The Art of Navigating

through

HYPERTEXT

Hypertext (3), (19), (25) is becoming a popular approach to many computer applications, especially those dealing with the on-line presentation of large amounts of loosely structured information such as on-line documentation or computer-aided learning. There are still many issues concerning hypertext that remain to be resolved, however, many of which are in the user interface area. One

Users often become lost when exploring hypertext networks, but their individual interaction history can be used to increase the sense of context in the information space.

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the user interface area. One of the major usability problems with hypertext is the user's risk of disorientation while navigating the information space. For example, our studies [23] showed that 56 percent of the readers of a document written in one of the most popular commercial hypertext systems agreed fully or partly with the statement *I was often confused about 'where I was.'*

To investigate a number of user interface options in hypertext systems we designed a prototype system in the form of a hypertext report on events at the 1987 hypertext workshop. This system was implemented on an Apple Macintosh with HyperCard as the programming system. (To get a feel for our hypertext system, the reader is encouraged to review Figures 1 to 10 which contain screen dumps of a session with the system and thus constitute a kind of printed demonstration or guided tour.) Hypertext is a very dynamic form of human-computer interaction and can only be fully appreciated in an interactive environment. However, even these figures give a much better understanding of the system than a traditional textual description could give.

HYPERTEXT is non-sequential writing: a directed graph, where each node contains some amount of text or other information. The nodes are connected by directed links. In most hypertext systems, a node may have several out-going links, each of which is then associated with some smaller part of the node called an *anchor*. When users activate an anchor, they follow the associated link to its destination node, thus *navigating* the hypertext network. Users backtrack by following the links they have used in navigation in the reverse direction. *Landmarks* are nodes which are especially prominent in the network, for example by being directly accessible from many (or all) other nodes.

Many other computer techniques may match this definition at least partly, but true hypertext should also make users *feel* that they can move freely through the information according to their own needs. This feeling is hard to define precisely but certainly implies short response times and low cognitive load when navigating.

USABILITY TESTING

A main motivation for the work reported in this article was to study the usability of various hypertext interface design ideas. We will illustrate how many of the ideas turned out to be less usable and had to be changed during a process of iterative interface design. It is extremely important for the development of usable computer products to conduct empirical usability testing [10] since real users will always interpret some aspects of an interface design in other ways than intended by the designer.

The development method used during this iterative design was the "discount usability engineering" method [21] which aims at getting rapid feedback about various design ideas such that more iterations can be tested. Because of this focus, the method does not provide quantitative test results which can be reported to "prove" statistically that the redesigns are better than the original designs. When two users or so have been observed having problems with an aspect of the interface and when that problem can be explained on the basis of established usability principles, then it is best to fix the problem at once and continue the test with the new design.

The reason for wanting to proceed with testing the new design is that it may have usability problems of its own so that the most usable end result is achieved by running the design through the iterative loop as many times as possible. If it is not possible to understand the reason for a problem on the basis of general usability principles, then a more detailed test may, of course, be called for, e.g. the video tapes Egan et al. [4], [5] made of readers looking at individual paragraphs in order to discover why the readers understood a certain concept better when they read about it in a *SuperBook* hypertext than when they read a printed book.

Except for the unresolved issue of randomness depicted in Figure 7, we were able to explain all the observed usability problems in our iterative design on the basis of well-known usability principles. We will refer to these principles when we discuss each of the problems based on our qualitative usability testing.

NAVIGATION FACILITIES

This hypertext system has two navigational dimensions: A linear dimension used to move back and forth among the text pages within a given node, and a nonlinear dimension used for hypertext jumps. To reinforce users' understanding of these two dimensions, two different animation techniques are used when shifting from one screen to another. Unfortunately, animation is the one aspect of our user interface which is impossible to show well in a set of printed figures, so it

Version 1 of the hypertext system described in this article is available on a Macintosh format CD-ROM on the *BMUG PD-ROM vol. 1* (1988) [path Stacks: Hyper Media: HyperText Stacks Folder: HyperTEXT '87 Trip Report], published by Discovery Systems, 7001 Discovery Blvd., Dublin, Ohio 43017, U.S.A. Readers with electronic mail access can download Version 3 of the system (the version described in this article) from the *Info-Mac* archives as `hypercard/hypertext-report-part1.hqx` and `..part 2.hqx` (the InfoMac archives are available by using FTP (account *anonymous*, any password) in the info-mac directory on sumex-aim.stanford.edu [36.44.0.6]). One can also get a copy by sending electronic mail to: `listserv@icsa.rice.edu` or `listserv@rice.bitnet` with the following two lines in the body of the message:

```
$MACARCH GET HYPERCARD/HYPERTEXT-REPORT-PART1.HQX
$MACARCH GET HYPERCARD/HYPERTEXT-REPORT-PART2.HQX
```

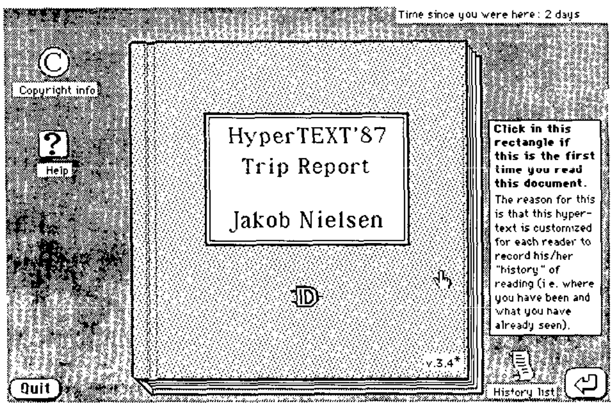
These two files should be concatenated and converted by the *StuffIt* utility which is available in many shareware collections.

is not included in the figures in this article.

Movement between pages within a node is seen as a linear left/right dimension, corresponding to the orientation of the scroll bars at the bottom of the screen and to the way printed books are read in Western society. A change to a new page along this dimension is visualized by an animated right or left wipe, using built-in visual effects from HyperCard which look quite like the turning of a page.

Hypertext jumps are seen as being orthogonal to the left/right page turning and are visualized as an in/out dimension using an animated iris which *opens* for anchored jumps and *closes* for return jumps. The opening iris gives users the impression of diving deeper into the hyperspace when they take a hypertext jump, and the closing iris for return jumps gives the inverse feeling of pulling back again.

We should note that both navigational dimensions are bi-directional, left/right or in/out, and that this bi-directionality is emphasized by the choice of user interface animation techniques.



Click in this rectangle if this is the first time you read this document. The reason for this is that this hypertext is customized for each reader to record his/her "history" of reading (i.e. where you have been and what you have already seen).

FIGURE 1

This is the opening screen of the hypertext system. It includes buttons for getting help and other general information and an option to reset the recorded user history. This screen serves as the "landmark" of the hypertext structure and is accessible from throughout the system by clicking on the *Front cover* icon.

The most prominent graphic on this screen is a picture of a book which is intended to convey a general sense of the nature of the data in this information base. If the user clicks on the name of the author of the book, a new screen will be displayed containing a digitized photo of the author. This facility was helpful in the iterative design of this system since people who had downloaded earlier versions from various computer network services could easily recognize the author at conferences to pass on their comments.

The upper right hand corner of the screen displays a timestamp informing us about the time since we last visited this node in the hypertext system. Since this is the front cover of the book, it also tells us the time since we last used this system.

In this demonstration example, we will assume that we click on the title of the book or on the book cover itself. This will display Figure 2 since the picture of the book itself is the anchor for opening the book. User studies indicate that the use of a book cover and its title as a hypertext anchor is fairly unintuitive for many users. They quickly understand clicking on icons and framed words (like "Quit" in this screen design) but often have to be encouraged to just click on a general graphics picture having no specific target indicated. In this case, a special problem is that the *affordance* [9], [24] of a book cover is to be pulled *up* while the mechanics of mouse-operated pointers require a push *down*. Because of this observation, the help screen (not shown here) was changed to explicitly state that the book was opened by clicking on it.

The Homogeneity Problem

To help users navigate the hyperspace we must help them understand and recognize their present location. This is partly done by facilities for utilizing the interaction history as will be discussed here. Recognizing locations is also facilitated by the dramatically varying graphical designs used for different elements of the system such as e.g. the front cover (Figure 1), the main text (Figure 4), and the literature references (Figure 7). There is no risk that users will confuse these different parts of the information space.

In an earlier version of the system we also relied on more subtle differences in graphics design such as varying background patterns for different kinds of information. This kind of design difference can be seen by comparing Figures 2 and 3, but the differences were more subtle in other parts of the earlier system where we also used different background patterns for screen designs which were mainly taken up with running text. During user testing of this earlier version it turned out that nobody actually noticed these subtle design differences, so they were removed in the current version of the system. One reason users do not notice different background patterns may be that they are used to the indiscriminate assignment of colors to various screen elements which is allowed as the primary interface customization in many current systems. Therefore, they do not associate screen colors with semantic importance.

The differences in graphical design are intended to reduce the *homogeneity problem* in on-line text, which basically is that on-line text always looks the same. Text on a computer screen is nicely formatted, normally using a single typefont. Furthermore, it is always displayed on the same screen, so on-line text is extremely homogeneous, which again makes it harder for users to recognize information and get a sense of location. On-line text does not have the variety which traditional text has, due to variations in typefont, book size, color, etc., or even the basic differences in physical looks between, say a real book, a newspaper, and a note written on a napkin in the cafeteria during a lunch break. In this system we have used different fonts to a small extent (see Figure 12) but mostly we have relied on the graphical screen design to introduce a heterogeneous feel. In hypertexts containing more nodes it might not always be possible to rely on distinct graphical design only, so certain subtle forms of variation might still be needed.

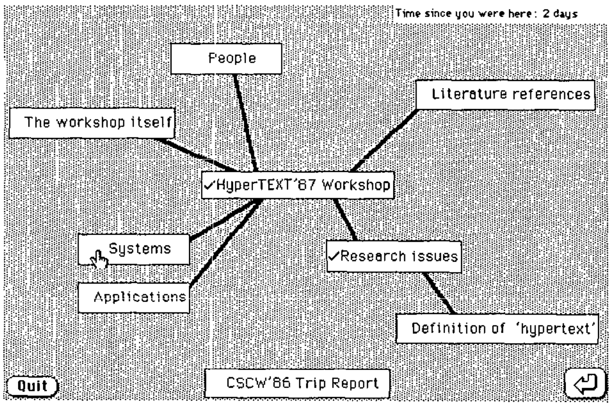


FIGURE 2

This is the global overview diagram of the contents of the hypertext structure. It serves as a two dimensional table of contents. The 2-D structure was chosen since there is by definition no linear structure of a hypertext: There is no "first" chapter. The layout of the items is intended to suggest their relation; i.e. "Systems" and "Applications" are related, while "Definition of hypertext" is a subissue of "Research issues."

"Definition of hypertext" is represented directly on the overview map because it is an especially important node in the hypertext network. Users can access the definition node directly throughout the system since the screens of the main text (Figure 4 etc.) include this global overview diagram as an active set of hypertext anchors.

The lines between the items are also intended to give an indication of how they are related since they show that "HyperTEXT '87 workshop" is the central topic while "CSCS '86 Trip Report" is a disconnected topic. In fact, there are hypertext links from some of the nodes in the Hypertext '87 report to some of the nodes in the CSCW '86 report but these links were judged to be of minor importance and are therefore not represented in this overview diagram.

Checkmarks indicate the nodes which we have visited in previous use of the system (in this case "Research issues").

One might argue that homogeneity could be desirable because it emphasizes the book metaphor and because readers can assimilate information faster when they encounter a familiar format. Of course, this is true to some extent but we would actually want to *avoid* the book metaphor in our future hypertext designs because it seems to limit the conceptual models of the search potential of hypertext and non-linear navigation of the information space. Furthermore, the available empirical evidence suggests that users behave very differently when reading hypertexts than when reading printed texts [22] and that this is even more true for experienced hypertext users who leave their book habits behind [14]. Therefore, it is unnecessary to keep the book metaphor except for walk-up-and-use situations where immediate transfer of past skills is needed. Of course, homogeneity should be retained to the extent that the *same* information should be presented in the same way to ensure consistent interfaces. For example, we used the same graphical language to encode the overview diagrams both at the global level (Figure 2) and at the local level (Figure 3).

Overview Diagrams

Overview diagrams have been used as navigational aids in several earlier hypertext systems. In this system we use two levels of overview diagrams to provide users with both a coarse-grained sense of location in the global information space and a more fine-grained sense of location in the local neighborhood of the current node. This approach works well in the current system which is fairly small, since its information space is divided into only 95 screens containing a text which took just 9 pages in the printed version [18].

For larger hypertext structures, it is an open question whether two levels of overview diagrams will be sufficient. One approach could be to use even more levels according to the principle that there should be "one, two, or enough" of any feature in a computer system. But in big hypertexts, using "enough" levels of diagrams will introduce navigation problems in itself as users move among the diagrams. Alternative designs might be to use fisheye views [8] or to show only the top and bottom-level diagrams and let users interpolate between them.

The overview diagrams in this system have been generated manually, even though some hypertext systems such as NoteCards [11] provide computer-generated diagrams. One reason for this decision was to speed up the implementation of the prototype interface, and another reason was the desire to have two levels of overview diagrams. It is not clear how one could automatically generate multi-level diagrams and how one should identify the important links to be included in the global diagram, even though some research has been done on nested hypertext structures and inheritance mechanisms [6]. One would probably not want *all* hypertext links from the local diagrams to propagate to the global diagrams, so some mechanism for using weights or relevance measures might be considered to prune the edges of the graph on the higher levels.

It is likely that big hypertexts will be the most useful ones and it is therefore important to address the issues of overview in large information spaces. We are currently working on methods for assigning relevance to links based on an information retrieval measure of similarity [7] between the two linked nodes as well as an estimate of the user's current interests. However, it is yet too early to judge the usability of such methods for real work. If such metrics can be tuned to correspond to users' actual intentions it would be possible to filter out links with ratings below some cutoff point. We are also experimenting with graphical methods to differentiate between anchors based on their estimated relevance to the user. Our limited experience indicates that users like this feature since it provides a prospective view on the links. A primitive example of such graphical differentiation in the current system is shown in Figure 4 where one of the buttons has been made prominent. The differentiation in Figure 4 was statically specified by the author, however, rather than being dynamically tailored for the individual reader as we are trying to do in our current experiments.

Our system is a single-user system which only keeps an individual interaction history, but one might speculate whether collective interaction histories could also be useful. For example, having the system keep statistics on how multiple users have moved through the hypertext might provide a means for automatically generating useful overview diagrams. If many users have been observed to have navigated between two specific nodes, it is likely that there should be a line between those nodes on one of the higher levels of overview diagram. And if almost no users have traversed certain links then they would be candidates for pruning. In this way the hypertext structure would constantly evolve towards a "survival of the fittest" nodes and links. Furthermore, it might be possible to use various clustering algorithms and multi-dimensional scaling techniques [28] to lay out the diagrams automatically.

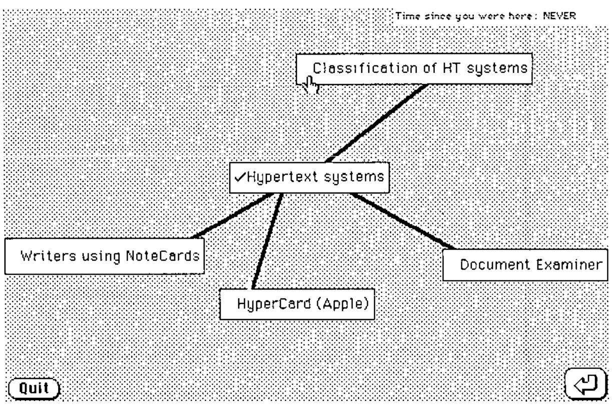


FIGURE 3

The more fine-grained overview diagram of hypertext nodes is the local diagram associated with the subject "Hypertext systems" which was chosen from the global overview diagram in Figure 2. We click on "Classification of hypertext systems" to get Figure 4 displayed.

We note that the timestamp in the upper right hand corner of the screen states that we have "NEVER" been here before. This is a general facility of the system intended to help readers recognize information they have already seen without having to wonder whether they actually have seen it before.

The local overview diagrams have a lighter background color than the global diagram in Figure 2. Almost no users notice this difference because they do not see the two colors simultaneously, but the same colors are consistently used in the small scale overview diagrams in the main text as shown in Figure 4 where they are more noticeable.

Backtracking

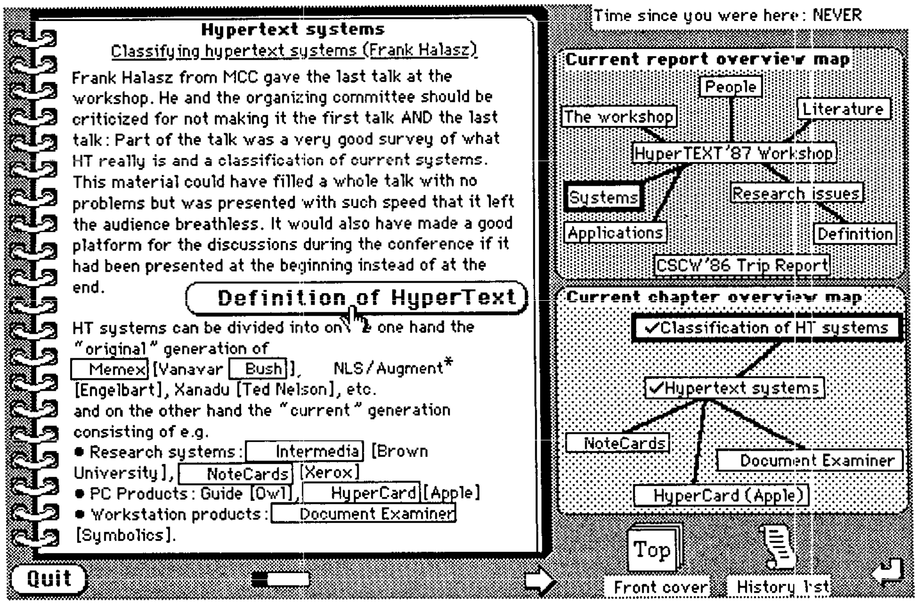
Earlier studies of the usability of videotex systems [17] showed that the backtrack facility was one of the most important navigation facilities, especially for novice users. Users frequently relied on backtrack to save them when they were in any kind of situation which they could not handle. Because of this result, a return arrow is always available in this system to take users back to the locations in the hypertext where they have jumped from.

The system has an unlimited backtrack capability within any one session, meaning that sufficiently many repeated clicks on the return arrow will take one back to the first screen (Figure 1). Since the first screen has a kind of landmark stature in the navigation space, the system also provides a direct hypertext jump to it from the pages of the main text.

The backtrack facility in this system is strictly path-following, meaning that nodes are revisited in exactly the reverse order in which the user originally visited them. This is implemented quite simply as a stack, and every time a node is visited, it is pushed onto the stack. The history list in the system (Figure 10) works in much the same way, except that nodes which are revisited as the result of a backtrack action are placed once more on the history list but removed from the stack. The history list, therefore, includes all the nodes the user has visited in the sequential order of the time of those visits. Even though hypertext is non-sequential, each user linearizes the information in time as part of the process of moving through it.

Because of the principle of following the user's path through the information space exactly, the same node may occur several times in the backtrack stack or on the history list. An alternative would be to do like HyperCard's built-in "*Recent*" history list (shown in Figure 11) and have each node occur only once. We have chosen the path-following principle to enable users to rely on their memory of their own navigation behavior when interpreting the history list or the result of backtracking. An out-of-context history list like Figure 11 is considerably harder to interpret than a path-following one since it removes information about the transitions between nodes: Users often remember information of the nature "after I was at **A**, I went to **B**."

In an earlier version of our hypertext system, we had the facility for reader-added annotations shown in Figure 12 which used structure-oriented backtrack. The idea was that the system could utilize its knowledge about the structure of the hypertext to provide a direct backtrack jump to the location which the user was likely to want to return to, instead of forcing the user to backtrack one step at a time through a number of intermediate screens. It turned out in user testing, however, that users were not able to understand this new kind of backtrack which was inconsistent with the general backtrack in the rest of the system, so we removed it from later versions of the system. It would probably have been possible for users to learn the structure-oriented backtrack if it had been used in more parts of the system instead of just in one isolated part, and it



Hypertext systems

Classifying hypertext systems (Frank Halasz)

Frank Halasz from MCC gave the last talk at the workshop. He and the organizing committee should be criticized for not making it the first talk AND the last talk: Part of the talk was a very good survey of what HT really is and a classification of current systems. This material could have filled a whole talk with no problems but was presented with such speed that it left the audience breathless. It would also have made a good platform for the discussions during the conference if it had been presented at the beginning instead of at the end.

Definition of HyperText

HT systems can be divided into on the one hand the "original" generation of Memex [Vanavar Bush], NLS/Augment* [Engelbart], Xanadu [Ted Nelson], etc.
and on the other hand the "current" generation consisting of e.g.
- Research systems: Intermedia [Brown University], NoteCards [Xerox]
- PC Products: Guide [Owl], HyperCard [Apple]
- Workstation products: Document Examiner [Symbolics].

Time since you were here: NEVER

FIGURE 4

This is a page showing the standard design of the main text of this hypertext. Since this node has more text than can be seen on this one screen, the system follows a book metaphor in allowing readers to page forward to the remaining text by clicking on the right arrow shown at the lower right corner of the book page. Screens other than the first page of a node will also display a left arrow which pages backwards.

The screen design includes small copies of the overview diagrams. All the screens in the main text part of the hypertext system show the same global diagram and further display the appropriate local diagram containing the current node. The overview diagrams are active since both of them highlight the user's current location, and they also serve as hypertext anchors: Clicks in the global diagram jump to the corresponding local diagram (e.g. to Figure 3 if "Systems" is clicked) and clicks in the local diagram jump directly to the corresponding node.

On this screen it would be a good thing to start by reading the definition of the word hypertext, so we click on that button which displays Figure 5. In general, it is a problem with hypertext that it destroys the authority of the author to determine which sections readers need to read first, but in this case we have at least hinted at the recommended reading order by making the anchor for the definition especially prominent.

Some people may think that the need to guide the reader on this screen is an indication that the whole notion of nonsequential text is flawed. If one needs to make certain buttons very large and graphically attractive in order to induce readers to select them first, why bother giving any options at all? The reason is that there are several different classes of readers. Some readers may be experts in the domain of the information base and will know how to navigate it to find the information of specific interest to them. They can certainly do so even though the author has made certain anchors prominent, since readers retain complete freedom of movement. Other readers, however, may be novices who are more in need of guidance. Instead of forcing people to read in certain ways, our hypertext design allows individual readers to customize their reading to their individual needs and learning styles in yet another way of providing individualized interaction. But since novices do not yet know the structure of the information space and may have difficulties in understanding the meaning of the terminology, we feel that it is reasonable for the author to provide them with hints.

would also have helped if it had been better explained. On the other hand, we do not want to increase the complexity of the user interface to the extent where users have to spend too much time reading instructions instead of reading the main text.

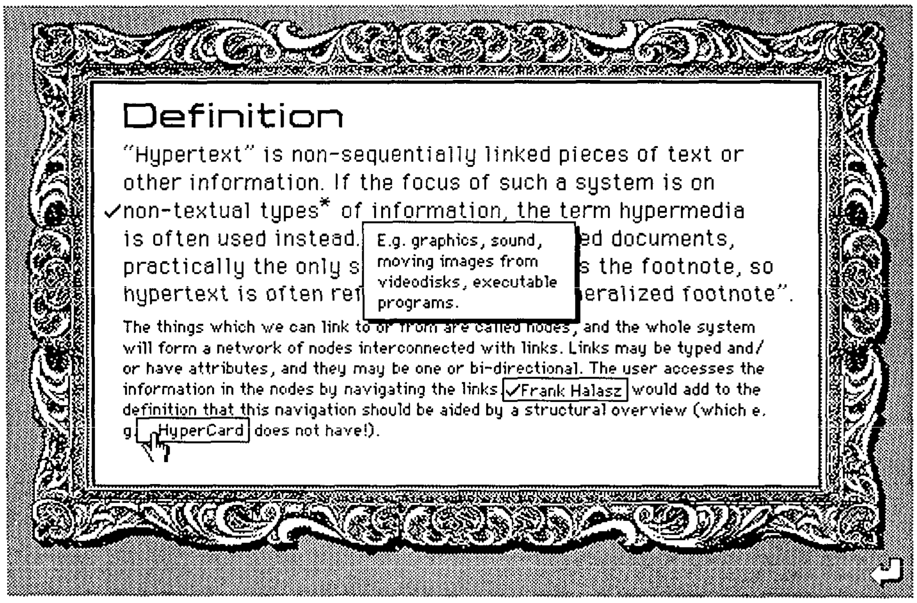
The importance of consistency in backtrack options can also be seen from Hardman's study of the *Glasgow Online* hypertext system [12], where half the subjects went back to the front screen and retraced long routes. In many of its screens *Glasgow Online* does have a backtrack facility but it is inconsistently labeled and not always present, so subjects felt more comfortable using the landmark facility for the front screen. From this we conclude that backtrack facilities need to be simple and consistent, so that users can always rely on them as a lifeline to get out of trouble.

INTERACTION HISTORY

This system relies heavily on the user's individual interaction history to provide a sense of context. The backtrack and history list facilities discussed previously are examples of interaction techniques that are defined relative to the actual user's previous personal use of the system.

Timestamps

All user movements between screens are timestamped. When a user returns to a location in the hypertext, the system displays the time which has passed since that user's previous visit to that location. When users visit a location where they have never been before, the system informs them about this fact instead of showing the timestamp. This time information can help users recognize the location since it relates it to their personal experience of how they used the system. One will view information in different ways depending on whether one has never seen it before or one has seen it a short or a long time ago.



Definition

"Hypertext" is non-sequentially linked pieces of text or
other information. If the focus of such a system is on
✓non-textual types* of information, the term hypermedia
is often used instead. | ed documents,
practically the only s | s the footnote, so
hypertext is often ref | eralized footnote".

E.g. graphics, sound,
moving images from
videodisks, executable
programs.

The things which we can link to or from are called nodes, and the whole system will form a network of nodes interconnected with links. Links may be typed and/or have attributes, and they may be one or bi-directional. The user accesses the information in the nodes by navigating the links. ✓Frank Halasz would add to the definition that this navigation should be aided by a structural overview (which e.g. HyperCard does not have!).

FIGURE 5

The graphic design of this screen is intended to emphasize its landmark status and to differentiate it from the text of the other nodes. The definition is accessible from all the screens of the main text through its anchor in the global overview diagram.

Just before the screen dump shown here was taken, we clicked on the hypertext anchor "non-textual types" to get the small pop-up annotation giving examples of these types. The pop-up will go away when we click on it or when we leave the screen to go elsewhere. Hypertext anchors for pop-ups are marked on the screen by a raised asterisk which is intended to invoke the notion of a footnote from traditional books. The asterisk is a different notation from the boxes used for anchors for hypertext links which jump the user to a new screen, since that helps users predict the actions of the system in response to their clicks. Version 1 and 2 of this system had the same box notation for both kinds of link, and users found it very frustrating not knowing in advance whether a click would just pop up a small annotation or take them to an entirely different context.

After we clicked on the anchor for the pop-up annotation, the system automatically put a checkmark in front of it to help us remember that we have already seen this annotation if we return to this page later. The system has also put in a checkmark at the anchor marked "Frank Halasz," since we have also seen the destination for that link (it is the screen in Figure 4). So let us click on "HyperCard" instead to go to Figure 6.

In addition to the timestamps, the system can also display the total accumulated time a user has spent on each location in the hypertext. History information like time stamps and accumulated time are automatically part of the use of traditional books, even though they are obviously much less precise. It is immediately apparent when looking at a traditional book if it has never been opened and it is also obvious if it is an old, well-worn volume. The books you use very often may be on the verge of falling apart. Including a similar kind of information in on-line text is yet another way of fighting the homogeneity problem discussed previously.

Footprints

The system uses checkmarks to serve as footprints on the overview diagrams, indicating where the user has been. It also checkmarks hypertext anchors leading to previously visited nodes in a way similar to the "breadcrumb" facility in the HyperGate system [2].

The first versions of the system did not have a footprinting facility, but users complained that they would often feel compelled to take hypertext links to places where they had recently been, just to make sure that they did not miss important information. In the example in the figures, we jumped from Figure 4 to Figure 5, but the screen in Figure 5 includes a hypertext link to Figure 4 in the form of a reference to "Frank Halasz." This kind of double reference is quite common in hypertext, since there is a good chance that if **A** is relevant to **B**, then **B** is relevant to **A**. However, users sometimes do not know which of the references in **B** would refer to **A**, even if they just came from **A**, so they may happen to activate a jump leading back to **A** instead of a jump leading them onwards. Checkmarking the anchor leading back alleviates this problem.

One problem with putting footprints on the maps and other hypertext anchors is that almost all parts of the structure will get marked eventually, if the user uses the system extensively. Perhaps a notation similar to that of the experimental *Color EMACS* text editor [15] could be used where changes to the file are shown in a contrasting color that "decays" over time to gradually match the color of the original text. In a similar way, footprints in a hypertext might erode gradually so that only current footprints were displayed prominently while older footprints were displayed in ever lighter shades of gray or not at all.

Another checkmark issue is whether the system should use one notation for the checkmarks placed at anchors which the user has actually activated, and another for checkmarks placed at anchors which are linked to destinations already seen by the user but have not been explicitly activated by that user. Our system uses a single notation to simplify both the implementation and the number of interface conventions which the user needs to learn.

CONTEXT-IN-THE-LARGE VS. CONTEXT-IN-THE-SMALL

Most of the issues discussed under navigation and interaction history have to do with providing the user with a sense of context and location in the entire hypertext structure. We will call this kind of context for context-in-the-large but Figure 9 shows that there can also be problems with context-in-the-small in reading a hypertext. When the computer display is as small as in our system, users can only see a very small part of the information at any one time. This means that they can very easily lose track of how the text they are currently reading is related to the immediately preceding or following text, since that text will often not be visible. In reading the text in Figure 9, we understand that we are seeing some kind of enumeration of items, but we have no idea of the author's intention with the list or what kind of list it is.

The previous designs of this hypertext system did not include the dynamic overview diagrams on each screen and thus had room for about twice as much text on each screen. This still did not solve the context-in-the-small problem, but it was much better. In the current design we have added lots of facilities to help with the context-in-the-large problem, such as the overview diagrams and timestamping and icons for the history list and direct access to the front cover. It is likely that this redesign represents a poor trade-off given the constraints of the small screen: The loss of context-in-the-small could well damage overall usability more than the added context-in-the-large improves it. We did the redesign anyway, since we wanted to experiment with these new features which will probably show their usefulness on the larger displays which will be much more common in the near future.

Figure 9 also shows another case of the problems with context-in-the-small. It was necessary to move the entire description of the third list element to a new page to avoid having a figure and the text explaining it split over different pages, which would have had an even worse impact on readability. The result, however, is to distribute the issues discussed over several pages, which means that the reader cannot get an overview of these issues and how they are related. In another part of this hypertext system shown in Figure 8, we have tried to solve a similar problem by having a list of issues represented as anchors for hypertext pop-ups each containing the full text for one issue.

Finally, the scroll bars at the bottom of the pages of the main text address a contextual problem on a level somewhat in between the in-the-small and the in-the-large levels since they provide readers with a sense of relative location within the individual hypertext node and an indication of the size of that node as illustrated in Figure 6. In general, we should remember that users need context not just in-the-large but also in-the-small when reading hypertexts, and that different mechanisms are usually required to provide the two kinds of context.

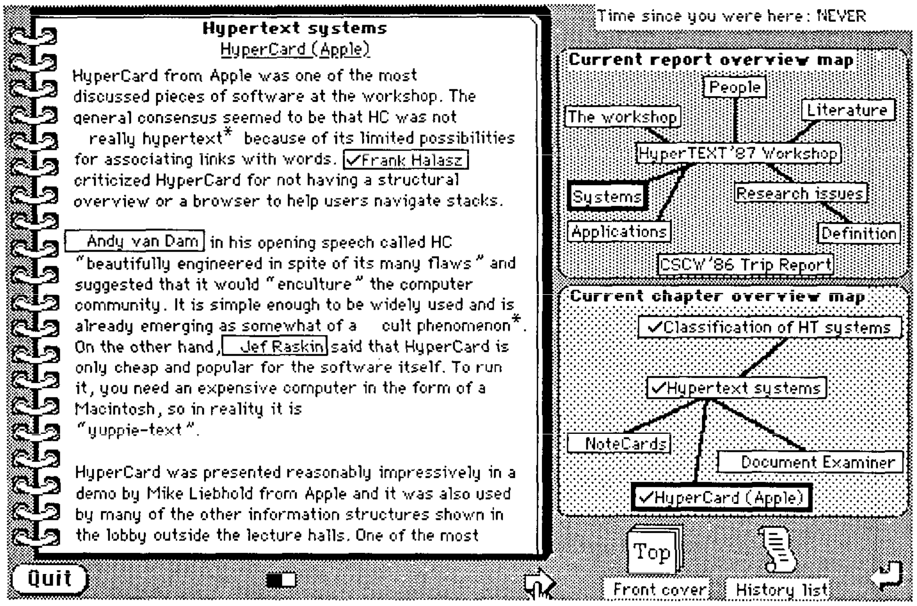
INDIVIDUALIZED INTERACTION HISTORY: **The interaction history in this system is obviously individualized in the sense that it shows the actual user's personal interaction with the hypertext. This again means that it provides an automatic way to customize the hypertext to the individual user as that user proceeds through the information space. One might consider customizing the interaction even further to match the particular user's needs. Bookmarks [2] are a simple technique for doing this and the user could also build a personalized table of contents [16] by pruning the history list to include only those nodes which were of interest to that user.**

It would also be possible to customize the interface to the interaction history and allow users to choose between the various design options considered in this article. We have not done so because we generally believe that users are poor designers and that it is the reponsibility of the usability engineer to construct a clean interface. Even so, there are several parameters which it may be reasonable to allow users to modify to suit their personal preferences, such as e.g. the speed with which old checkmarks would fade or the time the user needs to spend at a node to have it marked as having been read.

IMPLEMENTATION ISSUES

The hypertext system described in this article was implemented in HyperCard using the HyperTalk [1] programming language. Our emphasis in designing and implementing the system was on rapidly demonstrating our ideas for hypertext user interface features and not on producing a generally useful system. As a matter of fact, the system can only display the one hypertext document it was built to support.

HyperTalk is an object-oriented [27] programming language, but not with full generality. For example, HyperTalk does not allow the programmer to define subclasses of objects such as buttons, and this led to problems in the code implementing the automatic checkmarking of anchors leading to previously visited nodes. We wanted to look only at buttons which were hypertext anchors, and not at the buttons in the scroll bars, for example. We had to do this by inspecting the



Hypertext systems

HyperCard (Apple)

HyperCard from Apple was one of the most discussed pieces of software at the workshop. The general consensus seemed to be that HC was not really hypertext* because of its limited possibilities for associating links with words. ✓Frank Halasz criticized HyperCard for not having a structural overview or a browser to help users navigate stacks.

Andy van Dam in his opening speech called HC "beautifully engineered in spite of its many flaws" and suggested that it would "enculture" the computer community. It is simple enough to be widely used and is already emerging as somewhat of a cult phenomenon*. On the other hand, Jef Raskin said that HyperCard is only cheap and popular for the software itself. To run it, you need an expensive computer in the form of a Macintosh, so in reality it is "yuppie-text".

HyperCard was presented reasonably impressively in a demo by Mike Liebhold from Apple and it was also used by many of the other information structures shown in the lobby outside the lecture halls. One of the most

FIGURE 6

When we arrive at this node, the system puts checkmarks at the hypertext anchors for "Frank Halasz" and "Classification of HT systems" since we have visited the destinations for those links already.

This screen is part of the node describing Apple's HyperCard system as can be seen from the highlighting of that node in the local overview diagram and also by the two headings inside the picture of the book page. The bold faced heading describes the location in the global overview diagram while the underlined heading describes the location in the local overview diagram. These two headings are automatically concatenated by the system to form a text string referring to a node in the history list shown in Figure 10.

In a preliminary design of these headings the picture of the book page was smaller and the headings were placed outside the book page to indicate that the headings were a kind of "computer-generated state information" and not part of the running text. Even though the early design placed the headings in the same physical location on the screen as the current design, it did not work since test users did not view the text outside the book page as being a label for the contents of the book page. This result could be explained by the *gestalt* law of closure which states that things which are within the same closed region are seen as corresponding, so the solution was simply to move the headings within the closure of a larger book page.

The little black and white boxes below the book page form a scroll bar which indicates two things: Our relative location within the current node and the size of the node. The length of the scroll bar is proportional to the number of pages in the node, so the scroll bar in Figure 4 is longer than the scroll bar in this figure because the node visited in Figure 4 is bigger than node we visit here. Proportional scroll bars make it possible to always have the "thumb" of the scroll bar (the black box) be the same size, corresponding to the fact that the book pages have a fixed size. The relative size of the thumb compared to the entire scroll bar indicates the proportion of the total text which the user is currently seeing.

The black box indicates our relative position within the node in an analog format. An alternative would have been a digital format (e.g. "page 1 of 2") but the scroll bar design allows us also to use it as an anchor for direct hypertext jumps to the other pages within the node: When the user clicks in the scroll bar, the system jumps to the page in the node which has the relative location corresponding to the click.

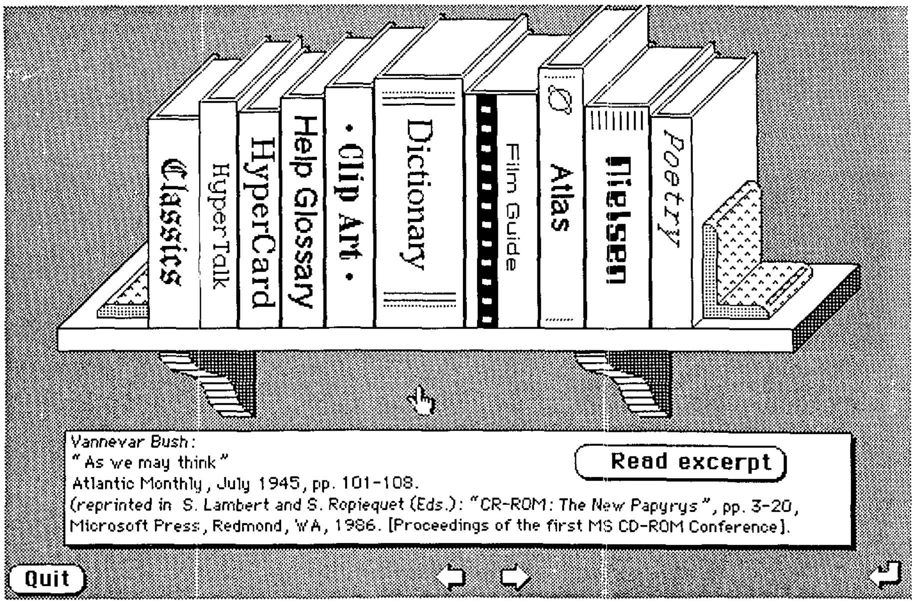
Here, we see that the current node is quite small and we are on its first page, so we might decide to look at the rest of the node by clicking on the right arrow button. The next page looks similar to this except that it has a left arrow button instead of a right arrow button, so it is not shown here. The next page has a hypertext reference to "Vannevar Bush" which we follow to get a reference to this famous author.

message handler associated with each button at runtime to see whether its text contained the word "jump" which was a procedure call used only in the code for hypertext jumps. Furthermore, since HyperTalk does not have instance variables for button objects, we had no clean way to get a reference to the node which the button linked to. Again, we had to go and inspect the button code to grab the destination address from the parameter list for the call of the "jump" procedure.

Many other "dirty" programming techniques were used in the implementation of this hypertext system [20], but the end result was that we were able to get a working system in a very short time. It should be remembered that the goal of the project was to get a running system for user interface experiments and not to study the programming techniques which one would have to use for a commercial hypertext product.

For the development of this prototype hypertext system, first 12 hours were spent writing the actual text which forms the information base used by the system. Then 17 hours were spent on software development to establish features for moving through the information space, and finally 11 hours were spent reorganizing the basic text into objects fitted to the software and adding hypertext links. After this original implementation, an additional 3 hours were spent on adding scroll bars to the interface. This feature was added quickly and shows that it was possible to modify the prototype according to user feedback.

For the third version of the prototype, major modi-



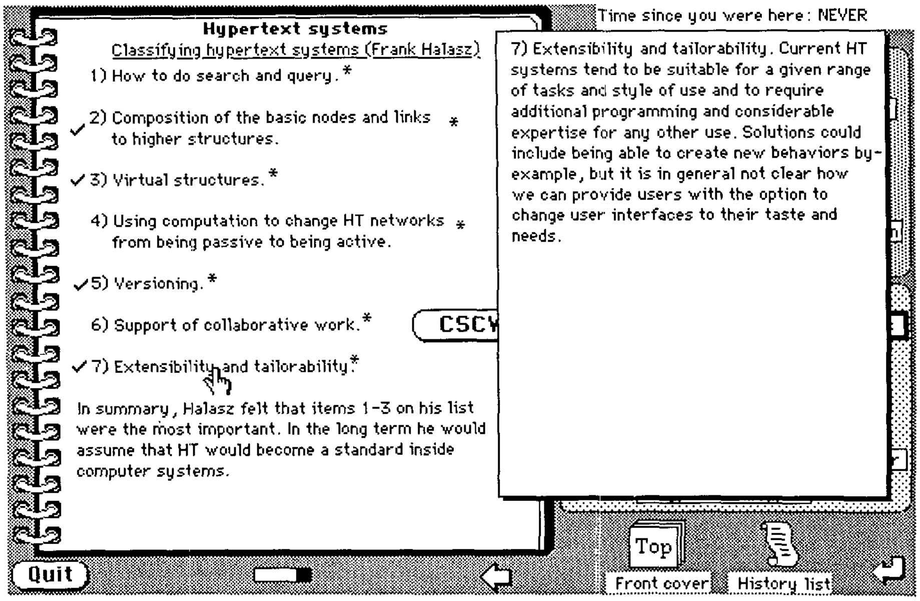
Vannevar Bush:
"As we may think"
Atlantic Monthly, July 1945, pp. 101-108.
(reprinted in S. Lambert and S. Ropiequet (Eds.): "CR-ROM: The New Papyrys", pp. 3-20,
Microsoft Press, Redmond, WA, 1986. [Proceedings of the first MS CD-ROM Conference].

FIGURE 7

As indicated by the drastically different graphic design, this screen is part of the literature reference section of the information space. The left and right arrows are for moving alphabetically through the reference list. The alphabetic order of authors' last names is an access mechanism with very low semantic meaning, so to utilize hypertext principles, the books on the book shelf have been designed as hypertext anchors to help users discover literature references. For instance, by clicking on the book marked "Poetry" we can jump to a literature reference about the use of hypertext for teaching poetry.

Some of the book buttons are linked to multiple destinations, one of which is chosen by random. For example, the book marked "Classics" will jump to one of the references considered to be classics in the hypertext field. This randomness was inspired by the "Something Else" feature in the Drexel Disk [13] and should only be used in situations, where users are exploring the information space in a browsing mode. In most situations, predictability would of course be the preferred interaction characteristic, and we actually had one user complain that he had spent almost an hour experimenting with the book buttons in a vain attempt to discover the algorithm used to select their destination. This user was a computer scientist, however, and it is likely that more ordinary users would ascribe the system's behavior to "magic" [26] and not worry too much about it. We do not have enough evidence from our usability studies to decide this design issue for certain since a more detailed study of effects of randomness in user interfaces would be required. Based on this limited experience, our intuition suggests that it would actually be better to go for a predictable design. One way of doing so would be to use the Intermedia [29] technique of popping up a menu listing the possible destinations whenever the user activated an anchor linked to multiple destinations.

From the screen in this figure we could click on the "Read excerpt" button to see some quotes from the original article by Vannevar Bush. Following automated cross reference to other articles is one of the great benefits of hypertext, but we will not do so in this example for copyright reasons. (The copyright problem is exactly one of the worst socioeconomic barriers to realizing the full potential of hypertext.) Instead we click several times on the backtrack ("return") arrow in the lower right corner of the screen, backtracking through the intervening screens until we return to the screen shown in Figure 4.



Time since you were here: NEVER

Hypertext systems

Classifying hypertext systems (Frank Halasz)

1) How to do search and query.*

✓ 2) Composition of the basic nodes and links to higher structures. *

✓ 3) Virtual structures.*

4) Using computation to change HT networks from being passive to being active. *

✓ 5) Versioning.*

6) Support of collaborative work.*

✓ 7) Extensibility and tailorability.*

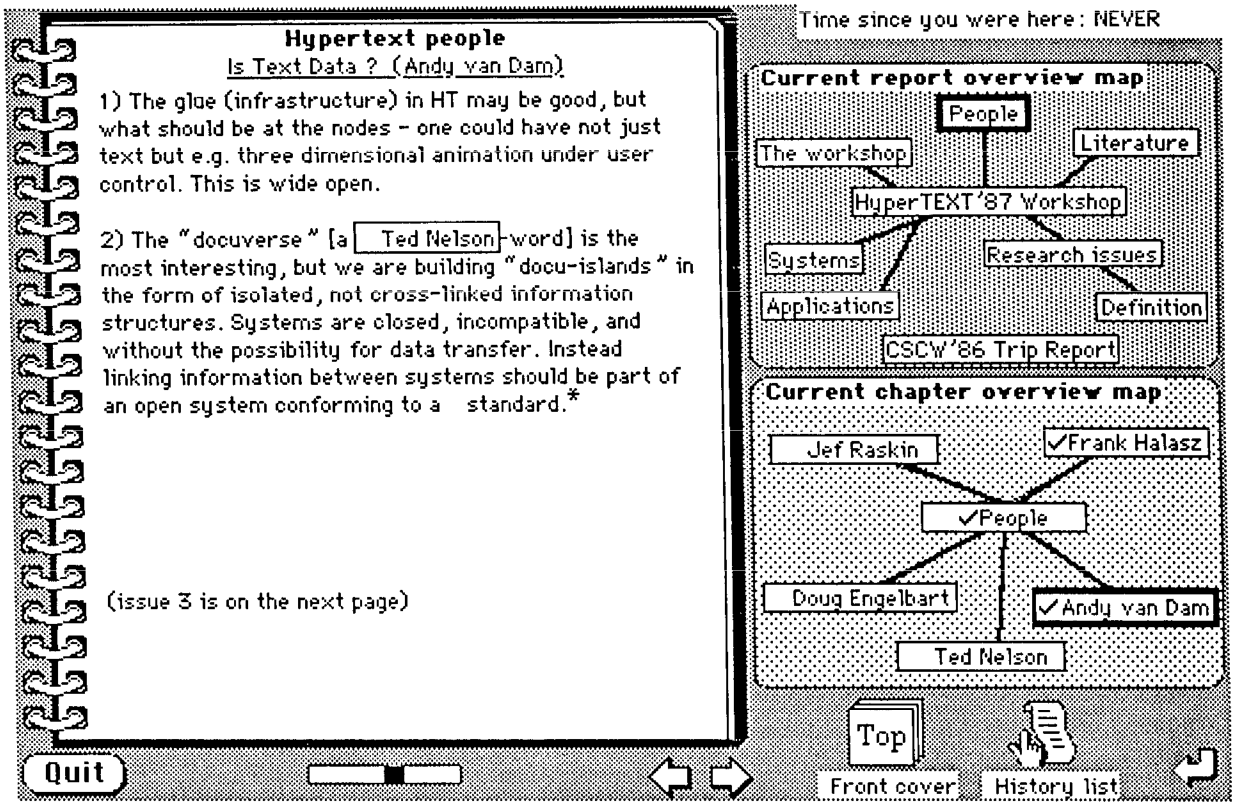
In summary, Halasz felt that items 1-3 on his list were the most important. In the long term he would assume that HT would become a standard inside computer systems.

7) Extensibility and tailorability. Current HT systems tend to be suitable for a given range of tasks and style of use and to require additional programming and considerable expertise for any other use. Solutions could include being able to create new behaviors by-example, but it is in general not clear how we can provide users with the option to change user interfaces to their taste and needs.

FIGURE 8

We have backtracked to the screen shown in Figure 4 and from there we have read through the rest of the node, ending up on the page shown here. This part of the text contains a list of seven issues which are hypertext anchors for pop-up windows. We have already seen issues 2, 3, and 5 (as indicated by the checkmarks put in by the system) and here we have just clicked on the anchor for issue 7 to get the screen to look like this.

We can now read the full text describing issue 7 while still being able to see the list outlining the full set of issues. Because of the small screen, the pop-up unfortunately obscures the overview diagrams, but we can always click on it to make it go away.



Time since you were here: NEVER

Hypertext people

Is Text Data ? (Andy van Dam)

1) The glue (infrastructure) in HT may be good, but what should be at the nodes - one could have not just text but e.g. three dimensional animation under user control. This is wide open.

2) The "docuverse" [a Ted Nelson-word] is the most interesting, but we are building "docu-islands" in the form of isolated, not cross-linked information structures. Systems are closed, incompatible, and without the possibility for data transfer. Instead linking information between systems should be part of an open system conforming to a standard.*

(issue 3 is on the next page)

FIGURE 9

To get from Figure 8 to this screen we have wandered a little bit around the hyperspace and finally happened to click on "People" in the global overview diagram and then on "Andy van Dam" in the local overview diagram which resulted from that action. We have then read through some of the pages in the node until we came to this list of hypertext research issues.

This design has some problems with context-in-the-small since not all the issues can be listed on the same screen. All the text for "issue 3" had to be moved to the next page to avoid breaking it up and getting even worse context-in-the-small problems. Originally, this screen did not have the extra line "(issue 3 is on the next page)" but usability testing indicated the need for this continuation notice, as many users would otherwise transfer their intuitions from printed books and assume that a screen with a blank bottom half was the end of the current chapter.

From this screen we decide that we do not want to read about Andy van Dam any more but that we want to return to one of the earlier nodes which we happened upon in our earlier browsing. To do so, we click on the "History list" button.

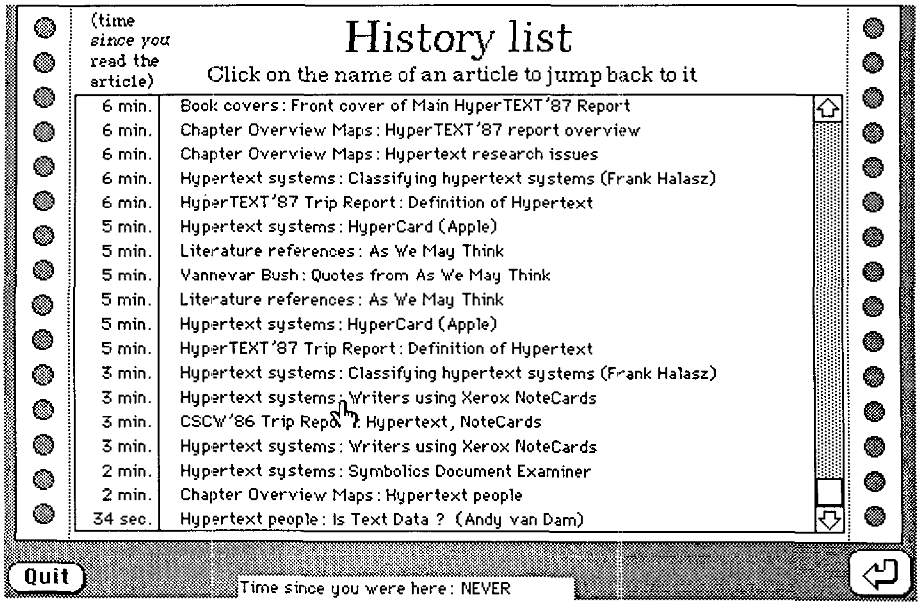
fications were needed which took about 25 hours to implement. The modifications included introduction of overview diagrams and timestamps as discussed earlier. After these changes, further maintenance of the system seems to be fairly difficult because of the distributed nature of its code and other user interface elements.

In addition to these three major version of the system, several subversions were released as part of the iterative design based on user tests. Each of these minor changes required only between 15 and 30 minutes to implement.

HyperCard proved to be very effective for our prototyping of graphical hypertext user interfaces. One reason for this was because the author was already an experienced HyperTalk programmer before starting this project. However, learning to implement user interfaces in HyperCard is very fast, compared with most other graphical and/or object-oriented programming systems, partly because it is very concrete in its use of traditional screen painting tools as the graphical programming language of the system. Many parts of an interface can be prototyped simply by painting them on the screen, and even the parts which are under dynamic program control behave in much the same way as one would directly operate the screen during non-programming use of HyperCard.

CONCLUSIONS

The hypertext principle can be useful for many things.



History list

Click on the name of an article to jump back to it

(time since you read the article)	
6 min.	Book covers : Front cover of Main HyperTEXT'87 Report
6 min.	Chapter Overview Maps : HyperTEXT'87 report overview
6 min.	Chapter Overview Maps : Hypertext research issues
6 min.	Hypertext systems : Classifying hypertext systems (Frank Halasz)
6 min.	HyperTEXT'87 Trip Report : Definition of Hypertext
5 min.	Hypertext systems : HyperCard (Apple)
5 min.	Literature references : As We May Think
5 min.	Vannevar Bush : Quotes from As We May Think
5 min.	Literature references : As We May Think
5 min.	Hypertext systems : HyperCard (Apple)
5 min.	HyperTEXT'87 Trip Report : Definition of Hypertext
3 min.	Hypertext systems : Classifying hypertext systems (Frank Halasz)
3 min.	Hypertext systems : Writers using Xerox NoteCards
3 min.	CSCW'86 Trip Rep[illegible] Hypertext, NoteCards
3 min.	Hypertext systems : Writers using Xerox NoteCards
2 min.	Hypertext systems : Symbolics Document Examiner
2 min.	Chapter Overview Maps : Hypertext people
34 sec.	Hypertext people : Is Text Data ? (Andy van Dam)

Time since you were here : NEVER

FIGURE 10

The history list is a sequential listing of all the nodes in the hypertext which we have visited. Each node we have visited is represented on the list once for every time we have visited it, thus making the list a truly linear mapping of our path through the nodes. For each visit to a node, the history list also indicates the time since that visit since our understanding of different parts of the list will depend quite a lot on whether it shows nodes we have just visited, nodes which we visited a few hours ago, or nodes which we visited some days (or perhaps years) ago.

Here we could click on the line listing a node to return to it, but we will not do so since this figure concludes the demonstration guided tour of the system.

In fact, this very article has some characteristics which would have made it suitable for presentation via a hypertext system, since it relies to a large extent on a non-linear discussion through the figures and captions and since it has many internal cross-references between the figure captions and the main text.

Hypertext, on the other hand, also has serious usability problems which must be solved before hypertext systems can see truly widespread use. This article has presented some approaches to solving the navigation problem and the context-in-the-large problem but we also need bigger screens or other methods for solving the context-in-the-small problem.

Acknowledgements. Many people have made constructive comments on earlier versions of this hypertext system. Specific changes to the interface have been made as the result of comments from Uffe Lyngbæk, Cathy Marshall, and Ben Shneiderman, but they are of course not responsible for the way I have chosen to address their criticisms. Helpful comments on earlier versions of this article have been given by Peter Brown, James D. Foley, Christian Gram, Lynda Hardman, Uffe Lyngbæk, Kurt Nørmark, John Schnizlein, Ben Shneiderman, and Patricia Wright as well as by anonymous *Communications* referees.

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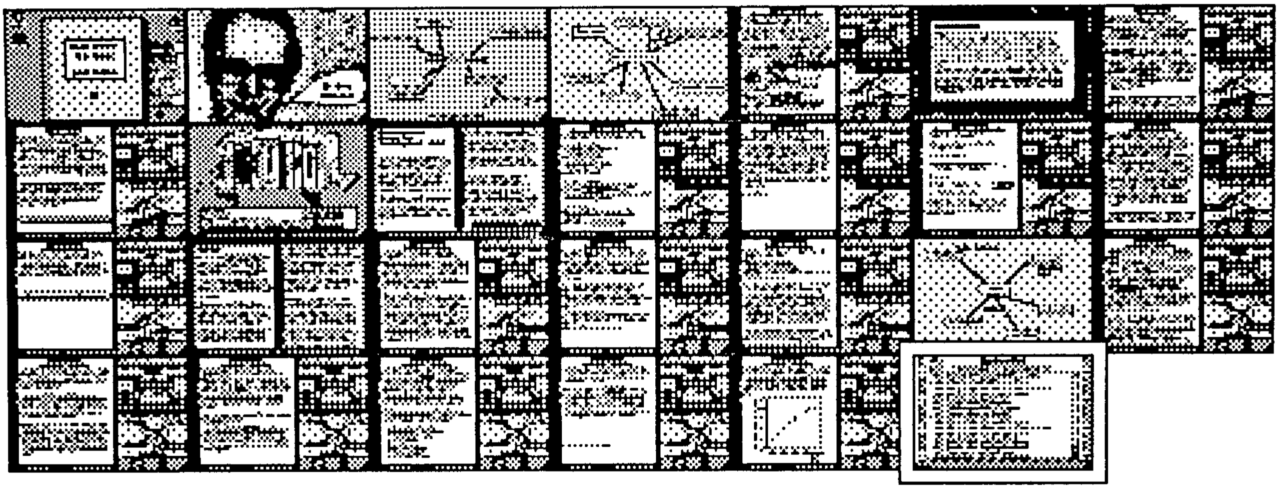


FIGURE 11

This is an alternative history list generated by HyperCard's built-in *Recent* command. Each miniature represents one screen which we have visited in the current session (navigation behavior from earlier sessions is not saved) and each screen is only represented once in the list, no matter how many times we have visited it. You go to a screen by clicking on its miniature.

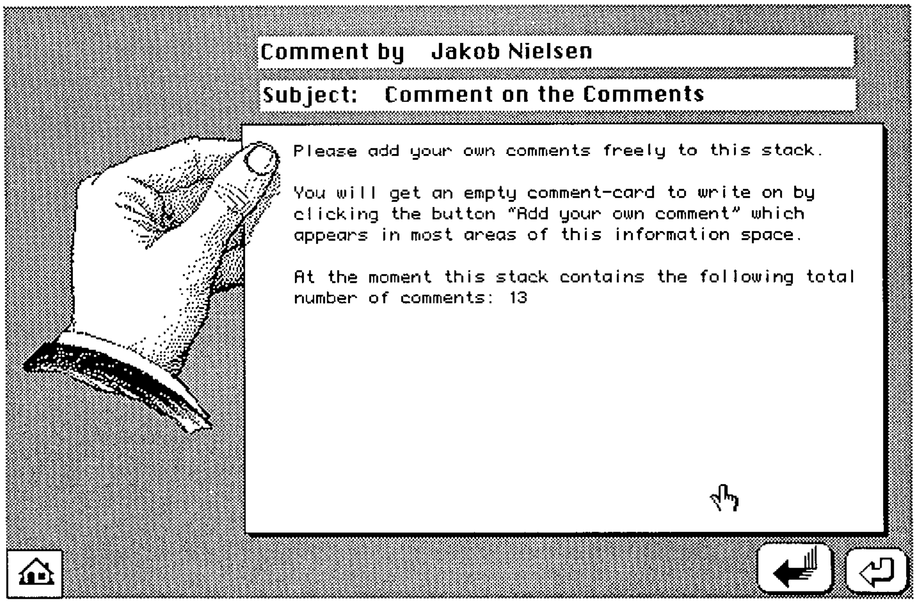
One reason we chose to use the textual history list in Figure 10 instead of this graphical history list is that it is very hard to distinguish the miniatures for screens which basically have the same graphical layout but contain different text.

FIGURE 12

An annotation page from version 1 of the hypertext system. The graphical design is intended to convey the impression that this is some short added material which is separate from the main report. A different typefont is used to indicate that the annotations will normally have been written by people other than the author of the main hypertext.

Since a single node in the hypertext could have several associated annotations, a user asking to read annotations would first be taken to a screen showing a menu of the annotations for the current node (not shown here). The user could then select to read an annotation based on the menu's listing of the authors and subjects of the annotations.

This screen design has two backtrack arrows since there are presumably two different ways the user might want to return from this node (which has no further hypertext jumps available since the system did not provide a facility for adding annotations to the comments themselves). The standard return arrow performs the standard backtrack function of returning the user to the departure point for the previous hypertext jump which in this case is the menu of annotations. An extra arrow to the left of the standard return arrow is an "express return" which returns readers directly to the location from which they jumped to the annotation menu, thus providing a shortcut through the straight backtrack path. It turned out, however, that almost no test users understood this facility.



Comment by Jakob Nielsen

Subject: Comment on the Comments

Please add your own comments freely to this stack.

You will get an empty comment-card to write on by clicking the button "Add your own comment" which appears in most areas of this information space.

At the moment this stack contains the following total number of comments: 13

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CR Categories and Subject Descriptors: H.1.2 **[Models and Principles]**: User/Machine Systems—*human factors*; H.3.3 **[Information Storage and Retrieval]**: Information Search and Retrieval—*search process*; H.4.3 **[Information Systems Applications]**: Types of Systems—*hypertext*; J.7 **[Computers in Other Systems]**—*publishing*

General Terms: Design, Experimentation, Human Factors

Additional Key Words and Phrases: Context, HyperCard, hypermedia, interaction history, user navigation

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