TRANSFORMING TEXT INTO HYPERTEXT FOR A COMPACT DISC ENCYCLOPEDIA

Robert J. Glushko

Search Technology, Inc.
4725 Peachtree Corners Circle, #200
Norcross, GA 30092

ABSTRACT
A hypertext version of a multi-volume engineering encyclopedia on a compact disc is described. The methods for characterizing the explicit and implicit structure of the document, the novel user interface to the compact disc version, and the design and development lessons that apply to any hypertext project involving realistic amounts of text and graphics are discussed.

KEYWORDS: Browsing, CD-ROM, compact disc, documents, encyclopedia, hypermedia, hypertext, searching, text.

INTRODUCTION
The *Engineering Data Compendium* [3] is a highly specialized encyclopedia containing comprehensive reference data about human perception and performance. Its four volumes include nearly 3000 pages of text and more than 2000 figures, tables, and illustrations. The *Compendium*'s primary users are designers of aircraft cockpits, control rooms, or other systems with complex user interfaces.

Recently, I led a team that designed and built a compact disc version of the *Compendium.* A user-oriented and document-oriented methodology was implied by our objectives:

1) Build upon the experience people have with printed reference books;

2) Preserve and enhance the extensive organization and user aids explicitly designed into the printed version;

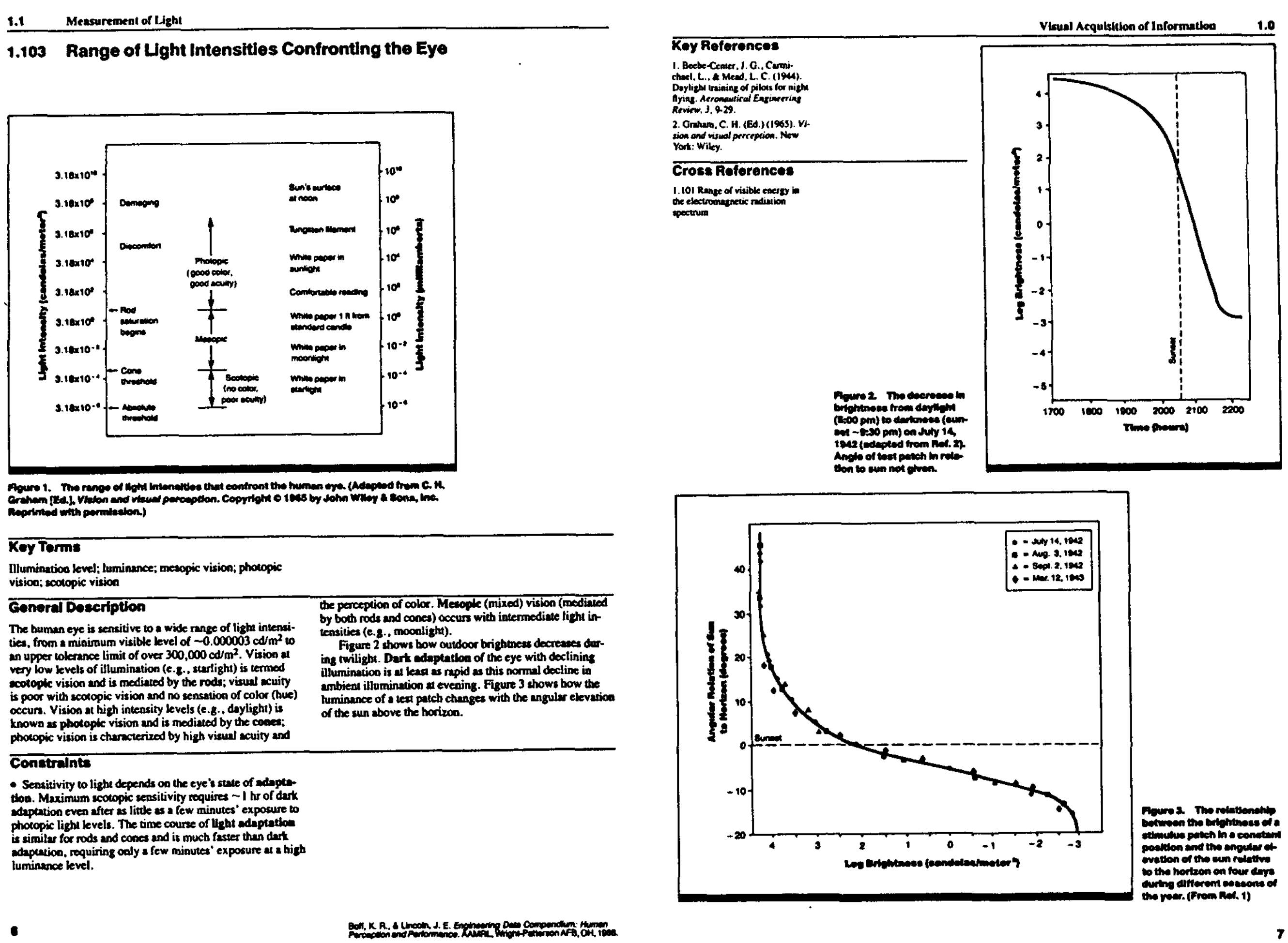
3) Make use of the structure implicit in the printed version that is not fully exploited because of constraints in the printed form or the process by which it was developed; and

4) Devise additional features to enhance the accessibility and usability of the information in the *Compendium.*

This approach contrasts with the technology-driven approach seen in many other compact disc document collections, which have apparently been transformed from their printed forms by mechanical application of full-text indexing. Not surprisingly, the *Compendium's* user interface also differs significantly from that provided on most compact discs. Most discs rely on Boolean search of the full text as the primary method of finding information [4], despite ample evidence that people find such interfaces hard to use [16]. In contrast, our user interface exploits the Table of Contents, the "back-of-the-book" Index, and other parts of books with which users are highly familiar.

This project was not a "proof of concept" or prototype demonstration with a small, ad hoc document database. It was a full-scale research and development effort to transform a multi-volume reference book into compact disc form while exploring new concepts in information storage and information retrieval. We made extensive use of "hypertext", defined by Conklin [5] as computer support for links within and between documents. Hypertext is not a new concept, but it has recently been popularized by new software tools for user interface design such as Apple's *HyperCard*(Tm) and OWL's *Guide*(Tm).

Creating a hypertext encyclopedia with realistic amounts of text and graphics is an engineering problem that requires disciplined methods for characterizing the physical and logical structure of the document, identifying the constraints embedded in this structure and in the target environment, and making the required trade-offs. We are far from a systematic view of "hypertext engineering," but the lessons we learned from this project are a start [8].


1.1 Measurement of Light

1.103 Range of Light Intensities Confronting the Eye

Figure 1. The range of light intensities that confront the human eye. (Adapted from C. H. Graham [Ed.], *Vision and visual perception*. Copyright © 1965 by John Wiley & Sons, Inc. Reprinted with permission.)

Key Terms

Illumination level; luminance; mesopic vision; photopic vision; scotopic vision

General Description

The human eye is sensitive to a wide range of light intensities, from a minimum visible level of ~0.000003 cd/m² to an upper tolerance limit of over 300,000 cd/m². Vision at very low levels of illumination (e.g., starlight) is termed **scotopic** vision and is mediated by the **rods**; visual acuity is poor with scotopic vision and no sensation of color (hue) occurs. Vision at high intensity levels (e.g., daylight) is known as **photopic** vision and is mediated by the **cones**; photopic vision is characterized by high visual acuity and the perception of color. **Mesopic** (mixed) vision (mediated by both rods and cones) occurs with intermediate light intensities (e.g., moonlight).

Figure 2 shows how outdoor brightness decreases during twilight. **Dark adaptation** of the eye with declining illumination is at least as rapid as this normal decline in ambient illumination at evening. Figure 3 shows how the luminance of a test patch changes with the angular elevation of the sun above the horizon.

Constraints

- Sensitivity to light depends on the eye's state of **adaptation**. Maximum scotopic sensitivity requires ~1 hr of dark adaptation even after as little as a few minutes' exposure to photopic light levels. The time course of **light adaptation** is similar for rods and cones and is much faster than dark adaptation, requiring only a few minutes' exposure at a high luminance level.

6

Boff, K. R., & Lincoln, J. E. *Engineering Data Compendium: Human Perception and Performance*. AAMRL, Wright-Patterson AFB, OH, 1988.

Visual Acquisition of Information 1.0

Key References

1. Beebe-Center, J. G., Carmichael, L., & Mead, L. C. (1944). Daylight training of pilots for night flying. *Aeronautical Engineering Review, 3*, 9-29.
2. Graham, C. H. (Ed.) (1965). *Vision and visual perception*. New York: Wiley.

Cross References

1.101 Range of visible energy in the electromagnetic radiation spectrum

Figure 2. The decrease in brightness from daylight (5:00 pm) to darkness (sunset ~9:30 pm) on July 14, 1942 (adapted from Ref. 2). Angle of test patch in relation to sun not given.

Figure 3. The relationship between the brightness of a stimulus patch in a constant position and the angular elevation of the sun relative to the horizon on four days during different seasons of the year. (From Ref. 1)

7

Figure 1. Typical entry from the *Engineering Data Compendium*, reduced from two facing pages in the printed version. Figures 2 and 3 show this entry as it is displayed from the compact disc.

THE ENGINEERING DATA COMPENDIUM

The *Engineering Data Compendium* is a multi-volume engineering encyclopedia whose 1138 entries contain comprehensive data on human perception and performance. In printed form, the *Compendium* is organized in three primary volumes that contain the entries. A fourth volume, the *User's Guide*, contains a Table of Contents, Index, Glossary, and other aids for finding relevant entries.

Figure 1 above shows a typical *Compendium* entry (reduced from two facing pages).

The *Compendium* is the latest product of a long-term research and development program aimed at making human perception and performance data more accessible and useful to designers with little knowledge or experience in the subject areas. The core information in the *Compendium* comes from the highly-regarded *Handbook of Perception and Human Performance* [2], transformed from a researcher's perspective to a practitioner's perspective.

This transformation required detailed study of how designers use human performance data [1][9], and this task analysis led to a novel format for presenting technical information that makes the *Compendium* highly usable in printed form [10]. This format also makes the *Compendium* an excellent candidate for hypertext representation on a compact disc. The format includes:

* Information segmented into small, self-contained entries that deal with narrow, well-defined topics. In the printed version, entries typically appear as a single spread of two 8.5 x 11 inch facing pages.

* Entries arranged according to a hierarchical table of contents in twelve broad topic areas and in several dozen sections and sub-sections. Each entry has ten explicit cross-references to other entries and dozens of implicit cross-references based on shared key words and glossary terms.

* Entries highly structured and typically containing all or most of ten standard text parts (Title, Key Terms, General Description, Applications, Methods, Experimental Results, Empirical Validation, Constraints, Key References, Cross References).

* Entries centered around one or more figures, tables, or illustrations (approximately 2000) that depict the key findings.

THE COMPENDIUM ON COMPACT DISC

The compact disc version of the *Compendium* contains all of the text and graphics from the printed version. The text of the *Compendium* occupies about 20Mb, with the graphics requiring another 150Mb. In addition, the disc contains another 40Mb for various indexes.

The user interface design emerged from our experiences as users of reference books, from interviews with users of the printed *Compendium,* from field studies of how designers use information, and from a review of other systems. The user interface supports a wide variety of methods for finding relevant *Compendium* entries. These methods include browsing of the Table of Contents, Index, and other hierarchical user access points, searching using Boolean expressions, and following links among related entries.

Hierarchical Browsing

The user interface emphasizes hierarchical browsing of the Table of Contents, Index, and other hierarchical user aids as a means for finding relevant *Compendium* entries. This is not "browsing" in the sense of casual, undirected, serendipitous information-seeking activity that is often contrasted with Boolean search [11]. We define hierarchical browsing as exploration by the progressive display of detail, and it is especially appropriate and effective for richly structured access points like the Table of Contents. Hierarchical browsing allows the user to exploit the extensive organization of the *Compendium* in locating information, in contrast to Boolean search of the full text, which ignores this structure.

The browser was designed after studying several other browsers to discover the range of functions they provide. Following the study, we identified seven distinct functions in *ThinkTank*(Tm), *Document Examiner*(Tm) [17], *NaviText SAM*(Tm) [13], *Guide*(Tm), and *KnowledgeSet*(Tm). These browsers differ remarkably in how they provide these functions (e.g., representing "where you are" and how details are expanded or hidden). More exploration of the design space and careful observation of the usability of different browsers is needed.

In the browser, the initial display of the Table of Contents contains only the 12 major topic areas into which the 1138 entries are arranged. Selecting an item expands it to show the levels below it in the hierarchy. At the same time, the details in other parts of the hierarchy are hidden from view. This "fisheye" view helps to focus the user's attention on the most recently selected item [7]. When the selected item is an entry number, the entry is displayed on the screen.

The printed Index contains over 2000 top-level headings and 10,000 items in all. An alphabetic level (i.e., the letters A to Z) was added to make it easier for the user to locate a starting point in the Index hierarchy. Because the *Compendium* contains many engineering and scientific terms with many distinct senses, it can be more efficient and precise to browse the Index than to search the full-text. This design guideline should hold until computer-generated indexes are as good as the ones created by human indexers!

Searching

The user interface supports Boolean search of the full text of the *Compendium,* and each of the ten text parts of each entry is treated as a separately-indexed field. But, our task analysis led us to use fields in a subtly different manner than most search interfaces. First, we define as the default search scope the Title, Key Terms, General Description, Application, and Captions fields of the entries. This increases precision by limiting searches to those fields that are most likely to contain the information needed by designers. Users can change the set of fields for other search tasks; for example, limiting the search to the Methods field may be appropriate for a researcher looking for uses of a particular experimental technique.

Second, the user receives the results of a search as a list of the matching entries, not as a list of matching fields. Users are more interested in knowing how many entries match the query than in knowing how many fields match. Selecting an entry from the results list displays it on the screen.

Finally, when viewing one of the entries found by a search, the user can select the "Next Hit" or "Previous Hit" from the list of candidate entries. This function was modeled after the familiar process of sticking your thumb in the Index at the back of the book to hold your place while you go back and forth to view each entry.

Viewing Entries

When an entry is selected, it is displayed in a "viewer window" that occupies most of the display screen. The text and graphic portions of each entry are displayed separately, and the user must alternate among them. This aspect of the user interface design was largely dictated by the computing environment most available to our intended users, the industry-standard PC or AT-class microcomputer with a standard 13-inch diagonal display screen.

Several alternative designs were experimented with and rejected for displaying text and graphics. Side-by-side text and graphics windows and a single window in which graphics were embedded in the text led to graphics that were difficult to read because they were too small. Resizable text and graphics windows made sense in principle, but many of the figures and tables contained multiple panels or spanned more than one page, so making them smaller made little sense. A better solution was to break up the complex graphics into parts. This approach made it possible to make the graphics larger and more legible on the small screen. Still, the resolution of the graphics is limited to 80 pixels per inch on the typical 640x400 pixel monitor, which suffers in comparison to the 300 bits per inch resolution offered by the printed page.

Figure 2 below shows how the screen appears when the text portion of the *Compendium* entry shown in Figure 1 is displayed in the viewer window. This figure also shows several of the important features of the user interface. Features whose role may not be obvious include:

The Main Menu. The main menu always appears at the top of the screen to show functions that are always available. On a larger screen, these functions might be arranged in dedicated windows. Novel functions invoked from this menu include bookmarks for returning to previously viewed or marked entries, and a facility for making notes on an entry or other part of the *Compendium.*

The Context Line. The context line describes the user's current context, and is the line just below the menu at the top of the screen. In Figure 2 the context is the title of the entry being viewed.

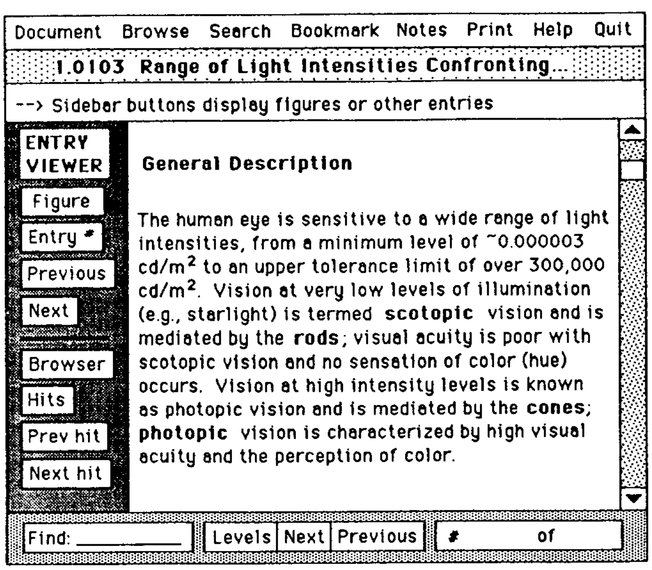


Figure 2. Appearance of the screen when the *Compendium* entry shown in Figure 1 is displayed from the compact disc. Sidebar and Bottom Panel contain context-sensitive buttons that support hypertext functions.

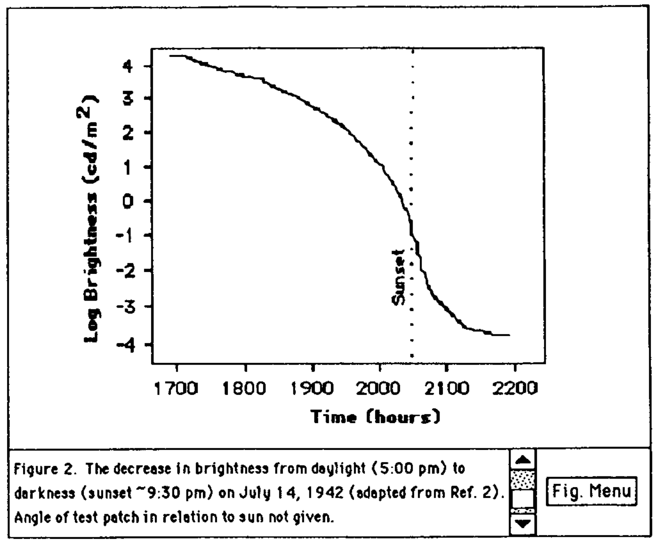


Figure 3. Appearance of the screen when one of the figures from the *Compendium* entry shown in Figure 1 is displayed from the compact disc.

The Help Line. The help line is the third line, below the Context Line, which contains a brief context-sensitive help message. More detailed context-sensitive help appears if the user selects HELP from the main menu.

Sidebar (here labeled Entry Viewer) and Bottom Panel. These are context-sensitive areas that present various "function buttons" and information areas. Here the Sidebar supports several hypertext functions to display the figures or other graphics associated with the entry or other related entries. The Bottom Panel contains functions that enable the user to locate and "jump" to words that occur in the text displayed in the browser or in the entry viewer.

Hypertext Functions

The top button, labeled "Figure", displays a menu of the figures, tables, and illustrations contained in the entry being viewed. Selecting one of the items from the menu displays it in the viewer window, as shown above in Figure 3.

In Figure 2, the three buttons below "Figure" in the sidebar invoke links to other *Compendium* entries to display them in the viewer window. "Entry#" displays any entry specified by number, while "Next" and "Previous" display entries that follow or precede the current entry in the Table of Contents order.

The remaining four sidebar buttons are enabled when their functions are contextually appropriate. "Browser" is enabled if the entry was selected by browsing the Table of Contents, Index, or other hierarchical access point; selecting it returns to that context. The "Browser" function was designed by analogy to "Hits", which returns the user to the list of candidate entries located by a Boolean search. "Previous Hit" and "Next Hit" are shortcut methods of selecting from the most recent candidate list.

Besides the hypertext functions that are invoked by explicit sidebar "buttons", several other navigation and information retrieval functions are supported. An entry can be displayed by selecting it from the list of Cross References. Users can also follow the implicit links between entries based on shared Key Terms. Selecting a key term displays a list of entries that share the term, and choosing one of them displays it in the viewer window. Another set of links are between the first occurrence of a Glossary term in the text and its definition. Selecting a highlighted term "pops up" a window that contains the definition.

TRANSFORMING TEXT INTO HYPERTEXT

It may appear that the *Compendium* is inherently well suited for hypertext. The core notions of hypertext are that modular text entities are linked together, and to make it easy to follow the links, the text and links are supported on a computer. Similarly, the essence of an encyclopedia is that it is a collection of text units that are designed to stand alone as separate modules but which are enhanced by cross-references to other entries. Nevertheless, though the task of translating encyclopedia text into hypertext seems simple, it defies a straightforward solution. The basic problem with the simplistic model of going from text to hypertext is that it can be difficult to identify the text units and link structure, even for an encyclopedia.

Identifying the Text Units

The *Compendium* entries have unique titles, which makes it natural to design the hypertext version with them as the basic text units. A good design rule might be to choose as the basic text unit the smallest logical structure with a unique name. The unique names are easy to refer to and manipulate in the user interface. Entries serve as the "selection key" in the hierarchical browser, in candidate lists as the result of a search, as "bookmarks" of previously viewed information, and as embedded cross references.

In contrast, physical structures of documents like pages or paragraphs are less suited as hypertext units because they have less relevance for the user and are hard to attach a "handle" to in the user interface.

Identifying the Links

It is more challenging to build the links between related information in a hypertext document. The hypertext designer must understand both the explicit and implicit link structure in the printed version. Each of the 1100 *Compendium* entries has about 10 explicit cross-references to other entries, and dozens more implicit ones based on shared key terms and glossary items. Thus it might have been possible to create hundreds of thousands of links on our disc. We had to decide which links to create, and which ones to not create. We chose to limit the number of links unless we were sure that they were "good" ones. Most of the possible links are not good ones.

The hype of hypertext in the popular computing press is that links are powerful and exciting -- the user can sail in a sea of text units, following links between items that are related in some interesting way. The user might start reading about Buffalo, New York and end up finding out about the design for the Buffalo nickel. For designers using a reference book to answer design questions, however, this model of hypertext is misguided. **The challenge for hypertext designers is to understand the user's task, and to support links that follow from some model of the user's need for information in some particular context.** Unless the user's task is to wander and explore the document, it is essential NOT to link pieces of information that are related in idiosyncratic or superficial ways. Unconstrained hypertext linking leads to spaghetti documents that like spaghetti code contain too many gotos. Instead of creating a "spaghetti document" with the resulting disorientation problems that others have noted [5] [6], it seems more sensible to prevent the disorientation caused by unconstrained linking. Without careful analysis of how users make use of the hypertext structures already explicit in and implied by the printed *Compendium*, it is premature to add new ones.

LESSONS LEARNED: TOWARD "HYPERTEXT ENGINEERING"

The *Engineering Data Compendium* was inherently an excellent document to transform to hypertext because of its modular structure and numerous links. Nevertheless, months of work was required to develop a complete understanding of the *Compendium* and to analyze the tasks for which it is used. A project of this scale is impossible without a comprehensive understanding of the document and its users. We were fortunate to have one of the editors of the *Compendium* as the project sponsor and the other as a member of the design team.

We have conveyed some of the lessons learned about how to identify and exploit the structure of a document in transforming it to hypertext. We know the value of these insights because they did not come cheaply. From conception to completion this project cost about $250,000, and the portion attributed to design and analysis is much larger than that due to text and graphics processing. Given the costs of a real project with realistic amounts of information, it is not surprising that the published literature on hypertext contains little work directly relevant to the scale or scope of the problems we faced in our project. (Most of the hypertext literature deals with *creating* small hypertext documents, not *converting* large documents to hypertext). We found useful lessons in the *Document Examiner* [17], *Navitext* [13], *Oxford English Dictionary* [14], and *Superbook* [15] projects. Oren's paper describing lessons learned from the *Grolier's Electronic Encyclopedia* project was also helpful [12].

Hypertext is an attractive concept and coupled with the enormous storage capacity of compact discs it opens up exciting new possibilities for information storage and retrieval. To make it more than a buzz word involved a mixture of research, engineering, and tedious "grunt work" that we had not anticipated, but which we now believe characterizes any hypertext project of realistic scale.

ACKNOWLEDGMENTS

This work was supported by the Designer's Associate project, AF #F33615-86-C-0542. Dr. Kenneth Boff of the Armstrong Aerospace Medical Research Laboratory at Wright-Patterson AFB, Ohio is not only the sponsor of this project but the principal designer and editor of the *Compendium.* We are grateful for his support and patience. Dr. Janet Lincoln, the co-editor of the *Compendium,* provided invaluable help as a member of the design team. Also, Tom Coonan and Mark Weaver of Search Technology, Inc. were key members of the design group.

Mike Adams from Iopis Corporation of Columbus, Ohio managed the premastering of the text and graphics. He also managed the user interface implementation work done by Jack Johnson, Steve Keller, and Leonard Rivers.

REFERENCES

1. Boff, K.R. The tower of Babel revisited: On cross-disciplinary chokepoints in system design. In W. B. Rouse and K. R. Boff (Eds.), *System Design: Behavioral perspectives on designers, tools, and organizations.* New York: Elsevier.

2. Boff, K.R., Kauffman, L., and Thomas, J. *Handbook of perception and human performance.* New York: Wiley, 1986.

3. Boff, K.R., and Lincoln, J.E. (1988). *Engineering Data Compendium: Human Perception and Performance.* AAMRL, Wright-Patterson AFB, OH.

4. Carr, R. New user interfaces for CD ROM. In S. Lambert and S. Ropiequet (Eds.) *CD ROM: The New Papyrus.* Redmond, WA: Microsoft Press, 1986, 185-196.

5. Conklin, J. Hypertext: An introduction and survey. *Computer,* 20(9), (Sept. 1987), 17-41.

6. Foss, C. Effective browsing in hypertext systems. *User-oriented content-based text and image handling.* Proceedings of the RIAO Conference, March 21-24, 1988, 83-98.

7. Furnas, G. Generalized fisheye views. In *CHI'86 Conference Proceedings* (Boston, 1988), 16-23.

8. Glushko, R.J, Weaver, M.D., Coonan, T.A., and Lincoln, J.E. (1988). "Hypertext Engineering": Practical methods for creating a compact disc encyclopedia. In *Proceedings of the ACM Conference on Document Processing Systems,* 11-20.

9. Klein, G., and Brezovic, C. Human performance data needed for training device design decisions. AAMRL-TR-87-010, March 1987.

10. Lincoln, J.E., and Boff, K.R. (1988). Making behavioral data useful for system design applications: Development of the *Engineering Data Compendium. Proceedings of the Human Factors Society 32nd Annual Meeting,* 1021-1025.

11. Marchionini, G., and Shneiderman, B. Finding facts vs. browsing knowledge in hypertext systems. *Computer* 21,1 (Jan. 1988), 70-80.

12. Oren, T. The architecture of static hypertexts. *Hypertext '87 Papers.* Proceedings of a conference held at the University of North Carolina, Chapel Hill. November 13-15, 1987, 291-306.

13. Perlman, G., and Moorhead, A. Applying hypertext methods for effective utilization of standards. *Proceedings of COMPSTAN'88 Conference on Computer Standards,* IEEE.

14. Raymond, D., and Tompa, F. (1988, July). Hypertext and the new *Oxford English Dictionary. Communications of the ACM,* 31(7), 871-879.

15. Remde, J., Gomez, L., and Landauer, T. SuperBook: An automatic tool for information exploration -- Hypertext? *Hypertext '87 Papers.* Proceedings of a conference held at the University of North Carolina, Chapel Hill. November 13-15, 1987, 175-188.

16. Thomas, J. (1983) Psychological issues in the design of data-base query languages. In *Designing for human-computer communication* (M. Sime and M. Coombs, Eds.). London: Academic Press.

17. Walker, J. Document examiner: Delivery interface for hypertext documents. *Hypertext '87 Papers.* Proceedings of a conference held at the University of North Carolina, Chapel Hill. November 13-15, 1987, 307-323.