horizontal version of the Cone Tree that has a wider card suitable for text labels.

There are numerous applications with large hierachical information structure that can take advantage of the Cone/Cam Trees. Three applications that have been implemented in the Information Visualizer are: Unix file structure, an organization hierachy consisting of 650 executive from an 80 page document, and an operating plan. When the user selects a card, animation is used to rotate the selected card and its ancestor cards to the front. The user can also manipulate Cone Trees to hide or move parts of the tree. Traditional information retrieval is also available. Search parameters are provided either by node selections or by typing paprameters into a pop-up property sheet. The results are presented with the same visualizations, which improves assimilation time.

Perspective Wall: Visualization of Linear Information

Perspective Walls are visualizations that fold 2D layouts with wide, inefficient aspect ratios into an intuitive 3D wall that has a center panel for viewing detail and two perspective panels on either side for viewing context. Case studies of a forensic architect's office and of a national study committee indicate that time is often an important retrieval cue for large document collections.

A major advantage of the Perspective Wall is that its intuitive 3D metaphor for distorting 2D layouts allows smooth transtions amoung views. When the user selects an item, the wall moves that item to the center panel with a smooth animation that takes about a second. The metaphor also supports stretching the wall like a sheet of rubber to adjust the ratio of detail and context when the user want to understand the fine structure of a particular section of the wall. Persective Walls also support traditional information retrieval.

Discussion

The Information Visualizer is an experimental system being used to develop a new user interface paradigm for information retrieval. Our approach is to exploit human experiences and capabilities by using emerging technologies for 3D visualization and interactive animation to develop highly interactive user unterfaces. Our experience so far suggests that it is possible to create effective user interfaces that improve management and access of information spaces. Interactive animation, in particular, seems to be a powerful technique because it shifts congitive load to the perceptual system and thus supports smooth transitions among views. We have been able to use these techniques to visualize the structures of information spaces, such as entire files systems, that have never been seen before. Our initial prototypes suggest that such highly interactive user interfaces are likely to support the applification of information-based work processes.

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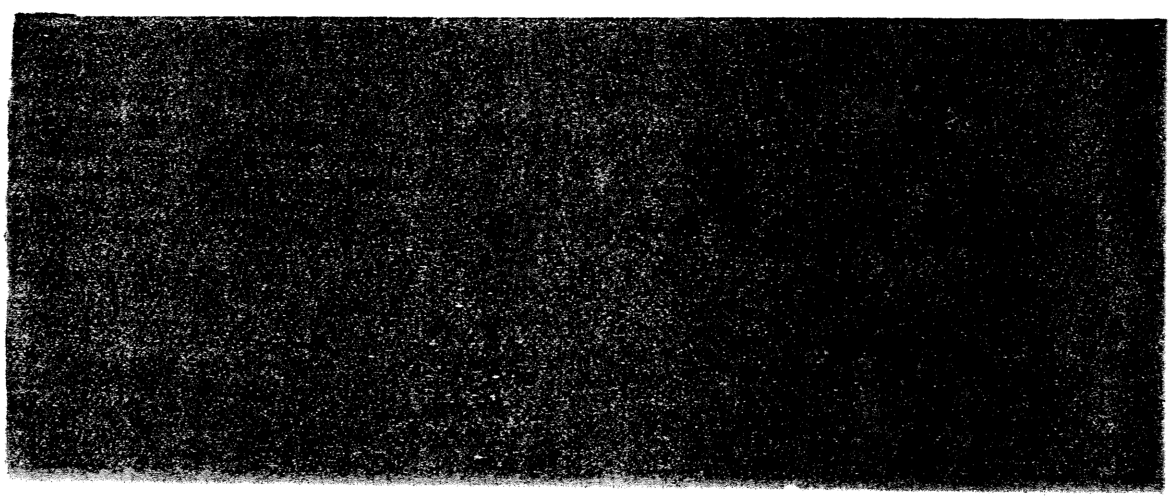

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