ISSN 0105-8517

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DAIMI PB – 287
September 1989

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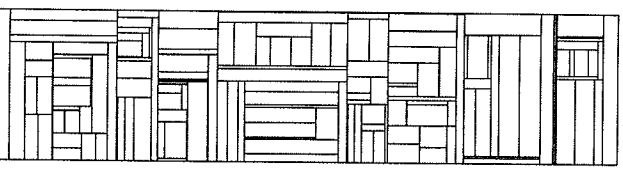


Hypermedia: Support for a more natural information organization*

Liam Bannon and Kaj Grønbæk[1]

Abstract: This paper gives an introduction and an overview of an emerging technology denoted Hypermedia. The technical capabilities of current systems are briefly described along with examples of usage. Based on our own experiences with Hypermedia systems we give a more detailed discussion of the use of Hypermedia for: authoring, organization and presentation of information, and sharing of information in a community. Finally some obstacles to the success of Hypermedia applications are discussed.

Keywords: *Authoring, Hypermedia, Hypertext, Information Systems, User-centered design.*

"***Everything is Deeply Intertwingled****.....In an important sense there are no "subjects" at all: there is only all knowledge, since the cross-connections among the myriad topics of this world simply cannot be divided up neatly.....Hypertext at last offers the possibility of representing and exploring it all without carving it up destructively."*

-Ted Nelson *(Computer Lib/Dream Machines)*

**Appears in the proceedings of the 7th Nordic Conference for Information and Documentation, Helge Clausen (ed.), pp 39-53, Aarhus, Denmark, August 1989.*

1 INTRODUCTION

In this paper we provide a short account of hypertext and hypermedia systems, giving a brief historical background, describing some systems implemented today, and discussing strengths and weaknesses of the concept as currently articulated with reference to our own experiences in the use of these systems. Our intent here is not to provide a thorough tutorial on the topic, since a readable one (Conklin, 1987) already exists. The literature on the topic has expanded rapidly since the first full-scale Hypertext conference in 1987 (Hypertext '87). We discuss how, from the point of view of the *system developer*, such a technology might provide new possibilities over conventional methods for organizing and displaying information. We also discuss, from the point of view of the *user*, how such systems can "engage" users in particularly captivating ways, allowing as it does a more natural form of browsing and organizing information.

Like many other technological developments, computer-based hypertext systems are being driven as much by the technology as by deep theories of how people think. Many words have been written about the concept of hypertext, and systems do exist, but usually only for very small-scale applications, or only in research laboratory settings, and so possibilities for widespread application of hypermedia systems, in libraries for example, have only begun to be investigated. Our aim is not to proselytize, but to put the more recent interest in the topic in a perspective, which shows that, really, there is nothing new under the sun, and certainly that the computer *per se* is not required to support such systems. However, computer-based Hypermedia can allow for significant increases in the flexibility of the kinds of systems that can be built, as we shall see.

We are committed to a *used-centered* design perspective, emphasizing how such systems are seen by the ultimate users, from the point of view of usability and utility of the system. An issue in the domain of certain forms of information systems, e.g. in libraries, is that we have quite different user communities, and their needs are not necessarily the same! For instance, from the library point of view, there is a need for a hierarchical classification system over and above any other cross-classification system, in order to ensure some systematicity in the bureaucratic procedure of filing and recording all accessions. However, from the point of view of the readers in the library, direct use of a hierarchical classification system in order to search a database is often not the most successful method of search. In general, it has been shown that users often get lost and are unsuccessful in searching large text databases (Furnas, Landauer, Gomez, and Dumais, 1983).

Our paper is structured as follows. Section 2 provides a brief historical introduction to the topic, going back to the classic article by Vannevar Bush "As We May Think" which has been accepted as a foundation for many of the hypermedia ideas mentioned today, and we briefly discuss the work of two pioneers in the field, Ted Nelson and Doug Engelbart. Yet again, most of the ideas in today's systems were not just mentioned, but actually worked out by these men twenty years ago. Section 3 provides a slightly more technical account of hypermedia systems together with a brief outline of some well-known systems available today. Section 4 then discusses uses of these systems with which we are familiar, and some lessons learned. The final sections discuss outstanding problems with current implementations of hypertext, some of which are inherent to the medium, others of which may be overcome with technology.

2 ORIGINS OF HYPERMEDIA

The origin of the term "hypertext" is usually ascribed to the maverick software guru and self-confessed dreamer, Ted Nelson, the self-published author of such bizarre and insightful books as Computer Lib/Dream Machines (1974) and Literary Machines (1981). It is unfortunate that these books are difficult to get hold

of, as they make fascinating reading. The basic point about hypertext is that it consists of *chunks* of text that are linked together in a variety of ways. Instead of a written document that has a logical sequence imposed on the pieces (paragraphs) by the author, a hypertext document consists of *non-linear text* which can be read in different ways by different users through following different links between the chunks of text. Note that the computer is not an intrinsic element in the definition of hypertext . It is quite possible to have an ordinary, even hand-written, hypertext document, and in books, we can see the table of contents pages and index pages, together with footnotes, as attempts to provide some nonlinearity in the text so as to allow readers the flexibility to read the material in a non-linear fashion. But it should be obvious how modern computer displays, with multiple windows on the screen that can be selectively opened, provide greater flexibility. It is the flexibility of the substrate that has excited some people about the possibilities of the hypertext concept. Note that the term hyper*media* is preferable to hyper*text* as we are interested in the linking together of not just pieces of text, but also other forms - voice, gesture, graphs, pictures etc., but the term hypertext has become synonymous with the extended term, so we will use the two interchangeably in this paper.

So, what can we do with such a facility? Why is it so intriguing? To provide an informative and also historically interesting example, let us go back to the inspired paper by Vannevar Bush "As We May Think" written in 1945. Bush was thinking of new possibilities with technology (not computers exactly) and suggested the need for a machine he called a MEMEX, which was " a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory." (Bush 1945). Bush saw that most existing indexing schemes were hierarchically organized alphabetically or numerically, yet he believed that this sort of indexing did not match with human abilities, as a key feature of human intelligence was characterized by the ability to make associations between objects - associative indexing, "...the basic idea of which is a provision whereby any item may be caused at will to select immediately and automatically another" (Bush, 1945). His MEMEX machine, which can be seen as the forerunner to the personal workstation, would allow people to build up links between different items in one's personal database, and whenever one of the items was displayed subsequently, it would also show if there were any links to other items, and if so, the reader could follow any of these paths if desired. Bush saw these links as threads weaving through the accumulated knowledge repository of the person's library, and he even speculated on how the very threads or trails that people made through documents would be themselves of interest in their own right: "The inheritance from the master becomes, not only his additions to the world's record, but for his disciples the entire scaffolding by which they were erected." (Bush 1945). Users could also add comments to documents and share their associations with others. The ideas outlined, even though based on scanty knowledge of computing developments (Bush thought of some form of mechanical microfilm-based MEMEX system) are at the core of modern hypertext developments.

Next we return to our visionary hero Ted Nelson, (mentioned at the beginning of this section as the originator of the term "hypertext"), who was the first person to really develop the ideas underlying hypertext, and devised methods for possible implementations. Nelson's dreams are often regarded as lunatic, but his vision is a powerful one, to have a universal library." The real dream is for "everything" to be in the hypertext.....We must again become a community of common access to a shared heritage." (Nelson 1974).

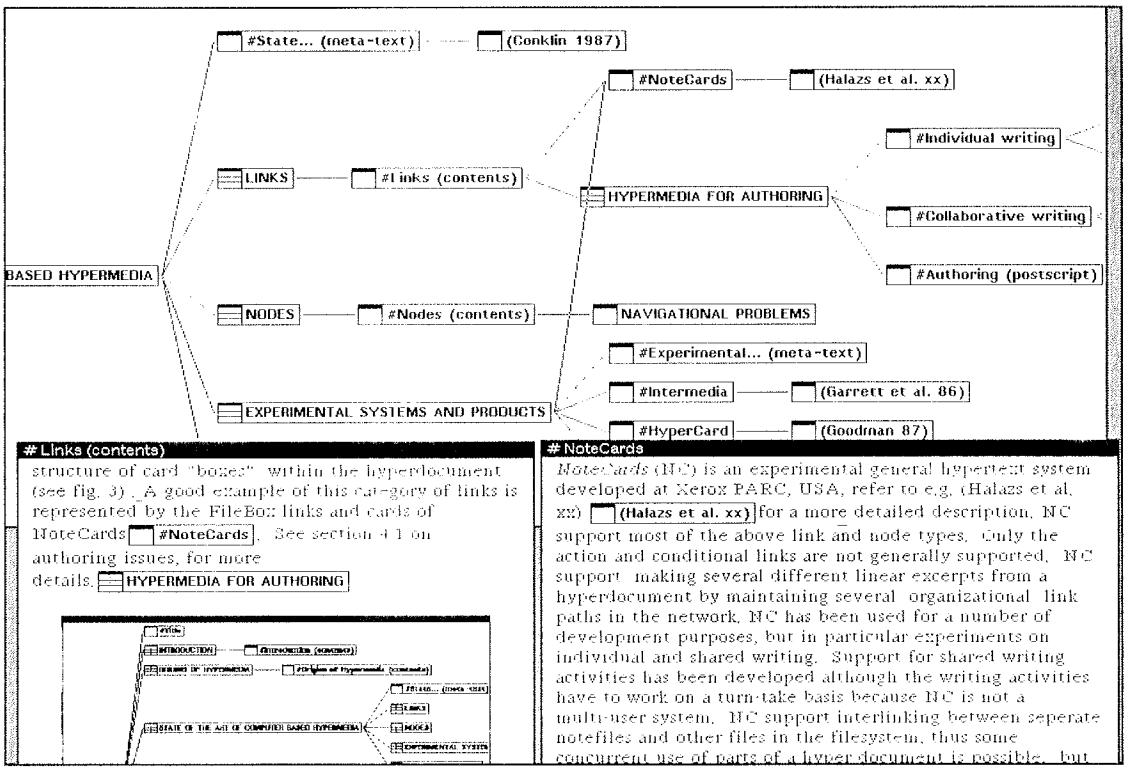


Figure 1: Example of a hypermedia network with two nodes displayed in open windows

The fecundity of Nelson's imagination was greater than his ability to get financial backing for his ideas, so only scraps of his ideas have been implemented, but his work is still worth reading, just for ideas, and he continues to plough his furrow on the Xanadu project.

The other early pioneer in the field, though he is not often associated specifically with hypertext, being more known for his invention of the now ubiquitous "mouse" pointing device and for his work on supporting group work through the computer was Douglas Engelbart (Engelbart 1963). He conceived a long range plan to use the computer to augment human intelligence in the fifties, and his project, was built up at the Augmentation Research Center in Stanford Research Institute (SRI) in the mid -sixties, peaking in the early seventies. The project produced the prototype computer system called NLS (for oNLine System), which was renamed on commercialization in 1978 as Augment (Engelbart, Watson, and Norton 1973, Engelbart 1984). This system had impressive capabilities to structure material of any form, and to include non-text material. A video demonstration of this system was given at a conference in 1968 which is still remarkable to see. An extract of this video appears in a 1988 video concerning his life's work that is publicly available. Although not referred to as hypertext as such, the "linking" capability supported on the NLS system can be considered a genuine hypertext. Some have argued that the strong hierarchical organization of material in this system implies that the result is not a true hypertext, but even Nelson himself notes that this is a bit unfair. True, the material is structured hierarchically, but the user can avoid any real implications of this underlying structure, and what is displayed on the screen can be controlled by a display

language program, thus entitling Engelbart to be entered into the ranks of the hypertext pioneers.

3 STATE OF THE ART OF COMPUTER BASED HYPERMEDIA

In this section we will give a brief but more detailed introduction to the capabilities of current Hypermedia systems, and we will give some examples of experimental systems and available products. The section covers some of the same territory as that in (Conklin 1987).

The basic characteristic of a Hypertext/Hypermedia system is that it supports the use of *links* to navigate within and between documents. Documents in a hypermedia network consist of interlinked nodes containing chunks of information such as text, pictures, program fragments, drawings and even sound. A metaphor of threaded cards within boxes is often used to describe a hypermedia network. The links in the network can have different types, corresponding to different colours of the threads between the cards in the boxes. Nodes can be referenced by numerous links, i.e. cards can be hung up on numerous threads at the same time. Refer to Figure 1 for an example of a network. The strength of hypermedia is the support for interactive navigation in the network rather than the ability to extract parts of the information in linear form on a printer as is the case with, e.g. word processors and report generators for databases. Thus hypermedia systems are best supported on graphical workstations with windows to contain the individual nodes of the network, and a pointing device such as a mouse to click the link icons wherever they appear on the display windows.

To describe the capabilities of hypermedia we will continue with a general view of the basic building blocks of hypermedia, namely *links* and *nodes*.

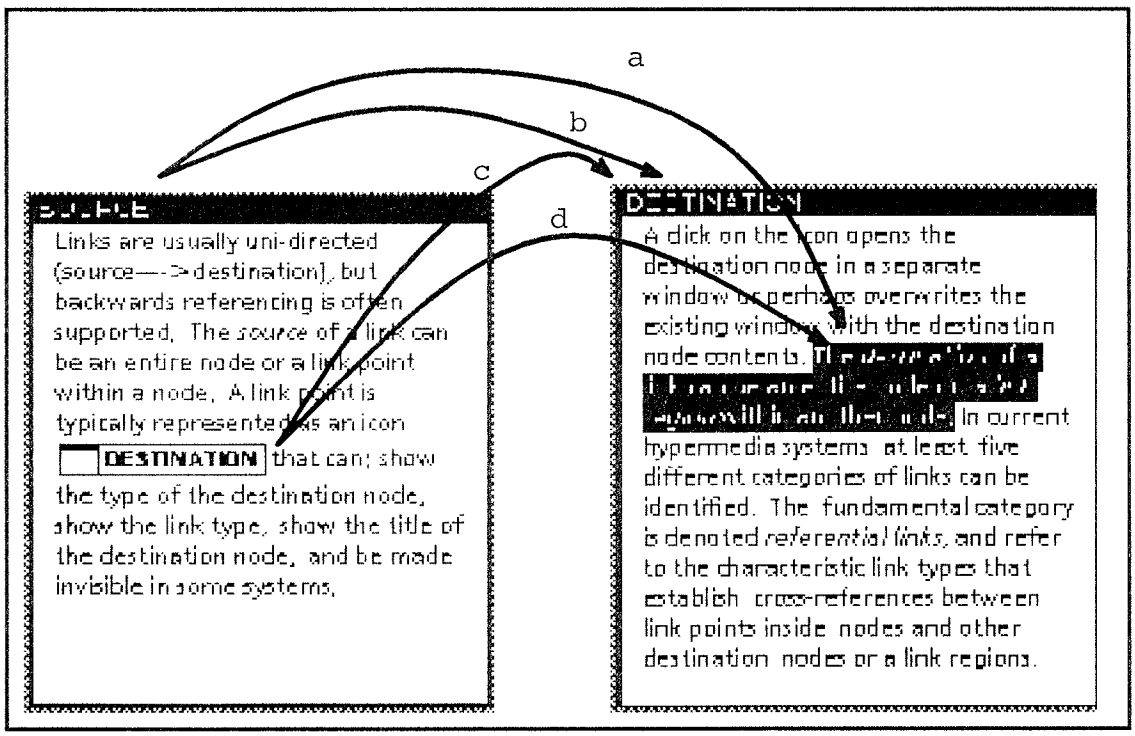


Figure 2: Linking options between sources and destinations. (*a: Link from node to region. b: Link from node to node. c: Link from icon to node. d: Link from icon to region.*)

3.1 LINKS

Links are usually uni-directional (source---->destination), but backward-pointing links are also often supported. The *source* of a link can be an entire node or a link point within a node. A link point is typically represented as an *icon* that typically indicates: the type of the destination node, the link type, and the title of the destination node. These links can be made invisible in some systems. A click on the icon opens the destination node in a separate window or perhaps overwrites the existing window with the destination node contents. The *destination* of a link can be an entire node or a *link region* within another node (See Figure 2).

In current hypermedia systems at least five different categories of links can be identified. The fundamental category is the *reference link*, and refers to the characteristic link type that establishes cross-references between link points inside nodes and other destination nodes or link regions. Reference links can be further classified, e.g. a "see" cross-reference, a bibliographic reference, or an annotation reference. With regard to the user-interface two variations of this link type exists, they are called *replacement links* and *note links*. Replacement links are reference links that replace the link point with the link destination instead of opening a new window on the screen. Note links are reference links that provide the link destination in a pop-up window that appears when the link icon is pushed and disappears when the link icon is released.

A second category of link types are denoted *organizational links*. Organizational links provide facilities to structure a document or material into a number of component parts related by these links. A good example of this category of links is represented by the FileBox links and cards of NoteCards (See Figure 3). For more details on authoring issues see section 4.1.

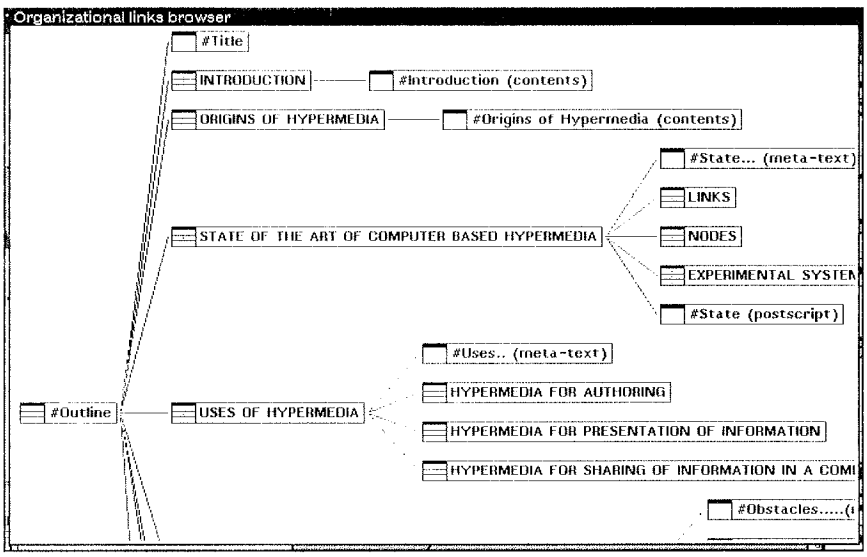


Figure 3: Organizational links for selected sections of our paper as they appear in the NoteCards system.

The third category of links are *keyword* or *search links*, a form of implicit linking, which supports regular "string" search on both card titles and within cards. Moreover, it is possible to combine string search with structural search, to search e.g. a certain *node type* with only a specific set of outgoing and incoming

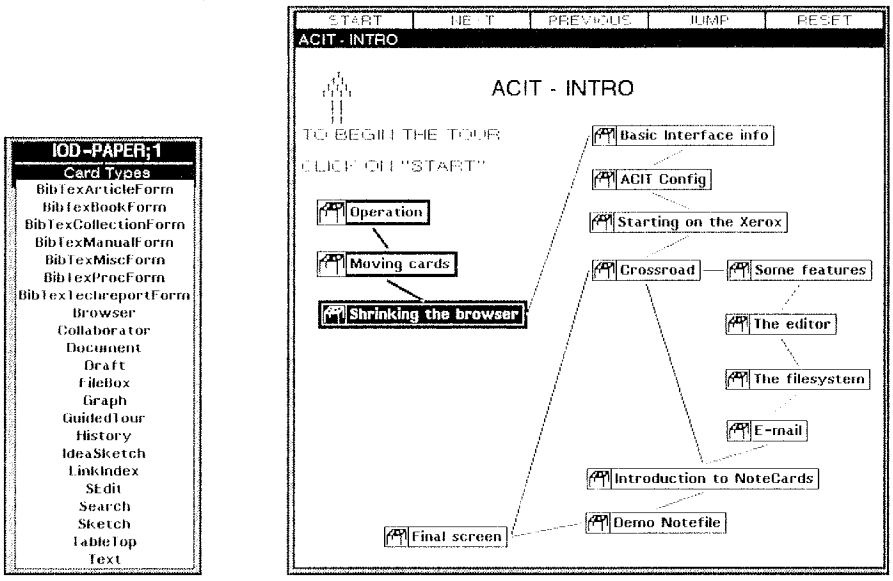
links that match the given structure being searched. Instead of clicking on a link icon this kind of link is typically provided as a search command/menu item, which when activated opens a dialogue with the user in order to specify a pattern and/or a structure to match. The result of the search is either a collection of link icons corresponding to matching destinations or an immediate opening of the matching set of cards found in the network. The string search links are very similar to the search facilities available on word-processors, but here we have a network of nodes as the scope of search, rather then a text document.

A fourth category of links are *action links*, i.e. clicking on an action link icon performs a user specified action different from the simple opening of a destination node. Examples of actions that could be performed from an action link might be: playing a certain piece of music or video film from a connected CD-ROM, starting a spreadsheet program on a certain budget, or dialing the phone number of a certain person.

The final category we classify as *conditional links*. These are links that are associated with a rule to be processed when clicking the link icon. The rule then determines which destination should open depending on the state of the variables in the system. An example of the use of conditional links could be to make the link destination depend on the users *level of expertise* or the users *previous visits* in the network (assuming this information is stored in appropriate data-structures).

3.2 NODES

As is the case with links, various types of *nodes* ("chunks" of material) are supported in different hypermedia systems. Examples of node types are: text editor nodes, drawing editor nodes, bitmap editor nodes, program editor nodes, and browser nodes (See Figure 4a).



(a) (b)

Figure 4: (a) Menu of different node (card) types in the NoteCards system. The top seven items refer to specialized form card types, designed and added to the menu by one of the authors to handle a database of bibliographic references. (b) A Guided Tour browser from the NoteCards system[2]. The edges in bold indicate the network path already visited in this tour, and the node in bold indicate the current position in the tour.

The various *editor node types* provide cards where the objects manipulated with that particular editor can be combined with link icons, e.g. part of a bitmap can be made into a link icon that reacts when clicked. In the case of bitmap editor nodes, link insertion could be applied to a scanned picture of an object or a map, to provide links to detailed textual descriptions beyond certain parts of the picture.

The *browser node types* support either automatic generation or manual layout of a *graph* representing part of a hypermedia network in order to be able to get an overview of the contents or to be able to view the contents at different levels of abstraction. Browser nodes can be used to attack navigation problems discussed in more detail in section 5. In the NoteCards system there is a special kind of browser node denoted a Guided Tour card to help a user follow a certain prepared path through a network. Moreover, the user can keep track of which nodes in the network he/she has visited (See Figure 4b).

3.3 EXPERIMENTAL SYSTEMS AND PRODUCTS

To give an impression of the current capabilities of systems available we give a brief description of a few hypertext/media systems. We make a distinction between research-oriented systems and commercial products.

RESEARCH VEHICLES

NoteCards is an experimental general hypertext system developed at Xerox PARC, USA, (See Halasz et al. 1987, for a more detailed description). NoteCards supports most of the above-mentioned link and node types. Only the action and conditional links are not generally supported. NoteCards allows one to make several different linear excerpts from a hypermedia network by maintaining several organizational link paths within the network. NoteCards has been used for a number of development purposes, especially experiments on individual and shared writing. Support for shared writing activities has been developed although the writing activities have to work on a somewhat awkward turn-taking basis because NoteCards was not designed as a multi-user system. NoteCards supports interlinking between separate notefiles and other general purpose files in the filesystem, thus some concurrent use of parts of a network is possible, but neither security nor notifications of changes are given to the simultaneous users. Finally NoteCards is an open and tailorable system that allows programmers to add new node types (See Figure 4a for an example) and process the network under program control.

Intermedia is an experimental hypermedia system developed at the Institute for Research on Information and Scholarship (IRIS) at Brown University, USA (See Garrett et al. 1986, for a more detailed description). Intermedia supports most of the link and node types discussed earlier. Action links are, however, not generally supported, but conditional links are being developed to make the link destination depend on the status of certain specified variables. Intermedia supports the user in maintaining private link structures (contexts) on top of existing information structures without disturbing that structure. With this facility Intermedia provides the capability that allows, e.g. library users to maintain a personal linked network of notes and references on top of a public read-only library system with references, reviews etc. Intermedia also provides support for some multi-user access to a hypermedia network by allowing the user to enter individual nodes in the network in either *read*, *annotate*, or *write* mode. Appropriate warnings are given when several users try to enter write mode on the same node, or when a user tries to enter a protected node in write mode.

PRODUCTS

HyperCard is a hypermedia based "database" system available as a cheap shareware product for the Apple Macintosh, refer to, e.g. (Goodman 1987) for a detailed description. HyperCard differs from the other experimental systems in that it does not primarily support hypertext networks, but rather information structured in fields. The only node type in HyperCard is a card that can contain a mixture of graphics (including bitmapped text), buttons, and fields. A card can be built up from a *card* level and a *background* level. The background level can be common to a number of cards. The basic link type is a "go to card" link which is provided by programming buttons that can be placed on the cards. Thus link points are implemented with the general button facility that is based on a script to be programmed in a special purpose programming language called HyperTalk. HyperCard supports conditional and action links generally, because all sorts of conditioned actions can be performed from the scripts of a button. Procedure calls to external programs such as spreadsheets, word processors, and CD players, can be inserted in the code of a button. HyperCard is currently a single-user system, but it can be used as a front-end to a multi-user database system called ORACLE, available for a number of mainframes and mini-computers. HyperCard is in widespread use for various applications such as personal information organization, presentation of user documentation for software products, and even as a design tool to sketch larger information systems (See, e.g.Bødker and Grønbæk (1989) for an example).

Guide is a hypermedia information presentation system available as a product for the Apple Macintosh, SUN, and PCs (Refer to (Guide 1986) for a description). Guide is capable of presenting text and graphics information, i.e. text and graphics editor nodes are available. Only the reference link types are supported, but in a number of variations: basic reference, note, and replacement. In Guide, a document is organized as a linear file where it is possible to use replacement links to coarsen parts of the file into a link point e.g. a section heading that can be expanded by clicking. Pop up note links can be added anywhere in the file, but all the notes have to be defined in a global *definitions* window, which makes the addition of notes a bit tedious. It is not possible to make paths consisting of links with different types of "colours". Guide is a single user system. The only way concurrent use of a network can be provided is through cross-file links, but this approach provides neither security nor notification on e.g. deletion of existing link destinations.

The four systems described above illustrate the variations in hypermedia support provided on current systems. Throughout the paper examples are taken from the NoteCards environment.

4 USES OF HYPERMEDIA

In this section we will highlight some application domains where hypermedia provides a more natural support for user tasks than previously applied technology. Hypermedia ideas have, because of their historical roots, of course been applied in a number of computer science application domains such as documentation of computer programs, and documentation of computer system development processes (Walker 1987). But for this audience we will focus on some other more relevant usages of hypermedia such as: Authoring, on-line presentation of information, and sharing of information in a community.

4.1 HYPERMEDIA FOR AUTHORING

Some hypermedia systems, e.g. NoteCards provide support for aspects of authoring that are impossible or at least quite artificially supported by ordinary

word processors. (See Trigg 1983, Trigg and Irish 1987, for more detailed discussions on authoring with hypermedia.)

Hypermedia support *idea generation* activities where an author enters a number of chunks of text or graphics in nodes and makes different types of links between these chunks. Links can also be used, e.g. as argumentation support references, references to examples/figures, bibliographic references, and ordinary cross-references (See section 5). The links can be traversed and edited over and over again in an iterative writing process that ends up with the establishment of a hierarchical structure (organizational links) that can be used to excerpt a linear text as output from the network of nodes. This writing style is often denoted a "bottom-up" writing style, because the direction of movement is from bits and pieces towards a hierarchical structure with sections, subsections, etc. Some problems related to this kind of authoring are discussed in section 5. Hypermedia also supports the opposite approach of *outlining*, i.e. a "top down" writing style where an author starts building a hierarchical structure of empty cards, with titles marked in, to contain the various sections and subsections of the text. Here organizational links are used from the beginning to build a structure, and reference links are used later on to establish references similar to those used for a "bottom-up" approach. This flexibility in authoring adds to the "naturalness" of the medium that we noted earlier.

Collaborative activities concerning authoring such as critiquing and commenting have traditionally been supported by reviewers making annotations in the margin of hardcopies of the text. Conventional word processors do not provide good support for such annotations. But with hypermedia it is possible to make annotations to an existing draft more easily. The reviewer inserts a link icon to a comment card at the place in the text that he/she wants to comment. When reading through the commented draft the author can push the link icons and read the comments whenever appropriate. Comments can easily be included in the revised draft, be excerpted on paper separate from the text, or optionally be made invisible in order to read a clean draft without comments.

Support for co-authoring — with multiple authors working on the same manuscript, is unfortunately not very good in current systems, although attempts have been made to extend them in this direction (See e.g. Trigg, Suchman, and Halasz 1986). Their extensions to NoteCards support co-authoring by: semi automatic maintenance of a revision *history card*, assignment of a different font to each author during the writing activities, and some conventions on the usage of link types. Whenever an individual author takes a new turn on the manuscript a *collaborator card* with a time stamp and the initials of the author is added to the bottom of the revision history card. A co-author can push the various link icons and examine the revisions on the destination cards, for this purpose the assignment of different fonts to the individual authors help co-authors in identifying the exact revisions inside the nodes.

This kind of hypermedia support for collaborative writing requires a commitment from the individual authors to add the extra information on revisions/additions to the automatically generated collaborator card. There is a danger that the process of making small revisions become rather tedious, because the overhead in coordinating the procedure becomes too large compared to the revisions made (refer to section 5 for a discussion of cognitive overhead problems with hypermedia). There are two possible solutions to this problem: one solution would be to establish some convenient conventions in the group of authors on the level of detail of the meta-information, another solution could be to further automatize the maintenance of meta-information, e.g. by having link icons to all modified cards for a given session automatically added to the collaborator card.

To summarize, the trends in development of hypermedia are extending computer support for authoring to cover aspects of the writing process such as the creativity and collaboration involved in developing the contents, rather than just the typing, correcting, and formatting aspects of text as conventional word processors support.

4.2 HYPERMEDIA FOR PRESENTATION OF INFORMATION

Traditionally detailed documentation on certain topics has been presented in highly structured documents ranging from huge encyclopedias to small booklets. The characteristics of this kind of information presentation is that the information on a topic can be browsed through various sorts of extensive indexes, and the information descriptions include a number of cross references to other subtopics.

Recently marketed hypermedia systems such as Guide and HyperCard have become frequently used tools for presenting such structured information on-line. Some examples are: documentation on software products, educational presentation of topics within, e.g. chemistry and geography, and guides to buildings and tourist attractions.

Using Guide or HyperCard for such presentations often means that the whole network with all links and all cards are made available for users exploration in an optional sequence. Another approach to provide hypermedia presentations is to set up a number of proposed paths, denoted guided tours, through a subset of the information. The user then choose a path that the presenter of the information claims to be useful, e.g. for a novice user, or an experienced user, and side-tracks are traversed on the user's own responsibility. The usage of Guided tours in NoteCards documents is discussed in (Trigg 1988).

The advantage of hypermedia presentations is that it is easy to navigate between the various subtopics through the interactive indexes and cross-reference links. Another intuitively appealing feature is that link icons can be embedded in a picture or a drawing to link in more detailed information, e.g. having a location on a map as a link icon bringing up a destination card with detailed information on the location motivates users in pursuing topics as and when they wish, rather than relying on the whims of the system designer for the presentation of material. It eliminates the need to go and consult one or more index references. Finally features for making personal links on top of a public available read- only information source (See the Intermedia system above) will provide an intriguing possibility for users to maintain their own personal method of combining publicly available information for later usage.

One obvious disadvantage of such on-line presentations is that it is hard to read and comprehend huge amounts of information from a screen. Moreover, a lot of information is still needed in contexts where hard copies are the most convenient medium, e.g. because computers to run hypermedia systems still are too big to be carried around a work place. Thus such presentation systems should still support extraction of meaningful linear hard copies segments.

4.3 HYPERMEDIA FOR SHARING OF INFORMATION IN A COMMUNITY

We have been involved in a small project at our department to build a demonstration community information base for users of our Xerox 1186 workstation. One of our interests in developing this system is concerned with discovering how we can improve traditional user support facilities for small communities by paying explicit attention to the social context in which the application is being used. We wish to support the ongoing workplace practices of the user community through the use of the computer medium, and wish to provide electronic analogies of varying forms to those informal informational exchanges that exist in every workplace.....not to replace already existing forms of social

interaction and embedded practices but to extend them into the electronic medium (See Bannon 1989, for further discussion of this issue).

We wanted to develop what might be called the "community memory" of the workplace - to encourage users to annotate the information within the database so as to make it more contextually based and meaningful for others in the work community. The possibility of critiqueing the information, suggesting new links between existing features, examples of use of system features etc. are relatively easy to support technically in the NoteCards hypermedia system (except for multi-user access), but the organizational and social factors involved in promoting this activity were not, and were part of the reason for the investigation. We entered certain basic information into the system ourselves, but worked on ways to encourage users to contribute with information on experiences with the computer system through comments, criticisms, and general annotations on the user support documentation that had been provided. For this purpose we needed a medium such as hypermedia to support storage and retrieval of the loosely structured information in a shared database. The hope was to support the community in "growing" the database itself through the contributions of the various users, thus ensuring that the additional information provided was context-relevant, coming from the actual working practices of the user community, not from an external "documentation support" group.

We tried to reduce the overhead involved in having users add to this information base by providing an interface to the system that made it easy for users to add comments into the system without large overheads in switching contexts and starting up the information utility, by having a small window open on the screen for comments that is automatically saved and incorporated into the information base. Other concerns were how to reward people for entering useful information, how to get feedback from other users on the utility of the information provided by users, and how to present the updated information.

Unfortunately the empirical data we have managed to collect to date has been meagre. A problem in our context has been that we do not have a stable community of users on the system. Some students just use the system for a particular project and then disappear. The sense of belonging to a community is not present to a significant degree, and so the commitment on the part of the users has been minimal. For the present, the project has been shelved, and the developed database is currently only used as an introduction device for new users of the Xerox system. But we still believe that hypermedia facilities may significantly assist this sharing of community knowledge[3].

A related idea of recording a history of development and use of a system (to assist in later maintainability of the system) - a form of a project "memory" - has recently come into prominence in the context of preserving the rationale for the design of large software systems (e.g. Conklin, 1989). The idea is to capture as it develops the thinking of designers, the arguments for and against particular design decisions, as well as the actual documents and ongoing exchanges about the project so as to help people at a later time to understand how and why the resulting system works as it does. While this work is still in its early stages, it is interesting to see others pay attention to the *process*, and not just the *product*, aspects of design, as documents alone are definitely insufficient to fully understand the resulting system. Hypermedia systems seem quite suitable to support such possible representations.

5 OBSTACLES TO THE SUCCESS OF HYPERMEDIA APPLICATIONS

Despite the "hype" about hypermedia in some commercial quarters recently, there remain a number of major issues that need to be resolved before such systems can deliver on their promises. One positive sign is that some of the leading

researchers in this field are themselves quite aware of the problems (e.g. Halasz 1988, van Dam 1988), articulating them clearly in their addresses at the initial Hypertext Conference (Hypertext '87) that was held in 1987. We will not enumerate all these issues here, but mention some that we feel, from our experience, are of particular importance.

In any hypertext application of even moderate complexity users are continually getting lost in the interconnected network of nodes and links. The "navigation problem" as it is called, is common even in such simple primitive network structures such as computer conferencing systems, where there is only a very limited form of linking available, and increases exponentially as linking possibilities are increased. The importance of graphical views over the material cannot be over-emphasized. Such efforts as providing graphical browsers over the network certainly help, but are not of themselves sufficient. Other techniques, such as "fish-eye" views (Furnas 1985) of parts of the structure could also assist, but it appears necessary to provide some forms of more traditional search facilities on top of the network. Halasz (1988) suggests the need for structure search mechanisms, which we briefly mentioned in Section 3, as well as the more conventional content-type search facilities. The former would allow users to take advantage of the structure present in the hypertext system.

We have seen two different kinds of system, those oriented mainly towards *browsing* existing information bases, for example library-type systems, and those that are intended to support *authoring*, where users add in information to the system and make links between items of information. With both kinds of systems, for many applications, there is a problem of determining exactly what constitutes a "chunk" of material? The "naturalness" of the hypertext form of organization is not very clear when one tries to "hyperize" a play for instance! The linear order imposed on certain pieces of text thus is not simply one forced by a more primitive technology. The full text may have a form and style of its own, that helps give meaning and structure to the whole. Fragmenting such a structure is a non-trivial problem, and one which we have little understanding of or support for. On the production side, the converse is also true. If we prepare material in such "bite-sized" morsels, it can be difficult to produce a readable and coherent document by simply juxtaposing these separate pieces. We can already begin to see some of the negative consequences of this process already, where authors are semi- automatically producing papers that are obviously concatenated from separate chunks of material that are not sufficiently integrated and have style inconsistencies. Part of the problem with such structures, which may work satisfactorily for such domains as technical documentation writing, is that a knowledge of the larger whole affects the way we would write about the individual pieces. Since we do not know the "whole" in advance, as certain chunks of information may be used in several different documents, a hypertext document lacks elegance and style when compared to a document produced in a more traditional fashion. Some people, recognizing this problem, are beginning to pay attention to the *rhetoric* of texts, a neglected area of study for many years, but to our eyes the problem is not "soluble" by means of a technical fix, it is inherent in the medium. Hypertext can thus be used as an excuse for lazy and ill-thought out presentations where the author is not willing to work on an overall ordering and layout of a complex issue, preferring the anarchy of loose webs of disconnected jottings. Conversely, we might be able to use the medium to produce a new form of structured discourse about a topic. Readers could interact with the structured text via a display terminal and follow particular lines of investigation as they see fit (See the example in Trigg 1988).

Yet another potential problem with hypermedia systems is what has been termed the "cognitive overhead" problem by Conklin (1987) in his review article.

This refers to the extra effort imposed on the author of a hypertext document when deciding on adding links to a document. On many systems one must also come up with a link type classification and a name for the link. This takes one's thoughts away from the original document and poses an additional "overhead" on the author, which can be significant as the linking possibilities increase. Even for a reader of such a document, the problem remains, as one must decide at each choice point, where there is a link, or several, whether to take one of these side-tracks, and if so, which one. There are ways, technically, of reducing this overhead, for instance by delaying the necessity for labelling of links, by having very fast response time so the reader can quickly check a link to see if it is worth pursuing, etc., but the underlying problem will not disappear, as it is inherent in the hypertext medium. The unresolved question is whether we can work around the problem to the extent that this problem is not a major obstacle to building or using a particular hypertext system in a specific domain.

6 CONCLUDING REMARKS

We have provided a brief introduction to the idea of hypertext, its origins, uses and problems. We have shown how computer-supported linking of material can provide a powerful medium for both authoring and browsing of both textual and non-textual information. This particular paper has been produced from a NoteCards hypermedia network jointly developed by the authors. Certain nodes in the network were selected and then "linearized" to produce this report. Many of the Figures in the paper, also existing in the hypermedia network, show how earlier versions of this paper appeared in the network during the writing activities.

In conclusion, to echo a comment of Ted Nelson, we believe that hypertext fits better with how we naturally read and produce documents, and now with powerful hardware and large display screen technology we have the means to really explore the concept in all its rich diversity. Judging by the growth of interest in the topic, as witnessed by the explosion of articles, books, and journals in the field, the next few years should be interesting ones!

NOTES

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2: The Guided Tour example is from a student project made by C. M. Madsen.
3: Readers, who are interested in the technical problems we encountered in this project, are welcome to contact the authors for further information.

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