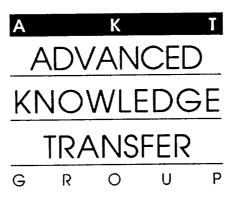# From Knowledge Presentation to Knowledge Representation to Knowledge Construction:
Future Directions for Hypermedia

by

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Introduction

Much of the excitement surrounding hypermedia systems is their ability to meet the needs of various users. These include authors, designers, on-line readers and others using the idea processing capabilities of such systems (Marshall, 1987). The central theme of currently available systems is knowledge presentation. However to fulfill their promise hypermedia systems need to move toward more sophisticated interpretations of knowledge representation and finally toward knowledge construction. This paper begins with a discussion of the relationships between human memory systems and hypermedia system with particular emphasis on the underlying importance of associational memory. Then the distinctions between knowledge presentation, knowledge representation, and knowledge construction are addressed. Finally issues involved in actually developing individualizable hypermedia based knowledge construction tools are presented.

Parallels Between Human Memory and Hypermedia

Much is made of the similarities of hypermedia-based systems and current conceptions of human memory. These human memory models are primarily based on information processing theory. In this section we will examine this relationship as well as discuss strengths and weaknesses inherent in these current analogies between hypermedia and human memory.

Similarities

Current conceptions of learning are based on principles of cognitive psychology. Learning can be defined as the reorganization of knowledge in semantic memory (Jonassen, 1988) The interconnections of knowledge in a structured associative network allow learners to combined ideas, extrapolate, and infer. These structural networks are composed of both the information presented as well as the relational links which interconnect them (Norman, Gentner, & Stevens, 1976). Based on this description of semantic networks, learning can more explicitly be described as building new knowledge nodes and connecting them with existing ones and with each other (Norman, 1976). The stronger the connection between the existing knowledge stored in

memory and the newly acquired knowledge, the better the information will be learned. Learning, therefore, becomes a function of connecting new material onto one's preexisting knowledge structure (Jonassen, 1988).

If we accept this cognitive definition of learning as a reorganization of cognitive structure, then, we need access to tools for assessing cognitive structure, tools for depicting and displaying appropriate knowledge structures, and ways of mapping that structure onto the learner's existing knowledge structure. Current computer environments, especially those based on hypermedia, are capable of doing this. In fact much of the excitement surrounding hypermedia's potential centers on its use as such a tool.

From this description, it is clear to see the common terminology used by both cognitive psychology in describing the operation of human memory and hypermedia systems. Nodes and links form the basic structure of each. In fact the human memory model is currently based strongly on a computer analogy, comparing the storage and retrieval from human memory with similar mechanisms in computer-based technologies. Hypermedia extends this notion by allowing for a more explicit relationship between information in a computerized information base. Associations between information, a key aspect of human memory, are also central to hypermedia.

Rumelhart (1977) points out that the essential attribute of the human memory system is not the storage or retrieval of specific units of knowledge, but rather the organizational schemes by which knowledge is associatively related. Hypermedia has provided a computerized technology to achieve similar relationships. A second fundamental aspect of human memory is that when new associations and therefore new organizational schemes are developed, it is not necessary to completely recodify the prior knowledge within the newly acquired structure. Hypermedia environments also provide such flexibility in computer information systems, in that new information and new relationships can be easily integrated into previously stored information without having to recode that information.

Human memory also utilizes a variety of organizational schemes, not just on general scheme, to store and retrieve the variety of knowledge presented. Research has demonstrated that the human memory system stores and structures information and associational schemes that preserve the most important aspects of the associations, yet does not preserve other possible association (Bransford & Franks, 1971; Bransford, Barclay, & Franks,

1972). Hypermedia systems offer the possibility of similar organizational schemes, allowing the the designer and/or the user to decide on relevant relationships between information, while not attending to other possible, yet less important relationships.

Differences

It is worthwhile to note that prior to the inception of the computer as an acceptable metaphor for human memory models, the library was used as the prime analogy. However, both the computer, especially when used as a hypermedia device, and the library metaphor breakdown at certain points in their respective parallels with the human brain. For instance, Rumelhart (1977) points out that while other information storage systems, such as a library of books stores "complete" units of information, the human brain appears to store fragmented bits of information which, must then be somehow processed via the retrieval system to form a complete unit of knowledge and therefore allow the answer to a specific query of the human knowledge base.

Hypermedia systems, like a library of books, store complete information "chunks" in each node. If fact, it is now a point of contention whether such systems should have the capability to contain more than one complete "chunk" of information per node. A second issue is whether, in hypermedia systems, the nodes should be seen as repositories of these units of informations or should the nodes be constructed as the information itself.

Thus the retrieval of information from the human memory system can be broken down into two equally important processes: first, the location of the desired information; and secondly, the reconstruction of appropriate output from the incomplete information stored. Hypermedia systems differ in that they do not accommodate this second aspect since they traditionally hold complete units of information, and therefore no processing of information is required to provide an answer to a specific query.

Linking Information

Information in both human memory and hypermedia is related through associational links. Much of the concern in developing current hypermedia systems focuses on the underlying problem of using merely associative links. Most systems support only that one unit of information is

somehow related to another unit of information. Human memory supports a much stronger linking mechanism, in that the links also convey information about the associational relationship.

This is especially evident in the placement of nodes of information in a large hyperspace. An underlying assumption of hypermedia designers, which is often then passed on to users is that distance between nodes in hyperspace is directly related to the strength of their association (Locatis, Letourneau, & Banvard, 1989). Yet this is not necessarily the case. And reliance on such a metaphor may increase both the development cycle, and therefore the cost, of a hypermedia, as well as the cognitive load associated with using the system. Since there is still no consensus in the brain physiology of information storage and retrieval, no such reliance on distance is present in human memory. The strength of the relationships are conveyed by the value of the associational relationships.

Hypermedia systems that allow for typed link relationships may alleviate much of this problem in that a designer can connote the strength of a relationship by the type of link used to connect two nodes of information, regardless of the distance between them in hyperspace.

Conclusion

While information processing models of human memory and hypermedia share many common features that seem relevant in assessing the potential impact of hypermedia in learning environments, it is clear that there are certain differences that prevent one from asserting that hypermedia is simply a computerized information processing system that parallels its human equivalent. The importance of associational memories in both systems merits a closer look at common features shared by all associative memories. These include that:

(1) they can recall information based on incomplete or garbled inputs

(2) they can store information in a distributed fashion

(3) they display some degree of content addressability

(4) they are strongly robust in that they do not degrade appreciably when nodes and/or links are lost or information is input inaccurately

(5) they can generalize between information, both in terms of content and structure, and previously stored information

(Caudill & Butler, 1990)

While hypermedia proponents have based much of their theoretical claims on parallels between hypermedia and associative memory, one can quickly see that current hypermedia systems do not meet all of these central requirements. If the relationship between hypermedia and associative memories is critical, then the next generation of these system should focus on meeting these essential characteristics.

Knowledge Presentation, Knowledge Representation, and Knowledge Construction

Much of the discussion about the impact potential of hypermedia has centered on the ways that such systems may become infused into our society. Current systems tend to focus on either the presentation of information or the representation of information in an advanced storage and retrieval system. Others propose a next generation of hypermedia that will focus on the the construction of knowledge.

The power of hypermedia applications is seen in the following three characteristics that relate directly to their use as presentation tools, representation tools, and construction tools (Collier, 1987):

(1) Printed knowledge is inherently nonlinear and often has arbitrary ordering forced on it by the print medium. Hypermedia systems eliminate such constrains in the presentation of information. Such benefits relate directly to hypermedia as a knowledge presentation environment.

(2) Semantically and logically related information can be tied together in conceptual webs. This benefit draws heavily from the parallel between hypermedia systems and human memory and is explicitly related to the power of hypermedia to structure and represent knowledge in an associational network similar to the function of the human brain.

(3) Other means for making connections among information support only part of the potential web of interconnections. Since their is no way to fully anticipate the prior knowledge, experiences, and learning style of a potential user, other information systems are limited in that users may be unable to adequately transfer desired information into their existing cognitive structure. Hypermedia, on the other hand, holds the potential to allow users access to the tools by which they can construction the transitions between the information to be accessed and their cognitive structure; thus, truly individualizing the learning environment.

Hypermedia as a Presentation System

As a presentation system, the ability of hypermedia systems to show or exhibit information in a multimedia framework is emphasized. In fact much of the excitement of lower end hypermedia systems, such as Hypercard and Supercard, tends to focus on their multimedia aspects rather than the non-linear attributes critical to any hypermedia system.

The emphasis of hypermedia as a presentation system is exemplified in Oren's (1987) discussion involving the notion that the designers of hypermedia systems should focus on construction of the most useful pathway for the user to proceed through the information in a particular hypermedia. Thus, he notes that hypermedia design should anticipate the needs of the learner and present information accordingly.

However, one must note that simply because hypermedia systems appear to be good vehicles for capturing, structuring, and presenting information, such attributes do not necessitate that these will be used to their fullest potential in the development of hypermedia-based knowledge representation systems.

Proponents have addresses several ways in which the Notecard hypermedia system can be extended to more fully move from a multimedia presentation system to a more sophisticated knowledge representation

system. One is that such systems will need to become more adept at formalizing the representational process within the system.

Hypermedia as Knowledge Representation

As a representation system, much is made of the similarity of hypermedia to current models of long term memory as previously discussed. In fact, the definition of representation as the capacity to picture to the mind a mental image or idea, leads one to such parallels. Certainly there is a common terminology that also promotes such a relationship. Nodes and links are the metaphor for both. Nodes and links are also the common ground of artificial intelligence and linguistics researchers. Yet researchers in these disciplines have been hesitant to claim that they are referring to the same entities. In fact the field of cognitive science has evolved to reconcile the psychological, linguistic, and computer conceptions of knowledge representation and promote a more multidisciplinary approach to study in this important area.

In fact, researchers are beginning to see that while one of the often tauted aspects of hypermedia is their ability to support the emergent properties of the representation process, current hypermedia systems have failed to develop these opportunities. Specific inquiry into the fundamental aspects of nodes and links are needed if hypermedia is to become a sophisticated knowledge representation system.

Current systems differ in the way information is related to the nodes of a hypermedia. One difference is that in some systems, such as the IRIS Intermedia program, the information is stored as nodes. Other systems, such as the Thoth-II systems, separate the nodes and the information they contain. The benefit of this second type of system is that they allow for more than simple connection between units of information by allowing the conception of the knowledge representation to be conveyed from the designer to the user (Collier, 1987).

Hypermedia systems also differ in the amount of information that may be placed in the nodes of this second type of system. One type, exemplified by Textnet, allows only one unit of information to be placed in a particular node. The principle behind the Thoth-II system, on the other hand, is to allow for multiple units of knowledge to be placed in any node.

The use of linkages in hypermedia is also a critical issue as such systems move from mere presenters of information, to more sophisticated knowledge representational systems. "In many representations, a key decision centers around the distribution of meaning- should links or cards carry the semantic burden" (Mitchell, 1987, p.265). The semantic weight of a hypermedia needs to be equably distributed between its nodes and links as neither entity is capable of supporting the full semantic load alone.

While initially much of this weight was placed on the nodes of the network, current implementations are moving more of this burden to network links. The possibility of making value a link property would be beneficial in developing more complete knowledge representation systems in hypermedia. However, performing a representational task or interpreting the results of an analysis may become confusing if link types are used for too many semantically orthogonal purposes (Mitchell, 1987).

One future direction of hypermedia is to develop systems that are capable of capturing knowledge representations via some type of concrete structure that could then be reapplied to other knowledge bases (Mitchell, 1987).

Hypermedia as Knowledge Construction

Another key claim of hypermedia proponents is that these systems will be effective as a teaching medium by allowing users to individually access a large knowledge base and seek out relevant information that meets their particular needs, both in terms of their prior knowledge as well as their preferred learning style. The development of systems to achieve these ends is still a possibility. However, there is little empirical evidence that by simply providing an advanced presentation system, or even a more elaborate information storage and retrieval system that parallels the way that the human brain seems to represent knowledge, that more effective or efficient learning will occur (Locatis, Letourneau, & Banvard, 1989). A more constructivist environment, where the user not only browses the information base, but also has the ability to build additional nodes and linkages, holds more promise to promote learning. Many hypermedia systems support such an environment, yet little has been does to promote this obvious advantage.

Raskin (1987) laments that hypermedia has been heralded with mostly uncritical attention. And while he does state that current implementations of hypermedia are worth pursuing, he strongly cautions that they may fail to realize the expectations currently promised. His criticisms, however, focus mainly on technological and user-interface design limitations that seem addressable in the near term. However this rationale can also serve as the basis of more daunting concerns in that current directions in hypermedia development focus on the presentation aspects and storage/retrieval capabilities inherent in such systems, while to make a more substantial impact hypermedia systems need to focus on allowing users to actively construct information, via typed linkages. The potential of such systems is more strongly grounded in psychological literature on learning and transfer.

A key issue in the emergence of hypermedia is the ability of these systems to promote learning in an effective and efficient manner. In fact, the term HAI (hypermedia assisted instruction) has been proposed to describe the use of such systems (Heller, 1990). While it is beneficial to extend beyond the traditional uses of computers in instructional settings (e.g. drill and practice and tutorial remediation) inherent in Heller's rationale is that current hypermedia systems are incomplete and need to be augmented to meet this challenge. The issues that she addresses also focus on presentation and user interface issues. A more important issue that hypermedia developers need to address, especially within the cognitive paradigm proposed by Heller, is in allowing the user to construct knowledge from within the hypermedia environment.

Individualized Learning Environments

The ability to individualize information access to accommodate the diversity of possible users has been traditionally seem as a stronghold of computerized environments. As our society continues to evolve into a more global one where accommodating only the ethic and cultural majority no longer proves effective, technologies that transparently accommodate the differences inherent in this global society are needed.

Computer assisted instructional environments first offered the ability to individualize information access. Such systems, however, are limited in that they can realistically only accommodate differences in the rate at which a

variety of users progress through the information base. More sophisticated individualized systems are necessary, and proponents of hypermedia hold hope that hypermedia based systems will provide the environment to truly accommodate the evolving needs of a global information society.

Hypermedia and Learning Styles

Research has supported the claim that cultural influences have an effect on the cognitive learning styles exhibited by individuals (Ramirez & Price-Williams, 1974; Witkin, 1967). Learners' cultural background may effect differences in both their intellectual skills and intellectual performance. Children of different cultural and linguistic groups exhibit significant variations in both the cognitive and sensory perceptions.

Cohen (1969) has identified two basic learning styles, analytic and relational. Those who learn in an analytic style view information as part specific, objective, and tend to view information as it is, rather than in some context. Those who exhibit a relational learning style focus on a more global context and in a subjective form. They also tend to view information in its own context. Kirby (1979) points that to address the cognitive learning styles of all learners, information environments should be structured bicognitively since users who do not function effectively in the currently practiced analytically structured environment will be poor achievers and also will become successively worse.

A crucial, and yet often neglected, aspect of effective information transfer is ascertaining users' learning styles and then accommodating them accordingly (Ausubel, 1968). Research suggests that learners who were taught by their preferred method achieved better, were more interested in the subject matter, liked the way the subject was taught, and wanted to interact with other subjects in the same way (Smith & Rezulli, 1984). Matching presentation style of the information with the desired learning style of the user enhances cognitive outcomes. Therefore, by taking users' learning styles into consideration, they may become more involved in the learning process.

Hypermedia as an Instructional Environment

Hypermedia based systems allow the redefinition of both the structure and content of the material to be learned. This ability alters the constraints and opportunities for conveying information when compared to traditional

forms of information presentation. The power of such a tool can be seen as both subtle and incremental; yet we need to harness this power to effectively and efficiently develop training programs that meet the requirements of the information age (Scacchi, 1988).

In traditional forms of instruction, learners most often are presented with information in a sequentially formatted environment. Hypermedia, on the other hand, allows the learner to access any information in the knowledge base (Jonassen, 1988). Learners need not be constrained by the structure imposed by either the information or the instructor. Since each learner has an unique knowledge structure based on their experiences and abilities, the way that they choose to access, interact, and interrelate information in the knowledge base will also vary. Hypermedia based learning environments allow the knowledge base to accommodate the learner rather than the learner accommodating the knowledge base.

In allowing for maximum use of this type of environment, the learners should be encouraged to explore information, make associated links and relationships and even alter the knowledge base to make more sense from their previous experiences and learning style. Hypermedia offers the potential to construct an environment that allows for these beneficial activities (Jonassen, 1986).

A major characteristic of hypermedia environments is that they allow users to link information together in many ways and to make these relationships obvious as well as the conceptual relationships that they describe. Instructors and learners may create different pathways through the hypermedia knowledge base. Users can also annotate the knowledge base by creating notes, explanations, and analogies. A major goal of hypermedia is to provide a learning environment that facilitates exploration (Jonassen, 1988). This type of learning environment provides immediate access to large collections of information. The most distinct aspect of hypermedia learning environments is their ability in a node-link framework based upon semantic structures, to portray an accurate structural description of the knowledge base they are representing.

Hypermedia offers advances from previously available technologies in that it is strongly connected with a cognitive conceptual framework, yet this framework does not limit or constrain it possible application (Jonassen, 1988).

Cognitive Load

A second benefit of hypermedia-based individualized learning environments is in the possibility of decreasing the cognitive load associated with accessing information from within such an environment. Any information presentation/retrieval system has some load associated with its operation. Users must accommodate issues of learnibility, efficiency, ease of remembering, and error frequency. The amount of time a user must devote to such system operational issues, directly increases the amount of time and cognitive energy required to effectively interact with the information system. Efficiency of use is also adversely affected. Therefore, systems that decrease the cognitive load induced by the system will allow for more efficient use of the system.

Nielsen (1990) addresses five usability parameters that are directly related to cognitive load. These include the ease to which the operation of the hypermedia system is learned; how efficiently the system can be used once the user has learned its effective operational structure; how easily the operation of the system is remembered from one interaction to the next; the number and cost of errors associated with system operation; and how pleasant the system is to use.

Certainly, if hypermedia systems can more effectively accommodate the usability parameters addressed above, then they would also decrease the cognitive load when compared with other methods of information access. However, while some are praising hypermedia in this area, others point to cognitive load as one of the largest drawbacks of hypermedia environments.

The question of how much and at what level information should be presented to the user is often at the heart of such concerns. Issues of how many simultaneously displayed nodes should be allowed on any given screen and the how many links should any one node of information support are questions that need further investigation. To see how strongly this issue is tied to the issue of cognitive load, one of the prevailing sentiments in this area is that the number of nodes displayed and the the number of links allowed per node should be limited to seven; a direct connection to Miller's (1956) assessment of the limits of human working memory.

Novice/Expert Users of Hypermedia

Another key issue in the use of hypermedia is the prior expertise and knowledge requirements of the intended user. While knowledge presentation systems may be very useful to those considered expert in the content area of a particular hypermedia, such presentation systems do not hold the key learning tools required by those non-experts when relating to a particular knowledge base.

While there is a clear continuum between novices and experts in a particular knowledge area, a distinction between experts and non-experts is appropriate in interpreting the potential of hypermedia as a learning tool. Issues of cognitive overload, user disorientation, superficial browsing and disinterest often reported by users of hypermedia may well center on the issue of the level of experience of the user. Thus while current hypermedia systems may well decrease the cognitive load of those users closer to the expert end of the continuum, they may well increase the load on more novice users.

Summary: Two Directions for Hypermedia

This paper has addressed two possible future directions for hypermedia, both of which hold promise, yet need further investigation if hypermedia is to become more than just another "hyped" media (Locatis, Letourneau, Banvard, 1989).

The Next Generation Database?

While the focus of this paper centers on the movement from the storage and retrieval capabilities of hypermedia to a more constructionist learning environment, hypermedia does possess attributes that may lead to a next generation of database, one whose major characteristics include hypermedia. Such systems would clearly be useful to any number of users. As we move head long into the information age, an important attribute of the work force will be the ability to access information; as it will no longer be important what information one possesses, only how efficiently they can access the desired information.

Current work in hypermedia seems to focus on this direction and much of the current criticism of available systems rests on the inability of hypermedia users to access such large volumes of knowledge in efficient

ways. Organizational aspects of hypermedia are now a central development issue (Conklin, 1987, Halasz, 1988). Some system designers have moved toward a hierarchical linking structure, where movement between information nodes at one level of the hypermedia is restricted to access only those nodes directly above or below it in the designers structure. Other systems support referential linking, where any two nodes can be linked together. Certainly this second type of systems, while more difficult to construct, especially if the designer is to construct all meaningful linkages, meets more the central attributes of non-linearity in hypermedia development and would be critical if a new generation of databases of information centered on hypermedia are to become a reality.

Another issue that makes the possibility of this direction seem more reasonable is the requirement for the next generation databases to contain more that textual information. Hypermedia, with its multimedia capabilities seems ideal to allow database-like retrieval of textual, graphic, auditory, and filmic information.

Current proponents of this type of hypermedia development also stress other benefits that hypermedia offers in this area. These include the ability to mix both highly structures and loosely structured information together. They also would allow for multiple representations of the same information. And they would allow for the extension of the information base in ways that may not conform to the original pattern (Marshall, 1987).

Knowledge Construction Sets

Initial hypermedia systems such as Notecards, IBIS, and Intermedia required large computer systems. The recent introduction of microcomputer-based hypermedia systems such as Hypercard, Linkways, and Guide have substantively contributed to the hype surrounding hypermedia. However, these microcomputer-based systems have focused more on the presentation of materials rather than the instructional applications that hypermedia may promote. Systems such as Hypercard are often referred to as programming constructor sets, where a user with little computer programming experience can successfully produce a functional piece of software with minimal effort do to the ease to which their scripting environments can be mastered.

The promise of hypermedia, however, does not revolve around an easy way to produce software. Instead, rather than working to promote

programming constructor sets, proponents of hypermedia need to focus on developing knowledge constructor sets. Environments where information presentations can successfully and efficiently be transferred into knowledge to a diverse and every changing population of learners.

Much of the theoretical framework for hypermedia promotes the development of such systems. Yet, little has been done to support such implementations. Future work in the area of hypermedia needs to address the movement of hypermedia systems into the area of cognitive science, issues of transfer of training from the hypermedia to the learner, and the incorporation of artificial intelligent systems within hypermedia information bases that will effectively and efficiently allow learners of all experience levels, abilities, and learning styles to the interact with the information environment.

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