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Hypertext presentation of thesauri used in online searching

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SUMMARY

In this article we explore the strengths and limitations of hypertext for the online presentation of thesauri used in information retrieval. We examine the ability of hypertext to support each of three common types of thesaurus display: graphic, alphabetical, and hierarchical. Graphic displays generated by hypertext browsers appear to be inferior to their printed counterparts. The simple alphabetical display can be easily mapped onto hypertext systems but has the inherent disadvantage of not showing a full hierarchy at the entry point for a term. Hierarchical displays are well suited to hypertext presentation but do not include definitional or complete relational information. We present a design for a hypertext-based hierarchical display that addresses many inadequacies of printed hierarchical displays. We also illustrate how this design might be implemented using a commercially available hypertext system. Finally, we consider issues related to the implementation and evaluation of hypertext-based thesauri.

KEY WORDS Hypertext Thesauri Online searching Guide

INTRODUCTION

Hypertext is becoming a popular approach to the online presentation of large corpora of information. Examples of large paper documents converted to hypertext include a 500-page manual of medical therapeutics [1], an eight-thousand-page set of manuals for a software product [2] and the twelve-volume Oxford English Dictionary [3]. Nielsen [4] reviews the commercially available hypertext versions of an interactive fiction, an encyclopedia, and the *Whole Earth Catalog*. These products are classified as medium-sized hypertexts since each contains fewer than ten thousand nodes.

In this article we explore the strengths and limitations of hypertext for the online presentation of thesauri used in information retrieval. These thesauri typically contain several thousand terms connected by a large number of inter-term relationships. The *Thesaurus of ERIC Descriptors* [5], for example, contains in excess of nine thousand terms and sixty-six thousand relationships.

Typical reasons for implementing documents in hypertext form are to support browsing, to explore alternate display methods, and to integrate the documents with the users' tasks [3, page 872]. Our motivation for investigating the hypertext representation of online thesauri is similar. However, an additional objective of our work is to help users develop an accurate mental model of the intellectual structure that a thesaurus represents.

In the following sections we present an introduction to thesaurus structure and display

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and review previous work on hypertext-based thesauri. We then discuss the design of a hierarchical display for a hypertext-based online thesaurus.

THESAURUS STRUCTURE AND DISPLAY

The international standard for monolingual thesauri [6] defines a thesaurus as "the vocabulary of a controlled indexing language, formally organized so that the *a priori* relationships between concepts are made explicit." The Standard (ISO 2788) further defines an indexing language as "a controlled set of terms selected from natural language and used to represent, in summary form, the subjects of documents."

The foregoing definitions indicate that the two major components of a thesaurus are a set of terms and a set of relationships. ISO 2788 recognizes three classes of inter-term relationship: equivalence, hierarchical, and associative. These three classes of relationship are usually represented in thesauri by the notation USE/UF for equivalence, BT/NT for hierarchical, and RT for associative.

There are several ways of displaying thesaurus terms and their interrelationships. Aitchison and Gilchrist [7] discuss basic types of thesaurus display in some detail. In the following subsections we give brief descriptions of alphabetical, hierarchical, and graphic displays.

Alphabetical display

The alphabetical display is used widely either as the main display or as a supplement to other types of display. As the name suggests, the alphabetical display lists all preferred and non-preferred terms in a single alphabetical sequence. Preferred terms are accompanied by scope notes (SN), references to equivalent non-preferred terms (UF), and references to broader (BT), narrower (NT), and related terms (RT). Non-preferred terms are shown with references to their preferred equivalents (USE). An example alphabetic display in the style of the *Thesaurus of ERIC Descriptors* is shown in Figure 1.

Hierarchical display

Some thesauri, particularly those that are available in machine-readable form, include hierarchical displays as a complement to the main alphabetical display. Two common forms of hierarchical display are the top term arrangement and two-way hierarchies [7]. In the top term arrangement the broadest terms in the thesaurus are arranged in an alphabetical sequence. Each of these 'top terms' is accompanied by an indented list of subordinate terms. Multiple levels of indention are used to indicate successively lower levels in the hierarchy. An example of this type of display and its accompanying alphabetical display is shown in Figure 2.

In the two-way hierarchical display all preferred terms are arranged in an alphabetical sequence. Each entry is shown with broader terms listed above it and narrower terms listed below. For example, the two-way hierarchical display in the *Thesaurus of ERIC Descriptors* shows broader terms identified by colons with multiple colons indicating successively higher levels in the hierarchy. Narrower terms are identified by periods with multiple periods indicating successively lower hierarchical levels. Figure 3 shows an example of a two-way hierarchical display.

North American History

SN History of the geographic area that includes the United States and Canada
NT United States History
BT History
RT American Indian History
Black History
North American Culture
North American Literature
North Americans
Western Civilization

•
•
•

Northward Movement
USE Migration

Figure 1. Alphabetical display (in the style of the Thesaurus of ERIC Descriptors*)*

```
Liberal Arts
. Humanities
.. History
... North American History
.... United States History
..... Civil War (united States)
```

North American History

```
TT   Liberal Arts
NT   United States History
BT   History
RT   American Indian History
     Black History
     North American Culture
     North American Literature
     North Americans
     Western Civilization
```

Figure 2. Top-term hierarchical display and accompanying alphabetical display

```
::: Liberal Arts
:: Humanities
: History
North American history
. United States History
.. Civil War (United States)
```

Figure 3. Two-way hierarchical display (in the style of the Thesaurus of ERIC Descriptors*)*

Graphic display

In this article we use the term 'graphic display' to refer to a two-dimensional figure that depicts thesaurus terms and their interrelationships. Perhaps the simplest type of graphic display is the tree structure. This type of display only depicts hierarchical relationships between thesaurus terms: scope notes, equivalence and associative relationships are relegated to an accompanying alphabetical section.

Arrowgraphs, which are described in ISO 2788, show the thesaurus network as a series of subnetworks superimposed on a grid. The broadest term in the subnetwork is placed in a central position with subordinate terms connected to it by lines. The level of subordination is indicated by the relative distance of the subordinate term from the broadest term. Associatively related terms are shown outside the grid but are connected to the terms within it by dotted lines. Grid coordinates are used to refer to individual terms within the subnetworks and a system of addresses is used to refer to the subnetworks themselves. Figure 4 shows an arrowgraph for the term 'Health.' In this figure, hierarchical relationships are represented by lines with a single arrowhead; associative relationships are represented by lines with an arrowhead at each end. The address of the arrowgraph (E417) is shown at the upper left-hand corner of the grid.

ONLINE THESAURI

Thesauri are an integral part of many manual and computerized information retrieval systems. A discussion of the role of thesauri in information retrieval can be found elsewhere [8]. In this article we simply consider thesauri as tools for selecting terms to be included in an online search.

Although thesauri are used with online databases, it appears that most are published only in print format. A recent study of 122 thesauri used by large online bibliographic databases [9] found that 96 of these thesauri were available only in print format. A printed thesaurus, unlike its online counterpart, may not always be available at the time or place that a searcher chooses to perform an online search. This leads to searchers not using a thesaurus at all [10]. Providing wider online access to thesauri would appear to be the solution to this problem. However, thesauri that are available online have been criticized for being incomplete, confusing, and difficult to use [11].

HYPERTEXT AND ONLINE THESAURI

Shneiderman [12] suggests that hypertext is appropriate in situations where "there is a large body of information organized into numerous fragments, the fragments relate to

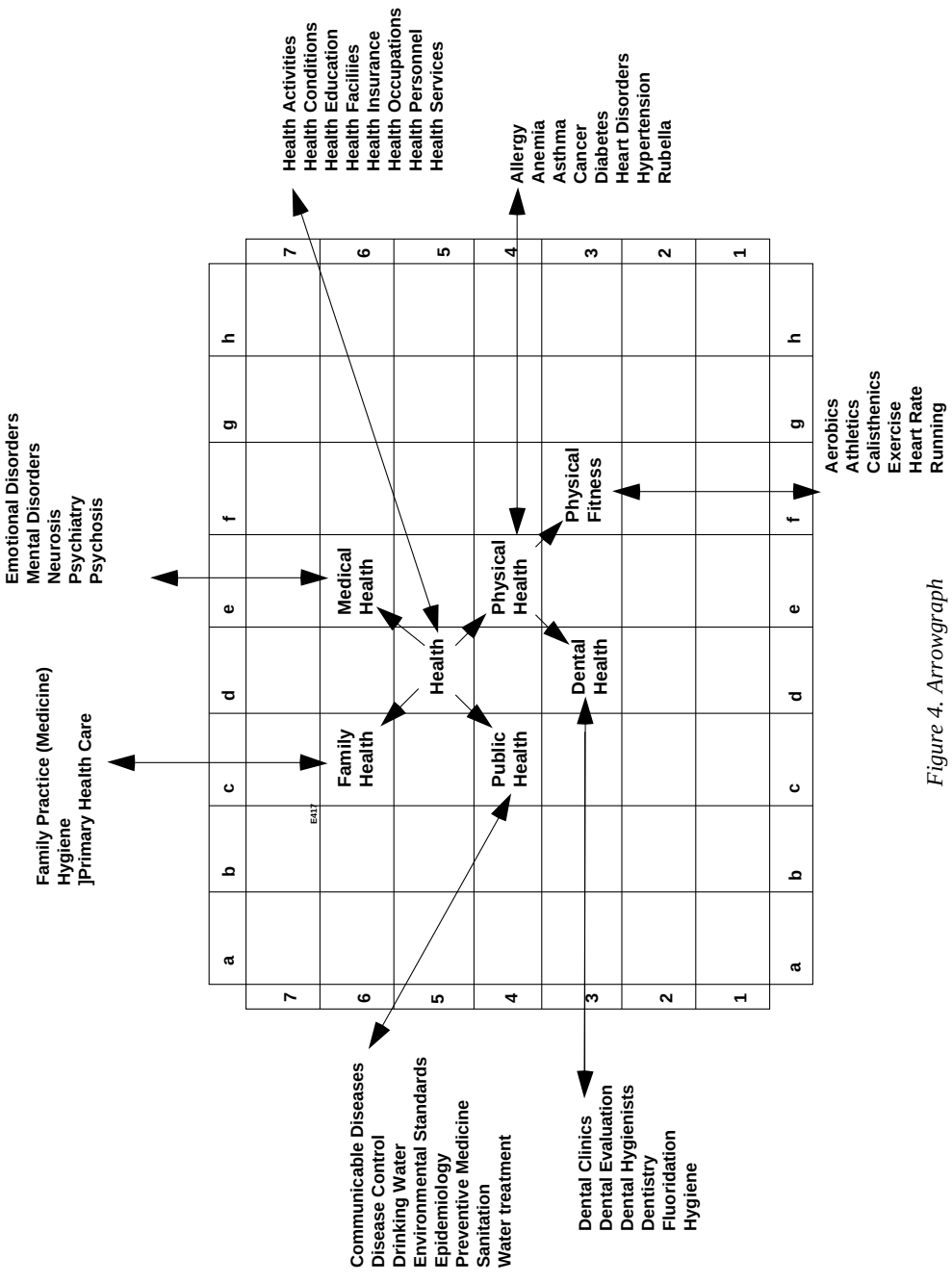

Figure 4. Arrowgraph

each other, and the user needs only a small fraction at any time." Thesauri fit this pattern exceptionally well. A typical thesaurus contains many thousands of individual terms that are explicitly related to one another in a well-defined manner. At any time, the user of a thesaurus is interested in identifying only a small subset of the available terms.

A singular characteristic of hypertext is its ability to provide nonlinear access to information [13]. With its mixture of equivalence, hierarchical, and associative relationships, a thesaurus has an inherently nonlinear structure. Hypertext has an obvious potential for making this structure apparent to users.

Despite the apparent match between hypertext and thesauri relatively little work on hypertext presentation of thesauri has been reported in the literature. McAleese and Duncan [14] describe a hypertext-based thesaurus in which each term is assigned to a node and inter-term relationships are represented by links between nodes. The system, which is implemented in Notecards [15], uses a graphical browser to display global and local maps of the network. Terms may be selected directly from a local map and displayed in a window. The window shows the alphabetical display for the selected term. Items listed in the alphabetical display are link anchors to nodes that represent the corresponding terms. Users can browse the thesaurus either by using the graphic display or by clicking on link anchors in the alphabetical display.

McMath, Tamaru, and Rada [16] discuss an information retrieval system that supports a hypertext-like implementation of the ACM Computing Reviews Classification System [17]. Their system has a graphic display that shows the current node in the center of a window surrounded by labelled circles representing child nodes. The child nodes have their children displayed as smaller circles around them. Users traverse this purely hierarchical structure by clicking on the circle that represents the node of interest. The system responds by redrawing the display with the newly selected term in a central position surrounded by its children and grandchildren.

HYPERTEXT-BASED GRAPHIC DISPLAYS

A common aspect of these systems is their use of computer-generated graphic displays. The potential of graphic displays of thesaurus terms and relationships is well known to information scientists. Lancaster [8, page 89], for example, explains that a graphic display "brings related terms into physical proximity and allows an indexer or searcher to view a complete conspectus of these associations at a glance." Lancaster warns us, however, that a disadvantage of such displays is that "large hierarchies involving multiple relationships and levels are difficult to display intelligibly in graphic form." This might explain why relatively few thesauri contain graphic displays. Of the 779 thesauri surveyed by Bertrand-Gastaldy and Davidson [18] only 5.5% had graphic displays.

The graphic displays that do exist in printed thesauri contain a great deal of semantic information. The terminographs of the *EUDISED multilingual thesaurus* [19], for example, display a complete microthesaurus on a single page. Each term in the microthesaurus is listed under a top term with levels of subordination represented by indention to the right. Associative relationships within the microthesaurus are shown by lines of varying width, the width being determined by the hierarchical level of the terms taking part in the relationship. The scheme also includes notations for representing polyhierarchical relationships and associative relationships between microthesauri.

Compared to these printed displays, the displays produced by hypertext graphic browsers are relatively crude. A typical graphic browser represents nodes as labelled boxes and the links between nodes as lines. The lines may be styled to indicate the type of link involved. A global and local view of the network may be shown together. The global view shows the entire network without semantic information. The local view retains semantic information but typically shows only the current node and its immediate neighborhood.

The utility of maps of hyperdocument structure has been questioned by Akscyn *et al.* [20] and Brown [21]. Utting and Yankelovich [22] report that the global maps generated by the Intermedia system were "too large and entangled to be of any use" with webs of even a few hundred documents. One assumes that a global map of a typical thesaurus containing several thousand terms also would be of little use.

After examining a variety of alternatives, Utting and Yankelovich decided to abandon global maps in favor of local maps supplemented by a path history and a scope indicator. The strategy of providing local maps in preference to global maps still leaves the problem of determining their extent. The simplest approach is to provide a local map that shows only the current node and nodes directly connected to it. In the context of a thesaurus this arrangement provides no more information than the corresponding alphabetical display. As most thesauri are richly connected networks, increasing the extent of a local map can lead to a dramatic increase in the number of nodes and links to be displayed. This in turn leads to an increase in the complexity of the map and the amount of screen space consumed.

In summary, a desirable feature of graphic displays is their ability to represent visually the extent and structure of a hypertext network. The evidence suggests, however, that hypertext graphic browsers are currently unable to fulfill this potential for large, richly interconnected networks such as thesauri. For this reason we direct our attention to other methods of displaying thesaurus terms and their relationships.

HYPERTEXT-BASED ALPHABETICAL DISPLAYS

The hypertext-based thesaurus proposed by McAleese and Duncan supports an alphabetical as well as a graphic display. The alphabetical display is implemented using a simple mapping onto Notecards. For the purpose of discussion we present a similar rendition of the alphabetical display using a commercial version of the hypertext system GUIDE [23].

In the manner of McAleese and Duncan we assign each term in the thesaurus to a hypertext node (a GUIDE document) and represent inter-term relationships by links between nodes. The user accesses the thesaurus through an index node that contains an alphabetical list of preferred and non-preferred terms. Each entry in the index is linked to a corresponding node in the hypertext database. Assume that the user has selected the index entry 'History.' The system responds by presenting the first part of the alphabetical display for this term in the scrollable window shown in Figure 5. In this display each item that is prefixed by one of the tags UF, BT, NT, or RT is an anchor for a link to the node for the corresponding term.

In Figure 6 the user has scrolled the display and placed the mouse cursor over the item 'North American History.' In GUIDE the shape of the cursor indicates the type of button to which one is pointing. The right-arrow shape denotes a GUIDE reference button, that

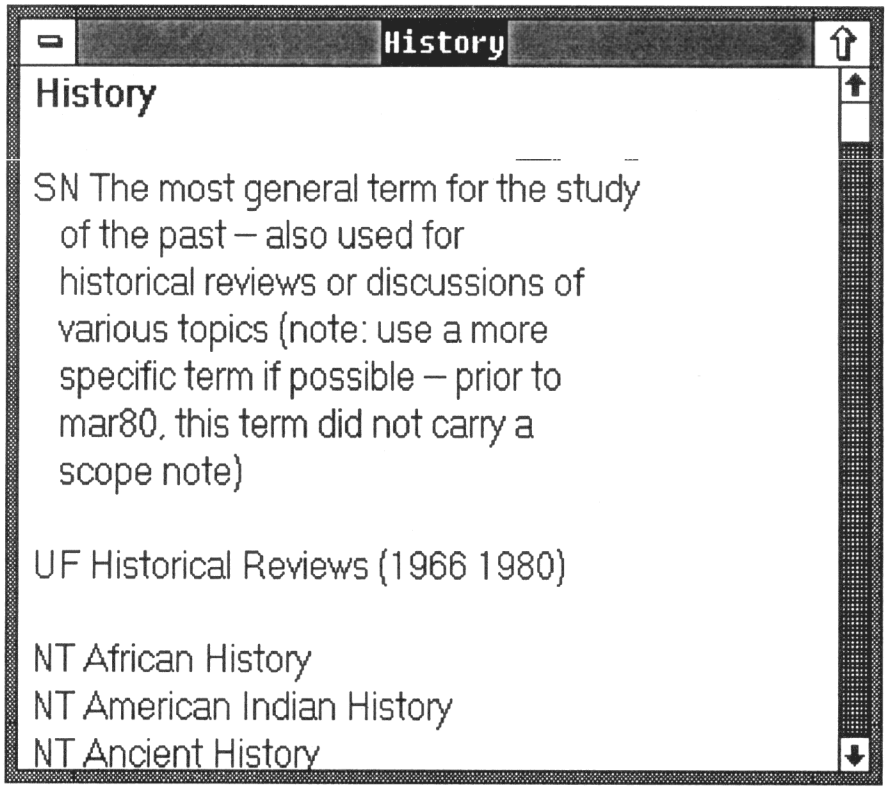

Figure 5. Hypertext alphabetical display

is, a hypertext link anchor. If the user selects this anchor the alphabetic display for the narrower term 'North American History' will appear in the overlapping window shown in Figure 7. Associatively related terms are selected in the same way. The user may browse through the thesaurus by selecting link anchors until the desired term has been located.

An advantage of this hypertext rendition of the alphabetical display is that it provides temporal context, allowing users to answer the question, "How did I get here?" Temporal context is provided by means of a path history (GUIDE's list of open documents feature) and, to a limited extent, by the title bars of overlapping windows. Terms can be selected directly from the path history enabling the user to return immediately to any previously visited node. Implementing these facilities with a printed thesaurus is inconvenient at best.

A limitation of this hypertext alphabetical display is that it does no more than a print thesaurus to distinguish between hierarchical and associative relationships. The visual feedback provided by the system on selection of a hierarchically related term is identical with that provided on selection of an associatively related term. This homogeneity results from the use of a single type of link to represent both kinds of relationship. One might argue that this limitation could be circumvented by using a hypertext system with typed or labelled links such as Trigg's Textnet [24]. However, this argument would hold true

Figure 6. Scrolled alphabetical display with cursor on the link anchor 'North American History'

only if the traversal of each type of link were to have a unique visual representation at the user interface. Further discussion of the role of graphic representation in reducing homogeneity in hypertexts can be found in Nielsen [25].

An inherent disadvantage of the simple alphabetic display is that it only shows terms at one hierarchical step above and below the selected term. As a result, users cannot see the full hierarchy of broader and narrower terms at the entry point for a given term. Compare, for example, the simple alphabetic display shown in Figure 1 with the two-way hierarchical display shown in Figure 3. This disadvantage is shared by both hypertext and print versions of the display.

HYPERTEXT-BASED HIERARCHICAL DISPLAYS

In a previous section of this article we described two common forms of hierarchical display: the top term arrangement and two-way hierarchies. The top term arrangement requires that a supplementary alphabetical display be used to identify the hierarchy to which a term belongs (see Figure 2). Once the appropriate hierarchy has been identified the user has to locate the selected term within that hierarchy. The two-way hierarchical display circumvents this problem by having a separate entry for each term (see Figure 3). However, the presence of a potentially large number of terms above and below an entry makes it difficult to locate a given term within the display. A disadvantage shared

Figure 7. Alphabetical display for 'North American History' in an overlapping window

by both types of hierarchical display is that they do not usually carry scope notes or information on associative relationships. This information has to be obtained from the supplementary alphabetical display.

In the following subsections we discuss the design of a hierarchical display for a hypertext-based thesaurus that addresses some of the inadequacies of printed hierarchical displays. We have two major desiderata for this display. First, it should include all hierarchical, relational, and definitional information. Second, it should provide visual feedback to emphasize the difference between hierarchical and associative relationships.

Hierarchical information

The top-term hierarchical display can be conveniently implemented by assigning each hierarchy to an individual hypertext node. In its printed form, the top-term arrangement is accompanied by an alphabetical section that points the user to an entire hierarchy rather than to a specific term. This disadvantage can be overcome by using a hypertext system that allows links to be anchored to a region of the destination node rather than the entire node. If one uses such a system, entries in the index can be linked directly to individual terms within the hierarchies.

Printed thesaurus displays show fully expanded hierarchies in which indention is used to represent hierarchical relationships between terms. This arrangement is less than satisfactory when displayed on a computer screen, particularly in a windowed environment. A user who is directed to a term located deep within a large hierarchy may have difficulty identifying terms at adjacent levels. The window can be scrolled to bring additional terms on one side of the current term into view, but in so doing terms on the other side may be scrolled out of view. The window also may be enlarged but the available space is ultimately limited by the size of the screen.

In a hypertext system this difficulty may be alleviated by using links to represent the hierarchical relationships between terms. Brown has argued that hierarchical links are an important component of hypertext systems [26]. The commercial version of GUIDE supports bidirectional hierarchical links by means of expansion buttons. When the user selects an expansion button it is expanded in-line to reveal the linked text. Clicking on the linked text reverses the operation. This mechanism, which will be familiar to users of outlining programs, is also known as 'folding' and 'stretchtext.'

Each term in the hypertext hierarchical display, with the exception of those at the lowest level in the hierarchy, is an anchor for the list of terms at the next lower level. A GUIDE implementation of this display is shown in Figure 8. The user has selected the index entry 'History' and the system responds by displaying the hierarchy with top term

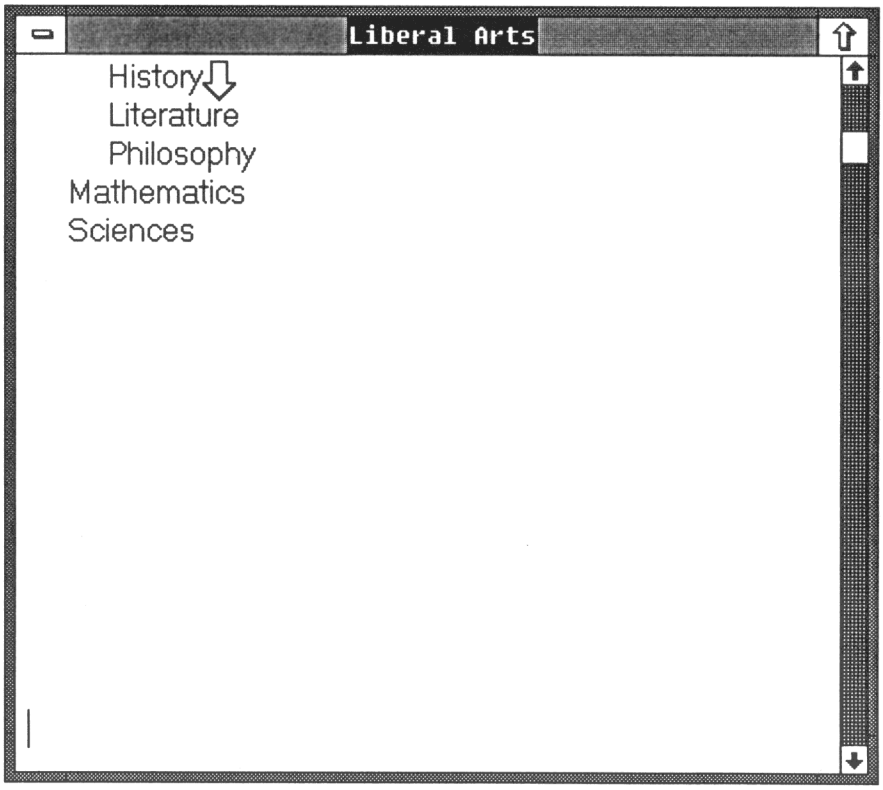

Figure 8. Hypertext hierarchical display for the term 'History'

'Liberal Arts' in a window. The top term of the hierarchy is identified in the window's title bar. The selected term in this hierarchy is shown at the top of the window for ease of location. If desired, the user can scroll this display to view the selected term in context with terms at the same or adjacent hierarchical levels. As an aid to the user we have retained the convention of using multiple levels of indention to indicate successively higher and lower hierarchical levels.

In Figure 8 the user has placed the cursor over the item 'History.' The down-arrow shape of the cursor indicates that 'History' is an expansion button. Selecting this button causes an indented list of narrower terms to be revealed and the remainder of the display to be pushed down as shown in Figure 9. The visual effect produced is one of 'expanding' the parent term. The user can now select from the list of narrower terms to reveal terms at the next lower level. This process may continue until an appropriate term is located, or the lowest level in the hierarchy is reached.

Figure 9. Expansion of 'History' to reveal narrower terms

At any point the user can move up a level in the hierarchy by selecting a term's expansion. When placed over an expansion the cursor takes an up-arrow shape. Selecting an expanded term will 'fold' the list of narrower terms back under the expansion button for the term. The remaining display lines will move up into the space formerly occupied by the expansion. The visual effect is one of 'contracting' the parent term.

Relational and definitional information

The next step in the design process was to add information on associatively related terms. We provide access to these terms through a link anchor labeled 'RT.' This anchor is linked to a list of related terms contained in another area of the current node. Figure 10 shows the hierarchical display for the term 'History' with the cursor placed over the 'RT' anchor. The right-arrow shape of the cursor denotes a GUIDE reference button, that is, an anchor for a hypertext link. When this button is selected the system displays the list of related terms shown in Figure 11. We have used the inherently associative hypertext link to help the user distinguish between the hierarchical and associative relationships contained in the thesaurus.

Each entry in the list of related terms is an anchor for a hypertext link. In Figure 11 the user has positioned the cursor over the reference button 'History Instruction.' Selecting this button causes the system to display the corresponding term at the top of the overlapping window for the hierarchy 'Instruction' as shown in Figure 12. In this example the visual effect of following an associative relationship differs markedly from that of following a hierarchical relationship. This is because the associative relationship in the example exists between terms in different hierarchies. Jumping from one hierarchy to another is represented visually by the opening of a new window on the screen.

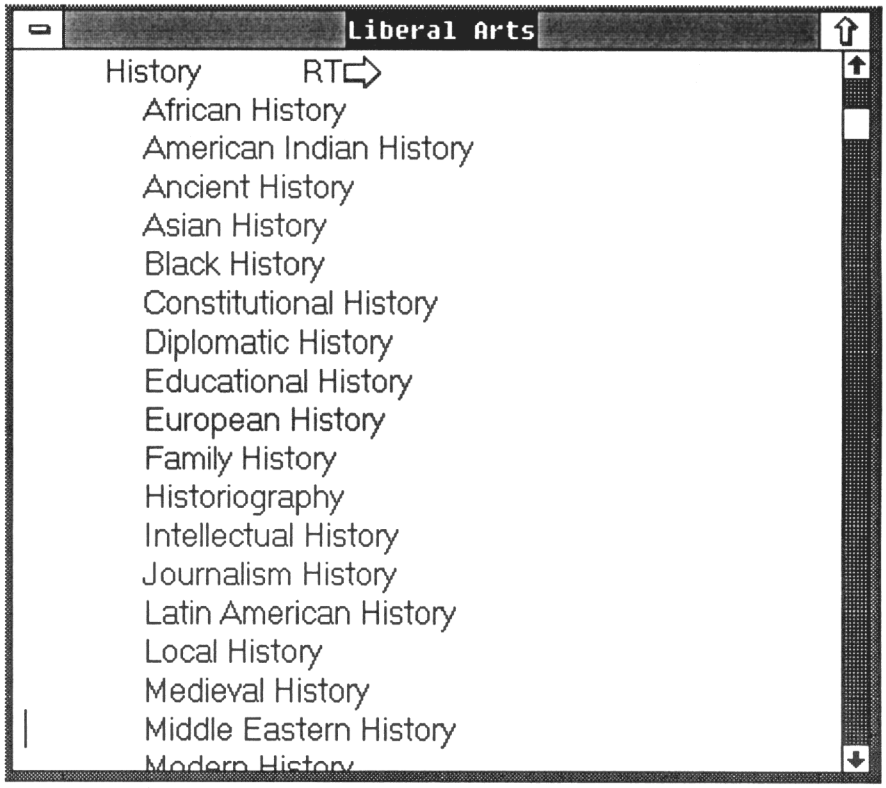

Figure 10. Hypertext hierarchical display with cursor on the link anchor 'RT'

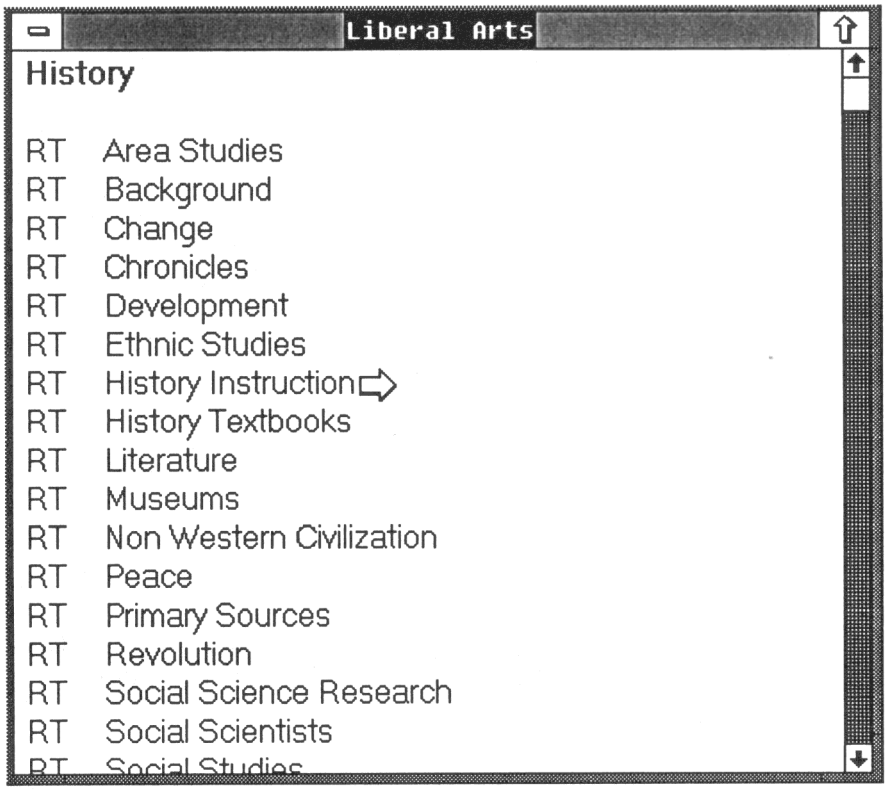

Figure 11. List of related terms with cursor on the link anchor 'History Instruction'

The final step in the design process was to add definitional information. This is achieved by adding an anchor labeled 'SN', the standard abbreviation for a scope note, to entries in the enhanced hierarchical display. The text of the scope note is linked to the anchor by an annotation link. Figure 13 shows the expanded term 'History' with the cursor placed over the scope note anchor. The asterisk shape of the cursor indicates that 'SN' is a GUIDE note button. Depressing the mouse button will cause the text of the scope note to be displayed in a pop-up window as shown in Figure 14. The pop-up window disappears when the mouse button is released.

DISCUSSION

A major design goal for the hypertext-based hierarchical display was that it should emphasize the differences between hierarchical and associative thesaural relationships. To achieve this goal we have used different types of link, each of which has a unique visual representation. Bidirectional hierarchical links are used to represent the hierarchical relationships in the thesaurus. The act of following a hierarchical relationship between a parent and child term is represented visually as an in-line 'expansion' and 'contraction' of the parent term. Hypertext links are used to represent the associative relationships in the thesaurus. Following an associative relationship between terms is represented visually

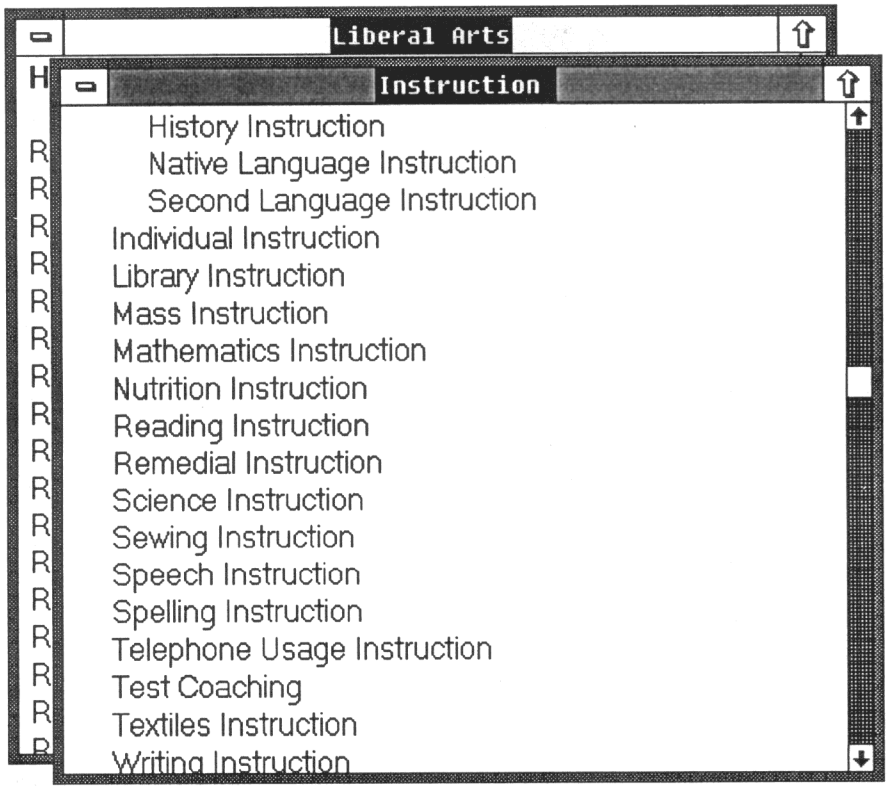

Figure 12. Hierarchical display for 'History Instruction' in an overlapping window

as a jump to another window (if the terms are in different hierarchies) or as a jump to another area of the current window (if the terms are in the same hierarchy). Definitions and scope notes are accessed via an annotation link.

The differential presentation of relationships is reinforced by a context-sensitive cursor. The cursor becomes an up- or down-arrow when placed over the anchor for a hierarchical link, a right-arrow when placed over the anchor for an associative link, and an asterisk when placed over the anchor for an annotation link. Field studies by Nielsen and Lyngbæk [27] indicate that users understand the differences between the three different types of link supported by GUIDE. We hope that these visual clues will help users develop an accurate mental model of thesaurus structure.

The usability [28] of the hypertext-based thesaurus described above will be evaluated by experiments involving users. We propose to use a formative design-evaluation strategy [29] to improve the usability of the design. Before such experiments can be conducted, however, the issue of implementation must be addressed. There are currently very few tools available for transforming text into hypertext. Implementors of hypertexts are often obliged to design special purpose conversion programs or perform the conversions manually. Thesauri are large documents typically containing several thousands of highly connected terms. As mentioned earlier, the *Thesaurus of ERIC Descriptors* contains in excess of nine thousand terms and defines more than sixty-six thousand inter-term

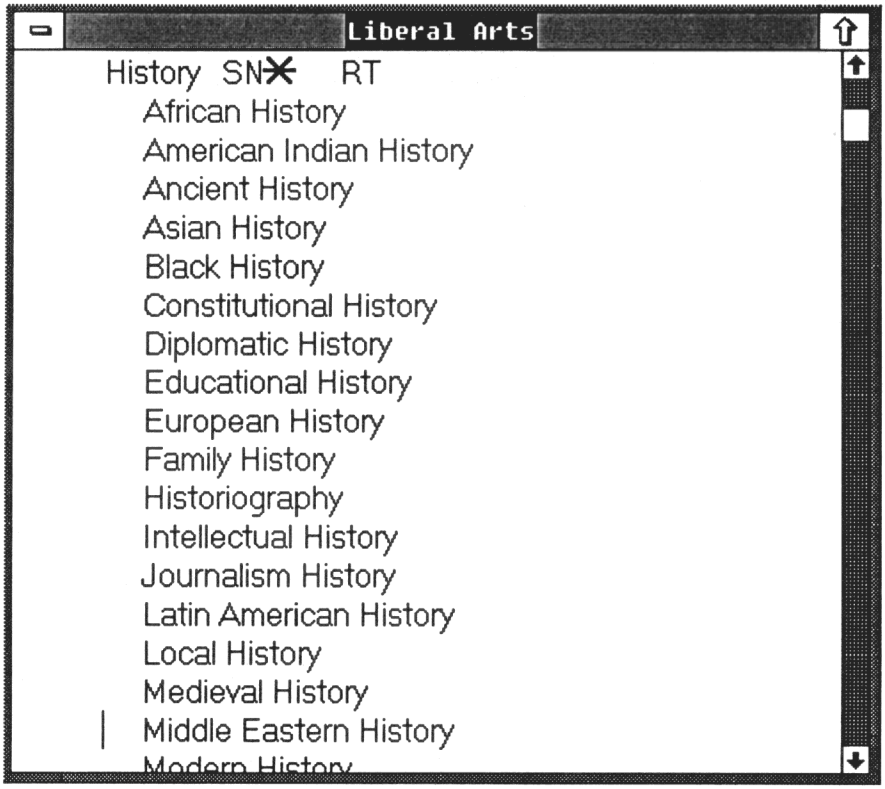

Figure 13. Hierarchical display with cursor over the link anchor 'SN'

relationships. Manual construction of a hypertext representation of this thesaurus would be a daunting task.

Furuta, Plaisant, and Shneiderman [30] found that regularly and repetitively structured documents are good candidates for automatic conversion. Their most successful conversions were achieved with documents in which the structure was well-defined and explicitly represented in the markup specification. Thesauri are, by design, regular and repetitive structures. In addition, the standard tags used to identify relationships between terms constitute a logical markup specification. We hope that fully automatic conversion of thesauri into hypertext will prove feasible, giving us the opportunity to implement, evaluate, and improve our design.

In this article we have proposed applying hypertext techniques to a problem in information science: the online presentation of thesauri used in information retrieval. Churcher [31] argues that structures used to represent knowledge and information in the fields of information science, psychology, artificial intelligence, and education are all amenable to hypertext representation. We hope that our work with hypertext-based thesauri will prove valuable not only to information scientists but also to researchers in other fields.

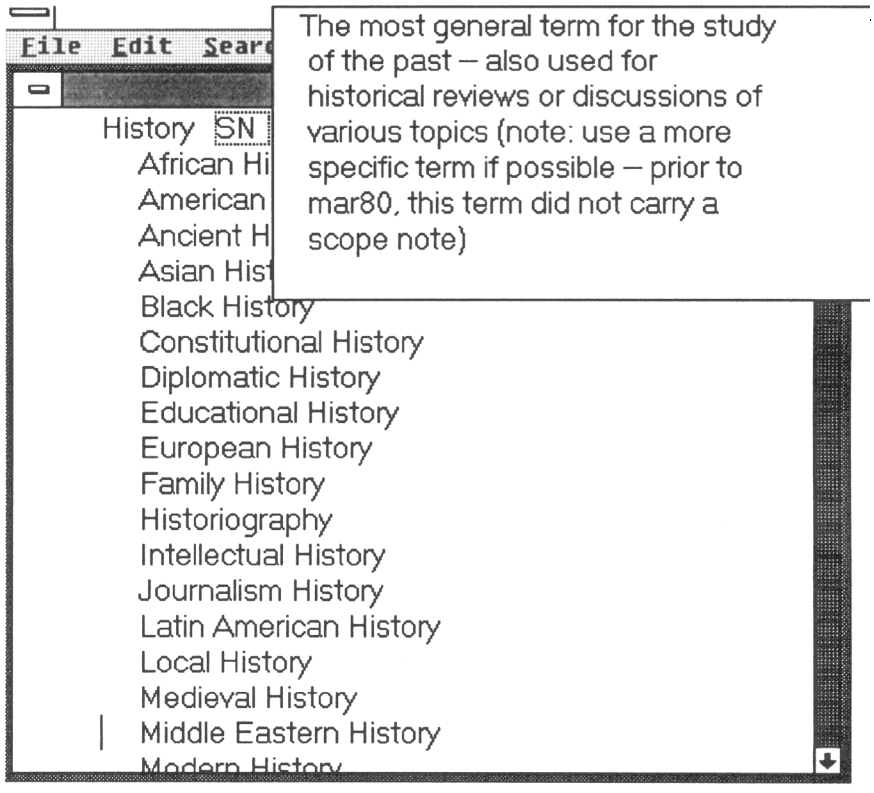

Figure 14. Scope note displayed in a pop-up window

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REFERENCES

1. M. E. Frisse, 'Searching for information in a hypertext medical handbook', *Communications of the Association for Computing Machinery*, **31** (7), 880–886 (1988).
2. J. H. Walker, 'Document Examiner: Delivery interface for hypertext documents', *Hypertext '87 Proceedings*, 307–323 (1989).
3. D. R. Raymond and F. W. Tompa, 'Hypertext and the Oxford English Dictionary', *Communications of the Association for Computing Machinery*, **31** (7), 871–879 (1988).
4. J. Nielsen, 'Three medium-sized hypertexts on CD-ROM', *SIGIR Forum*, **24** (1–2), 2–10 (1989/90).
5. Educational Resources Information Center, *Thesaurus of ERIC descriptors*, Oryx Press, Phoenix, AZ, 1987.
6. *International Standard ISO 2788: Documentation—Guidelines for the establishment and development of monolingual thesauri*, International Organization for Standardization, 1986.

7. J. Aitchison and A. Gilchrist, *Thesaurus construction: A practical manual*, Aslib, London, UK, 1987.
8. F. W. Lancaster, *Vocabulary control for information retrieval*, Information Resources Press, Arlington, VA, 1986.
9. L. M. Chan and R. Pollard, *Thesauri used in online databases: An analytical guide*, Greenwood Press, Westport, CT, 1988.
10. R. Fidel, 'Controlled Vocabulary and free-text searching: Searchers' selection of search keys', *Proceedings of the American Society for Information Science Annual Meeting*, 71–73 (1987).
11. B. H. Weinberg and J. A. Cunningham, 'The design of online thesauri', *National Online Meeting*, 411–419 (1988).
12. B. Shneiderman, 'Reflections on authoring, editing, and managing hypertext', in *The Society of Text*, ed. E. Barrett, MIT Press, Cambridge, MA, pp. 115–131, 1989.
13. J. Conklin, 'Hypertext: introduction and survey', *IEEE Computer*, **20** (9), 17–41 (1987).
14. R. McAleese and E. B. Duncan, 'The graphical representation of 'terrain' and 'street' knowledge in an interface to a database system', *International Online Information Meeting*, 443–456 (1987).
15. F. G. Halasz, T. P. Moran, and R. H. Trigg, 'NoteCards in a nutshell,' *Proceedings of ACM CHI+GI*, Toronto, Canada, April 1987, pp. 45–52.
16. C. F. McMath, R. S. Tamaru, and R. Rada, 'A graphical thesaurus-based information retrieval system', *International Journal of Man-Machine Studies*, **31**, 121–147 (1989).
17. J. E. Sammet and A. Ralston, 'The new (1982) computing reviews classification system—final version', *Communications of the Association for Computing Machinery*, **25** (1), 13–25 (1982).
18. S. Bertrand-Gastaldy and C. H. Davidson, 'Improved design of graphic thesauri through technology and ergonomics', *Journal of Documentation*, **42** (4), 225–251 (1986).
19. J. Viet and G. van Slype, *EUDISED multilingual thesaurus for information processing in the field of education*, Mouton, Berlin, 1984.
20. R. M. Akscyn, D. L. McCracken, and E. A. Yoder, 'KMS: a distributed hypermedia system for managing knowledge in organizations', *Communications of the Association for Computing Machinery*, **31** (7), 820–835 (1988).
21. P. J. Brown, 'Do we need maps to navigate round hypertext documents?', *Electronic Publishing: Origination, Dissemination and Design*, **2** (2), 91–100 (1989).
22. K. Utting and N. Yankelovich, 'Context and orientation in hypermedia networks', *Association for Computing Machinery Transactions on Information Systems*, **7** (1), 58–84 (1989).
23. OWL International Inc., *GUIDE: Hypermedia information system, version 3.0*, Bellevue, WA, 1990.
24. R. H. Trigg and M. Weiser, 'Textnet: a network-based approach to text handling', *ACM Transactions on Office Information Systems*, **4** (1), 1–23 (1986).
25. J. Nielsen, 'The art of navigating through hypertext', *Communications of the Association for Computing Machinery*, **33** (3), 296–310 (1990).
26. P. J. Brown, 'Turning ideas into products: The GUIDE system', *Hypertext '87 Proceedings*, 33–40 (1989).
27. J. Nielsen and U. Lyngbæk, 'Two field studies of hypermedia usability', *Proceedings of the Hypertext II Conference*, York, UK (1989).
28. J. D. Gould, 'How to design usable systems', in *Handbook of Human-Computer Interaction*, ed. M. Helander, Elsevier Science Publishers, Amsterdam, pp. 757–789, 1988.
29. D. E. Egan, *et al*., 'Formative design-evaluation of SuperBook,' *ACM Transactions on Information Systems*, **7** (1), 30–57 (1989).
30. R. Furuta, C. Plaisant, and B. Shneiderman, 'A spectrum of automatic hypertext constructions', *Hypermedia*, **1** (2), 179–195 (1989).
31. P. R. Churcher, 'A common notation for knowledge representation, cognitive models, learning and hypertext', *Hypermedia*, **1** (3), 235–254 (1989).