



Focus on Links: A Holistic View of Hypertext

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The disciplines of human-computer interaction, computer-supported collaborative work, information storage and retrieval, and artificial intelligence should complement one another in the new discipline of hypertext. This holistic view of hypertext focuses on links: links within a document (microtext), links among documents (macrotext), links among people (grouptext), and dynamic links (expertext). The principles and systems which are relevant to creating and accessing hypertext can be usefully presented under the headings of text, microtext, macrotext, grouptext, and expertext. From text to expertext, people consistently use hierarchical structures, particularly hierarchical semantic nets, to organize information. (Author)

1. Introduction

Hypertext is a popular term with an unclear meaning. In the literal sense the term implies extra dimensions to text. In practice the term is often applied to computer systems which allow a person to browse a document by gracefully jumping from text block to text block. Yet this notion of extra dimensions is limiting. The argument advanced here is that hypertext is most profitably viewed as a combination of dimensions that extends across large document collections, across collaborative work, and across artificial intelligence. One must start with an understanding of text and from there develop the perspectives that will allow the specification of new hypertext systems for the 1990s.

This examination of hypertext de-emphasizes the role of audio and video links. Clearly, hypermedia is the dominant force, as it includes hypertext. But one cannot effectively understand hypermedia without understanding hypertext.

2. Text

Hypertext is an extension of text, and to understand hypertext one must first understand text. Text is a recorded body of information. The terms text and document are synonymous, and while text contains predominantly natural, written language, it may contain graphics.

Six thousand years ago in the cradles of civilization, people were recording information on clay or papyrus. Thousands of years passed before significant libraries

were created. The introduction of the printing press in the middle ages took a century to influence the distribution of documents. New technologies for text take root gradually (1).

2.1 Text Principles

The words that form a text are the raw material from which a mental representation of the meaning of that text is first constructed. Local coherence is then established across sentence boundaries. Language users must establish coherence quickly (2). The language user makes preliminary hypotheses about local coherence from the title and first words of the text and from knowledge about global situations.

Readability means the relative ease with which texts can be read and remembered. Traditional readability models deal primarily with surface variables, such as sentence length. An adequate model of readability must account for the cost of constructing complex memory structures.

A good writer must produce a coherent text, but the process of writing is otherwise not necessarily like the process of reading. The three phases of writing a document are exploring, organizing, and encoding. These correspond in paper to notes, outlines, and prose, respectively. Authors like to move freely from one phase to another and are influenced by their own memory, the writing assignment, and the evolving text (7) (see Figure 1).

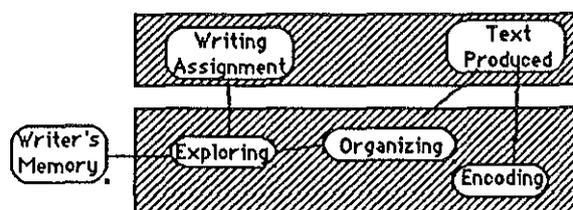


Figure 1: Writing Model.

2.2 Text Systems

To convert the abstract form of a text into a concrete visualization the author needs a layout language. The languages for the specification of layout come in two

generic forms. One requires commands embedded within text, while the alternative involves the direct manipulation of the physical appearance with a "What You See Is What You Get" environment.

To make electronic information more exchangeable, standards of logical document structure are useful. The Standard Generalized Markup Language is a language for logical document structure and is an international standard for publishing (11). It is based on the principles of generic encoding of documents and marks a document's logical structure, such as section headings, and not the document's physical presentation.

Tangibility is important to readers, and the tangibility of paper is greater than that of computer screens (6). While reading is typically easier on paper than on computer, the same does not apply to writing. The features of a computer tool for writing are often more attractive than that of a paper and pen tool. Writing tools have evolved from editors to word processors to outliners to desktop publishers. Outliners help the writer organize thoughts and attach text to the thoughts. Desktop publishing systems facilitate the addition of graphics and the layout of text.

3. Microtext

Microtext is text with explicit links among its components. A microtext system provides a computer medium for manipulating the links of microtext. A microtext system particularly supports browsing. The first microtext system was called the Augmentation System and was developed in the 1960s as an authoring and browsing tool (4).

3.1 Microtext Principles

An object-oriented design for microtext well suits the character of microtext and uses basically three objects: nodes, links, and attributes. A node contains arbitrary data, including text or images. A link relates two nodes. Attributes can be attached to nodes or links.

A reader is unlikely to want to see only one sentence, and the linking of a document would be excessively tedious, if it had to go at the sentence level. But a paragraph intuitively seems to be the right size for presentation in a window and for linking. Thus a natural object for microtext is the paragraph.

The screen presentation, the way the text is stored internally, and ways of logically viewing the text may differ. In Figure 2 the screen shows a text block with labeled links as three numbered ellipses. Internally the text is a flat file with markup commands. In one of the logical views, text fragments are the leaves of a tree whose branches are the labeled links. While the screen presentation omits an explicit name for the text block, such a name exists, and in the internal representation and logical representation of Figure 2 use the label 0 for the text block as a whole.

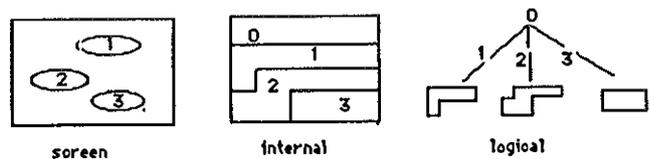


Figure 2: Screen, Internal, and Logical Views.

The network of microtext may be viewed as a semantic net. Semantic nets are models of human memory. The nodes and links of the net are labeled with terms that represent concepts. The semantic net of microtext may be independent or embedded (12). In the independent case, the nodes and links are tagged with terms that represent concepts (per the usual semantic net), but each node or link may point to text blocks (see Figure 3). When a user is presented with an independent semantic net microtext, he may traverse the semantic net without seeing a text block. In the embedded case, a text block is at the end of a link. In traversing an embedded semantic net, the user must visit text blocks.

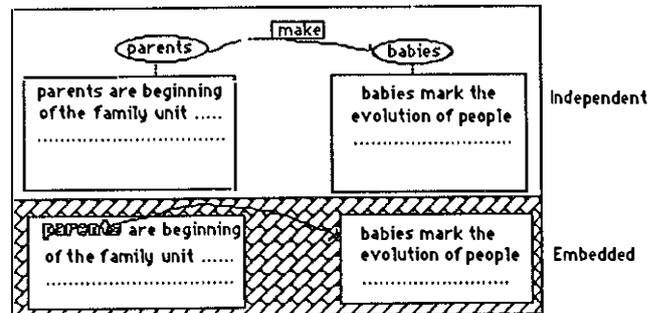


Figure 3: Independent versus embedded semantic net of microtext.

3.2 Microtext Systems

All of the popular microtext systems are of the embedded rather than independent semantic net type. NoteCards, HyperCard, and HyperTies emphasize the connecting of one text block to another. The user selects a highlighted term in one text block in order to see another text block. Guide, KMS, and Emacs-Info follow the model of highlighted terms in one text block pointing to other text blocks, but these microtext systems indirectly provide an independent semantic net. In Guide, KMS, and Emacs-Info outlines are critically important, and these have an implicit "independent semantic net" character. An outline is a restricted type of semantic net.

The importance of giving users an overview of the network of concepts was not lost to the developers of NoteCards. NoteCards provides special cards with a semantic net whose nodes point to text blocks. The developers of HyperTies have realized the importance of outlines and are incorporating features to facilitate the managing of outlines.

3.3 Text and Microtext

If microtext is to be successful, the ability to translate easily between text and microtext is essential. Two classes of text should be distinguished: clearly-structured and implicitly-structured. The links of clearly-structured text can be readily extracted from the markup commands in the text. The links of implicitly structured text must be extracted manually. Examples of clearly-structured text are technical manuals, dictionaries, encyclopedias, and course catalogs. Essays and novels are examples of implicitly-structured text; the logical structure is not suggested by markup commands in the text.

Converting text to microtext has immediate economic importance because of the vast amounts of text that could be converted to microtext. The reverse process of converting microtext to text will become more important as the amount of available microtext increases. A traversal of the network of a microtext that prints every text block once and only once has effectively linearized the text. For a hierarchically structured microtext like Guide or KMS, translation of microtext to text is straightforward. The hierarchy is traversed in a depth-first fashion. If the hierarchy was designed with a sequence in mind, as is often the case, the resulting sequence tends to make sense. For a complex, non-hierarchical network a meaningful traversal is less obvious.

4. Macrotext

Macrotext is hypertext in the large. The emphasis is on the links that exist among many documents rather than within one document. Typically, many people have contributed documents to macrotext and an institution maintains a macrotext system. Both the interface to the document collection and the links among documents must be maintained. The user is searching for a few documents from a large set. A macrotext system doesn't support the browsing of a single document -- that is a microtext system facility. Traditionally, the term "information storage and retrieval" was used when talking about storing and retrieving many documents.

Vannevar Bush argued already in the 1930s for the importance of using modern technology to turn text into macrotext (10). Bush described a scenario in which one individual dealt with the text of many other individuals by placing connections among the text items. The National Library of Medicine in the United States of America built the first major macrotext system in the mid-1960s. In its first year that system stored citations for over 100,000 documents and handled several thousand queries.

4.1 Macrotext Principles

If the language of queries and documents is not unified at some point, a match can not be made between queries and documents. The traditional way of representing the content of documents in a macrotext system is to label

each document with a handful of terms from an indexing language. An alternative strategy is to represent a document by the words which occur with significant frequency within the document.

One of the most popular forms for an indexing language is a thesaurus. While a thesaurus in the lay use of the term suggests an alphabetically sorted list of terms with attached synonyms, in the context of macrotext a thesaurus is more. A thesaurus is a set of concepts in which each concept is represented by synonymous terms, broader concepts, narrower concepts, and related concepts. The broader and narrower concepts form a hierarchical semantic net. This hierarchy helps users find terms to represent their query.

In the simplest query, the user presents a single term to the system, and the system returns those documents which have been indexed with that term. More generally, index terms are combined with operators, such as AND. If one asks for all the documents that have been indexed with the term "optical disk" AND "encyclopedia", one would get the documents which had been assigned both of the index terms. This notion of operators between terms of the semantic net to support querying is not part of the microtext system armamentarium. A macrotext system will also typically allow a user to request all documents indexed by a term or indexed by any of the terms narrower than that term in the thesaurus -- this is another instance of exploiting the hierarchical structure of the indexing language.

To maximally exploit the computer, methods have been developed to index and retrieve documents based on patterns of words. A document may be perceived as being about the subject symbolized by a certain word, if that word occurs more frequently in that document than could be expected in a randomly chosen document. Even in such cases, however, determining hierarchies may be important. To reduce search time, documents will be clustered according to their word patterns. By then clustering the clusters, a hierarchy is created. A search can thus start at the root cluster and proceed in a depth-first manner to the cluster which best matches the query.

When a very large thesaurus is accessed via a computer screen, the user may need to change the contents of the screen many times to find the terms for a query. As the number of hierarchical levels increases, users take longer and make more errors. Accordingly, parallel modes of presentation should be provided so that users can get as quickly and easily to the places they desire as possible. These insights about organization and presentation which have been derived from experiences with macrotext systems also apply to microtext systems.

4.2 Macrotext Systems

The 1970s witnessed a rapid growth in the availability of macrotext via telephone lines and time-sharing computers. By the late 1970s over 300 macrotext systems were

operating. They provided accesses to over 60 million document citations and processed over 5 million queries a year. In the 1980s optical discs became inexpensive enough to substantially impact the method of delivering macrotext. Now an entire macrotext system can be supported by one personal computer with an optical disk.

The National Library of Medicine system which was developed in the 1960s remains one of the salient macrotexts. That system now contains citations to over 6 million biomedical articles. While it remains accessible via telephone lines, optical disc versions are increasingly popular.

One of the latest developments in macrotext is the merging of macrotext with microtext. The IDEX system from Office Workstations Limited allows users to search massive document databases through a thesaurus and by author, title, and date of publication. Additionally, once a document is found which seems interesting, the user can stay in the same system with the same interface and proceed to browse the entire document with the Guide microtext system (14). Several groups are exploring the combination of word-frequency strategies of macrotext with network strategies of microtext. In such systems the user first locates a block of text within a document by searching for a text block that has a certain pattern of words in it (5). Having found such a text block, the user then browses from that point along the network of the document.

4.3 Macrotext to Macrotext

Whereas for microtext the connection of text to microtext is a current research problem, methods of automatically or systematically moving texts into macrotext have been well-established. In many ways, macrotext systems have features which microtext systems may eventually emulate. The most fascinating of these features concerns the connection of one body of text to another. The Vocabulary Switching System was developed in the early 1980s to connect the indexing languages of 15 different macrotext systems (9). This System depends in large part on lexical matching of terms. The United Nations, the American National Institutes of Health, and many other organizations have sponsored work to connect indexing languages. No comparable effort has occurred within the microtext arena, but the dream of hypertext is to connect text across more than one document boundary. One can predict that macrotext methods will be explored for connecting one microtext to another.

5. Grouptext

Grouptext is text which is created or accessed by several people collaboratively. A grouptext system must allow people to create private or public information. Additionally, a grouptext system must support messaging. A database is needed to keep track of which author made

what changes to the document and when. Screen sharing becomes particularly challenging when people collaborate synchronously.

One compelling argument for collaborative writing is that good writing requires an understanding of the reader, and a collaborating author can serve as a reader (see Figure 4). Expert writers differ from novice writers in the extent to which they have sophisticated models of the reader (15). Experiences with children suggest that their writing and reading abilities improve more quickly under collaborative than under solo conditions (13).

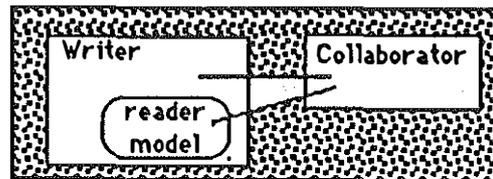


Figure 4: The writer has his reader model augmented by the collaborator.

Whereas in traditional databases a primary concern is to lock a record when one person uses it so that no one else will change it at the same time, the character of transactions for authoring calls for a different paradigm. Since a very large amount of material may be edited at once, the database should not require that one central server controls all events.

Instead, each user can have a copy of the database and changes are broadcast to a central server which subsequently checks for conflicts. In the case of conflict, those who participated in the conflicting changes are notified. They then must discuss among themselves how to resolve the conflict. This process of social mediation is contrary to the norm for databases but supports very rapid access for each user to arbitrary amounts of text.

In collaborative work another key ingredient is synchronous communication. The speed of electricity is so fast compared to the speed of human senses that a local network of computers can give every user the sense of sharing the same screen. Such 'What You See Is What I See' screen treatments allow actions that wouldn't be possible on paper. Furthermore, other media can be mixed with the computer one. Video and audio can be carried with the data signals and allow people to see and hear one another at the same time that they share the workspace of the screen.

Despite the flexibility of high technology to simulate the sense of being together without physically being near, studies suggest that people find physical proximity to be especially important in creating and maintaining collaborative efforts (8). New methods are needed to assess the impact of electronic media on work and to determine the conditions under which the computer can help people work together. There are many examples, such as the

PicturePhone (3), where technologists thought that society was ready for a new medium or way of work, but people preferred the traditional methods.

One analog of reading in the groupertext domain is annotation. As a group of people read a document on the computer, they can add notes that explain their reaction to the text. Not only might this help the authors revise the document, it might help other readers appreciate the various messages which the document contains. Group annotations on paper are difficult to manage. But with the computer many people can simultaneously make comments and others can elect to see or not see those comments. Furthermore, the look and feel of paper can be simulated with modern workstation software that allows the annotator to have a red pen and to write on the document. These annotations are, however, stored separately from the document, and any reader can elect to see them merged in various ways with the document or to ignore them entirely.

6. Expertext

While links within and among documents are critical to hypertext, the future of hypertext may depend on links that support complex computations. This computation capability converts hypertext into expertext as expertise is incorporated in the hypertext. The Dynabook microtext system of the 1970s had dynamic links. The user could cause different information to appear within a text block as a function of the traversal followed to that text block. Some of the most famous expert systems of the 1970s, such as MYCIN and INTERNIST, have been converted into systems that combine the facilities of expert systems and of hypertext systems.

The patterns in hypertext semantic networks can be exploited. One example of such a pattern is inheritance. If a node is connected by a hierarchical relation to another node, then the child node can be expected to inherit attributes of the parent node. A different kind of pattern is that exploited by spreading activation. In retrieval, one may want text blocks associated with nodes near another node. The computer can follow the links from a node and collect information from the user based on the assumption that two connected nodes are likely to have related information which the user may want.

Logic formalisms can be incorporated into the network representation so as to give hypertext the power of logic systems. If a node corresponds to a predicate and a link to an implication, then when the predicate at the node is true, the implication is activated. Rule-based expert systems are logic systems which can be represented as networks with nodes that are predicates. By associating text with the network, one converts an expert system into an expertext system. A product called Knowledge Pro does just this. An alternate example of a kind of logic system is a flow control model (also called Petri net model). Tokens are associated with nodes and links from a node are interpreted as transitions. A transition

can only be active when it has tokens in its source node. Models of hypertext have been based on the flow control model (16).

While on the one hand, the conversion of hypertext into a logic system provides inferencing capabilities, the logic approach also has its costs. Hypertext is intended to appeal to one's intuition--to be simple to create and to access. Logic systems are formal and not intuitive.

Procedures may be embedded in the links of hypertext. HyperCard is the most prominent example of a hypertext system that supports procedures on the links. The simplest procedure simply says to go to a certain card. But the procedures may be arbitrarily complex. For instance, the procedure may first ask the user about his background and then branch to one card or another based on the user's response -- all this within one link (see Figure 5).

```
on mouseUp
    answer "Do you have a theoretical background"
    with "yes" or "no"
    if it contains "no" then go card "simple"
    else go card "complex"
end if
end mouseUp
```

Figure 5: Example of procedure on link in HyperCard. When the user activates this link, the system will first ask a question and then make a decision.

Expertext systems will ultimately need to reference many different knowledge sources. For instance, one knowledge source may support the parsing of natural language queries. Another knowledge source may model user backgrounds and modify the interface style based on predictions of what the user wants. Another knowledge source may observe behavior across the population of users and make modifications to the knowledge of the system in accord with what users seem to want.

The applications of expertext can be divided into microexpertext, macroexpertext, and groupexpertext. Computer-assisted instruction is a prominent example of knowledge-based microtext. Macroexpertext systems exist which handle natural language queries and which search for documents based on knowledge about the documents. Groupexpertext systems have been built to monitor annotations or electronic mail and to notify participants when actions of one person should lead to responses by another.

Software engineering environments are a major application area for all of hypertext. For instance, the definition

of a subroutine in a program may be linked to the places where the subroutine is called in the program -- this is microtext. The program may be connected with the requirements document and the user's manual and with other programs that serve related purposes -- this is macrotext. Since groups of people inevitably write, read, and modify the documents of the software life cycle, groupertext is needed. In each of these areas, knowledge can be incorporated into the system to try to increase the productivity of the software engineers. Since software engineers naturally use computers as tools anyhow, the opportunities for improving those tools by incorporating expertext capabilities is riper in software engineering than anywhere else.

7. Epilogue

Hypertext applies to almost anything one might want to do with text and the computer. Furthermore, text itself is a broad notion that not only includes traditional documents, like books and reports, but also diverse items like messages or entries in a directory. Links are the drawing power of hypertext. In microtext, links among small blocks of text within a document are explicitly available to users. The user of a microtext system browses a document by following links. Macrotext is a collection of documents with links among the documents. Users search in a macrotext system across the links for the documents which they want. Groupertext connects people and the portions of the document which the people are modifying. Expertext has augmented links which support intelligent computations. All these aspects of hypertext belong under one roof and in a unifying discipline that differs from traditional computer science in its emphasis on documents and extends areas such as rhetoric by including the latest technological support.

The nodes and links of hypertext may often be fruitfully perceived as a semantic net. Across many developments in microtext, macrotext, groupertext, and expertext, one notices that hierarchical semantic nets are particularly valuable. People are comfortably creating and accessing hierarchies. Ways to systematically manage non-hierarchical semantic nets or non-hierarchical hypertext are less clear to people.

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