COLLABORATIVE HYPERTEXT IN COMPUTER MEDIATED COMMUNICATIONS

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ABSTRACT

A morphological model for Hypertext based upon Guilford's "Theory of the Intellect" is presented. The model is proposed as one encompassing the scope of human intellectual abilities in forming concepts and the relationships among concepts. In so doing, it provides a foundation for creation of Hypertext as a collaborative group process. Also discussed is the related concept of a "group memory" and analysis tools to support the utilization of the model.

Keys: Computer Mediated Communications, Hypertext, Collaborative Systems, Groupware, Computerized Conferencing

1. INTRODUCTION

Since the Vannevar Bush article on "Memex" in 1945, it has been recognized that a computer can be used to augment the composition and communication process. The word "Hypertext" has become synonymous with the ability to organize the components of a document with the same degree of flexibility implied by Bush (i.e. non-linear text). Among the fundamental elements of Hypertext (a term popularized by Ted Nelson in 1965 and subsequent publications), are the establishment of linkages among text fragments, the conditional handling of the linkages among fragments, and the idea that the fragments may be active programs rather than just passive pieces of text. Hypertext is the non-linear organization of concepts and thought in which the links between text fragments (nodes) are the organizing entities.

Incorporating Hypertext capabilities into a Computer-Mediated Communication System (CMC) so that it is possible for a group, rather than an individual, to be the author brings additional elements into play (Turoff, 1977). For example, constructing new fragments and establishing linkages among them may be dependent upon the assigned roles within the group which is creating the collection of items. The items, whether text, graphics or programs, may ask questions of the readers, and then incorporate the responses as changes in the original items. Thus, the initial content may be constantly changing and growing as a result of subsequent additions and actions imposed by the members of a group sharing access to the Hypertext compilation (Hiltz and Turoff, 1978). Furthermore, the "browsing paths" created by one member may be shared with other members of the group.

The CMC view of Hypertext is as a support tool to aid the collaborative processes of both composition and use of a collection of information. The resulting Hypertext web is a very dynamic and changing entity, with respect to both existing linkages and to the significance of those linkages, as users change their requirements for the data contained in the resulting collaborative knowledge base.

The essential character of communication in organizations is that each communication task is likely to be a sub-task related to a larger objective that the communicator is trying to accomplish (Hiltz and Turoff, 1985). That larger objective is the collaborative undertaking of a group of individuals. In order for a CMC system to adequately support organizational communications, it must provide sufficient linking, tracking, and reorganization capabilities to allow collaborative groups to process each communication transaction within the context of each team's objective. A Hypertext document in the CMC environment becomes a shared history of what has taken place from both the individual and shared group perspectives.

The emerging requirement in a CMC environment is for collaborative groups to be able to link large numbers of individual text items in a dynamic manner which services the complete cycle of recognizing, understanding, defining, investigating and solving a problem. The tracking of the Hypertext composition and linkage formulation is a closely associated challenge. The "Hypertext" concept is a desirable metaphor to use because it provides more flexibility than implied by the metaphors based on the physical world of internal memos, desk tops, "in-boxes," and file cabinets.

Every CMC system that has ever been implemented may be viewed as a specific tailored version of the Hypertext concept. The concepts of mail, conferences, comments, replies, and notifications are all specialized linking structures designed to support human communications (Turoff, 1990).

2. HYPERTEXT AND COGNITIVE MODELS

Another major issue that emerges in the CMC environment is the nature of linkages in Hypertext. It would be nice for designers if all real world problems could be mapped in 0 or 1 pointers in the internal structure of the software. However, this is far from the reality of the problems that users are trying to solve. Much of the earlier work on Delphi Design illustrates the tremendous variation that is possible in the nature of linking relationships which individuals use to solve complex problems (Linstone and Turoff, 1975). In the planning and analysis of tasks, the nature of links may vary by their degree of necessity, sufficiency, desirability, feasibility, intensity, significance, etc. Trying to represent this for conceptual purposes by using objects with attributes that only have or do not have links to other objects results in a model which provides only limited cognitive insights.

Some Hypertext efforts have tried to deal with the need to have different types of links. Trigg (1986), in his TEXTNET system for dealing with scientific discourse, presents approximately 50 different kinds of normal and commentary links (e.g. refutation, sources, etc.). The work of Lowe (1985) implies that links themselves in the context of formal debate are not merely typed, but are themselves content items, just as are nodes. The use of links can in fact modify the underlying data structure so that a linking is an active process. For example, the TOURS system on EIES (Turoff, 1990), the behavior of individuals in voting on the content determined the subsequent presentation of linking alternatives to the group utilizing the system.

There are also numerous examples in cognitive studies which indicate that more meaningful browsing paths can be determined from cognitive understandings (e.g. Foss, 1986). In Foss's study of the relationships of goals and tasks, it appears that individuals comprehend a situation better if exposed to the goals before being exposed to the consequences of the goals. Obviously a "good" Hypertext system should be able to guide a user along that preferred browsing path. The work by Hopkins (1987) indicates that there is considerable correlation between the perceived structure or linkages among concepts and the degree of expertise of an individual. As a result, the formulation and utilization of Hypertext should incorporate knowledge of the individuals and their contributions of both content and the "blazing of trails" through the content.

In our view, the current approach of defining unique Hypertext systems for each application is somewhat of a dead end, in terms of the wide scale applicability of Hypertext. The ultimate success of Hypertext for the general composition and browsing process must rest on the emergence of a framework for the behavior of links which is tied to general cognitive models of how individuals think about complex problems.

Within the context of a specific application, the users of systems should be free to assign their own semantic meanings to the nature of the links. The work by Smith (1987) appears to be one very important step in this direction. If Hypertext is viewed as a mechanism to enable an individual to impose a cognitive viewpoint on a collaborative database, and to facilitate group agreement on a shared understanding of the resulting semantics, then a possible paradigm for the design and role of Hypertext in Collaborative Systems begins to emerge.

3. A SEMANTIC MORPHOLOGY FOR HYPERTEXT

Current Hypertext systems either have few or no semantic type links, or are highly tailored to specific applications. In one case, the number of proposed semantic links is in the eighties (Trigg, 1986). Our work attempts to introduce more order into this situation by supplying a comprehensive and general model for Hypertext with twelve link types and six node types. It is our claim that link and mode types in any current or proposed Hypertext system can be mapped into this morphology.

The problem of browsing and navigation of Hypertext has received extensive attention (Conklin, 1987; Nielsen, 1990). However, the problem which is a key to the success of Hypertext is that of authoring it. Today, this creation process is largely an individual one, based upon the talents of a single individual to create coherent relationships. The only exception to this is highly tailored systems, which restrict the resulting material to very specific applications (e.g. Lowe, 1985) such as an argumentation process. A desirable goal for Collaborative Hypertext is the ability of any group member to express intellectual assessments of the relationships among objects, with a full range of the possible meanings for relationships (links) and objects (nodes) to draw upon.

Recent work at NJIT (Rao & Turoff, 1990) has resulted in a semantic model for the construction of a general theoretical framework for Hypertext. This framework is based upon Guilford's Theory of the Human Intellect (1956, 1967, 1982). Guilford's theory has been used successfully as a framework for classifying and evaluating the complete range of tests for human intellectual abilities. As such, it appears to encompass the scope of human intellectual abilities in forming concepts and relationships among concepts. Our premise is that Guilford's Theory, as a successful classification instrument for human intellectual testing, presents the best current choice for a Hypertext morphology.

We know from prior work in this field (Sternberg, 1985) that individuals differ considerably in the areas of intellectual activity at which they are best. For example, some individuals are better at formulating accurate generalizations of data, and others are better at dealing with the separation of critical data from noise. A necessary foundation for group collaboration on the formulation of Hypertext is a semantic model or morphology which will support the full range of human intellectual abilities. This, in turn, would allow individuals in a group to focus on contributions of concepts and relationships for which they are best suited. The prime benefit of group problem solving is the pooling of a diversity of talents and knowledge.

Our general morphology for Hypertext includes six generic node types and twelve generic link types, as illustrated in Figure 1. Guilford's six types of "cognitions" are interpreted by us to represent six basic types of nodes. For example, we have interpreted the concept of "classes" of objects in the Hypertext setting, as a "collection" node type. Guilford viewed this cognition process as the classification of an object. In Hypertext this becomes a node that classifies all the linked objects as related to a common concept or characteristic. The other nodes linked to a collection node would have some degree of membership in the set defined by the collection node.

Figure 1
HYPERTEXT MORPHOLOGY

THEORY OF INTELLECT MODEL:

GUILFORD:	Cognition	Convergent Production	Divergent Production
	HYPERTEXT:		
Product	Nodes	Convergent Links	Divergent Links
Units	Detail	Specification	Elaboration
Classes	Collection	Membership	Opposition
Relations	Proposition	Association	Speculation
Systems	Summary	Path	Branch
Transformations	Issue	Alternative	Lateral
Implications	Observation	Inference	Extrapolation

Guilford's concepts of "convergent and divergent production" of concepts has been interpreted by us to correspond to the creation of links between existing nodes. This provides six convergent and six divergent links which correspond to the same "product" morphology utilized for nodes (i.e. the first column in Figure 1). Convergent links are those that follow a major train of thought that encompasses a number of nodes. Divergent links are those that start a new or divergent train of thought. The concept of divergent and convergent links is an important duality for introduction into Hypertext. It is a significant factor for both the mental process of browsing and for the possible automated aids for analysis of a resulting web.

Given the ambiguity possible in natural language, Figure 2 presents a list of synonyms for the six node and twelve link types defined in this morphology. If Guilford's classification of human cognitive abilities is correct, then any possible semantic meanings of nodes and linkages should be mappable into this proposed morphology for Hypertext. If Guilford's Theory is proven later to be incomplete or incorrect, this does not invalidate the criteria we have proposed for a Hypertext morphology: representation of the complete range of human intellectual ability.

Figure 2
HYPERTEXT MORPHOLOGY SYNONYMS

NODES	Synonyms
Detail	definition, reference, fact fundamental, footnote, support
Collection	gathering, aggregation, set heading, conglomeration class, group
Proposition	analogy, relation, model axiom, assumption, theorem law, belief
Summary	generalization, pattern system, template, overview
Issue	question, problem, concern change, vision
Observation	action, implication, policy observation, recommendation conclusion, decision
CONVERGENT LINKS	
Specification	clarification, definitive explicit, expansion qualification, relevance articulation, underlie reference
Membership	Parent-child, naming subset, combine, form assemble, collect
Association	similarity, correspondence equivalence, concurrence correlation, index key
Path	sequence, order, chapter document, list, trail
Alternative	change, option, transform revision, choice, modify version, modification
Inference	influence, support, cause conclusion, implication induction, endorse, pro deduction, evidence
DIVERGENT LINKS	
Elaboration	footnote, detail, fact
Opposition	conflict, con, refute dispute, objection challenge, counter
Speculation	expression, conjecture emotional, artistic tentative, conjectural vague
Branch	subsection, split, fork offshoot, appendage
Lateral	deviation, creative shift, novelty, alter divergence, transposition
Extrapolation	goal, idea, value belief, objective, norm question

Common structures utilized for documents can easily be represented in this morphology. References would be "detail" nodes linked by "specification" links. Footnotes would also be "detail" nodes but linked by "elaboration" links. Index terms would be represented by a cyclic structure of "association" links. A table of contents (e.g. outline structure) would be a tree structure made up of "path" and "branch" links; paths at the same level and branches between levels. Delta edits (proposed changes to existing wordings) would be "issue" nodes linked by "alternative" linkages. Headings in a document are "collection" nodes.

A recent paper (Carlson and Ram, 1990) proposes a mental model of Hypertext to support the application of "planning." It is quite straightforward to map the definitions of links and nodes in that paper into the more general framework proposed here (Figure 3). Other existing Hypertext structures can also be mapped into this morphology as well (Rao and Turoff, 1990). This is what makes the morphology valuable. Any individual can utilize the appropriate mental model with the context of a specific application, while the underlying implementation of the system has a general semantic model that allows approaches to navigation and analysis of the database independent of the specific application and the different mental models of the individuals. It is unthinkable that in a real organizational setting, individuals would have to utilize different hypertext systems for each and every different application (e.g. collaborative writing of a scientific document, project coordination, planning or budgeting, etc.).

Figure 3
COMPARISON MAPPING

Carlson & Ram	Theory of Intellect
Nodes:	
Stakeholder	Collection
Organization	Collection
Objective	Observation
Position	Observation
Strategey	Proposition
Control	Proposition
Cause	Detail
Links:	
Responsible for	Membership
Holds	Membership
Addresses	Specification
Interests	Elaboration
Related	Association
Causes	Inference
Measures	Inference
Affects	Inference

An acceptable morphology provides a basis for a generalized Hypertext structure that can be used for any application. The morphology offered here is also proposed as the ideal vehicle for being able to employ general purpose analysis routines to aid the users in understanding the results of their collaboration.

4. UTILIZATION AND TEMPLATES

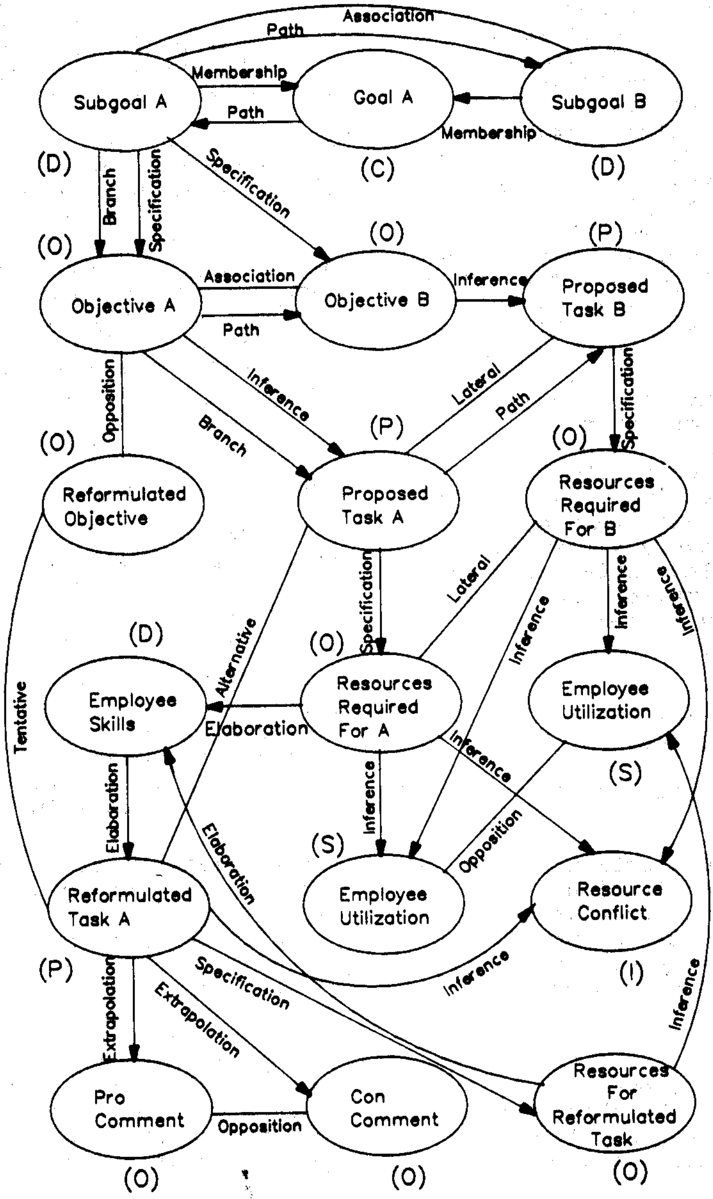
On the surface, the model proposed here might seem to be too complex for the average user. It is certainly true that the model, as proposed, is not something that can be mastered or learned in a single exposure or a short space of time. However, there are a number of crucial factors that mitigate this problem.

A team of people who are using a CMC system on a continuous basis can acquire and develop their knowledge of the use of such a model over a long period of time. Certain subsets of the morphology are quite easy to learn and utilize immediately, because they have mappings to familiar concepts in documents. For example, a heading in a document is a collection node and a linear sequence of text is a set of nodes connected by path links. Users may be introduced to the morphology in a gradual manner and through the use of familiar subsets of the complete morphology.

The model allows for the complexity of real life situations. Figure 4 provides an example of a Hypertext organization of a planning situation. This incomplete example serves to illustrate a use for every single node and link type defined in the model. While it may appear complex, it is actually made up of a number of re-occurring templates or frames. For example, the underlying structure that always goes with a proposed task is illustrated in Figure 5.

The template or frame in Figure 5 is composed of four nodes and three linkages, and is always repeated for any proposed task in the illustrated planning structure of Figure 4. Such templates can be created as macros or specific subgraphs that need to be filled in for any specific type of application. When a user proposes a task the system could automatically create the other required nodes and even notify those who have responsibility of entering the content. These templates serve a variety of objectives associated with allowing users to overcome the "tangled web" problem (Conklin, 1987) usually associated with trying to use Hypertext in complex situations.

Figure 4
HYPERTEXT EXAMPLE - PROJECT PLANNING



Nodes: (D) DETAIL (C) COLLECTION (P) PROPOSITION
(S) SUMMARY (I) ISSUE (O) OBSERVATION

Figure 5
TEMPLATE FOR PROPOSED TASK

<u>Proposition node</u>
Proposed Task

LINKED BY	TO
<u>Specification link</u>	<u>Observation node</u> Required Resources

<u>Observation node</u>
Required Resources

LINKED BY	TO
<u>Elaboration link</u>	<u>Detail node</u> Employee skills required

LINKED BY	TO
<u>Inference link</u>	<u>Summary node</u> Employee utilization

- The templates can be used to guide the creation of the nodes and to automatically track when missing information is needed to complete a required template. In a template different elements might be the responsibility of different individuals in the group.
- They provide an easy mechanism for users to begin to learn the more general model.
- They represent "super nodes" that can be used to automatically produce summary views of the web.
- The group can evolve these templates to suit its particular situation.
- Automatic routines can be introduced to look for and expose possible templates.

The nature of the morphology is such that it becomes very easy to introduce computer supported analysis of complex webs. For example, all the divergent links can be treated as "cut points," individually or collectively, in analyzing patterns in the resulting subgraphs. Users can be provided with powerful retrieval, organization, and summary features. Viewing a list of the collection nodes could be a desirable way for a user to decide where they wish to enter the web. There are a number of very powerful network analysis techniques and structural modeling methods such as Interpretive Structural Modeling (Lendaris, 1980) that can be applied to aid the users in getting a computer supported analysis of the web. Our proposed morphology provides a mechanism for easily forming various sub-graphs that can be subjected to these various analysis methods.

5. ATTRIBUTES

There are number of potential attributes that can go with a particular node or link. These are:

- The strength of a link
- Who created a link or node
- Level of agreement on the validity of a link or node
- The popularity (viewing and traversal frequency) of a link or node

In a collaborative environment, the process of agreeing on the underlying structure of a complex situation necessitates the need to expose and explore disagreements (Linstone and Turoff, 1975). The exposure of disagreements among group members about the structure of the problem is the key to obtaining better quality results.

Knowing the strength of a linkage would allow the introduction of prioritized search algorithms and the use of such methods as fuzzy logic. Information on the creation and usage of linkages by individuals allows members of a group to gain information on each others' preferences and concerns. As a result, the above four attributes are crucial to the design of a collaborative Hypertext situation.

The dynamic nature of the communication environment also means that those individuals who need to know what is changing must somehow be informed of those changes. Those who do not need to know must somehow be able to limit their encounter with information overload (Hiltz and Turoff, 1985). The tracking of the hypertext composition or evolution process is a closely associated challenge.

In our new EIES 2 system (Turoff and Hiltz, 1990; Turoff, 1990) we have introduced a general purpose notifications generator and associated personal user file of received notifications. These notifications are signals of any possible transaction within the CMC environment that the user needs to be made aware of. For example, in the Hypertext area a typical notification would alert an author of a node when another member of the group had created a link to the member's authored node. In applications such as education and project management it is absolutely necessary to provide these tracking mechanisms for instructors and managers (Hiltz, 1986, 1990; Turoff, 1990). Notifications may be established for any process carried out on EIES 2 and also serve as a direct manipulation retrieval handle for the items they refer to.

6. A COLLABORATIVE MEMORY

Given a semantic representation of the Hypertext database and the potential analysis techniques it supports, it is possible to address the design of structures which provide mechanisms and features for "collaborative composition and sharing of Hypertext." The essence of this requirement is that the collection of text which serves as the "database" can be viewed through many different linking and organization structures for different individuals, groups and application objectives. Only by establishing higher order patterns in the web through the analysis procedures (Delisle and Schwartz, 1987) can we hope to promote human understanding of large collaborative Hypertext databases.

A related issue is how to deal with individual Hypertext mappings on a collaborative basis. Implicitly, all the current work on Hypertext seems to be based upon the Associative Framework (AF) from cognitive psychology. It represents one of three models of how the human memory works. The other two are the Schema Framework (SF) and the Heading Record Framework (HRF). Each seems to explain certain human memory behavior better than the others (Morton, 1986). These three schemes also have their analogues in modern database models. Only the Heading Record Framework accounts for the process of forgetting information within the primary axioms of the model.

We are focusing on the design of a version of the Heading Record framework to form an implicit consensus process for collaborative Hypertext. This design will provide "memories" for each user of the Hypertext system and a collaborative "group memory." What is "remembered" will not be explicitly supplied by the user, but will be implicitly accumulated based upon the processes of the composition and browsing of links and nodes. The group memory will be allowed to forget relationships by allowing those "most active" linkages to float to the top of the stack type index provided by the HR framework.

Any individual in the group would be able to shift from using his or her own personal memory to utilizing the group memory for further explorations of the database. The degree of forgetting (deletion from the members memory list) allowed can be regulated by the owner of the memory. Forgetting is an extremely important property of this approach in ultimately avoiding information overload (Hiltz & Turoff, 1985). Users of information on an individual basis rarely make systematic use of deletion. And, this is a worse problem in collaborative environments. Equally important is the use of the forgetting process of the "group memory" as the defacto implicit voting process to arrive at the group consensus. Explicit voting processes take considerable time and effort on the part of individuals in a group. Therefore, explicit voting is not a promising approach to providing a collaborative atmosphere.

A simple explanation of the Heading Record Framework is a long list of records of information, each containing a header. The header may contain a variety of search keys relevant to the associated content of the record. Searching for a match on the header takes place sequentially through the list. Only the first match is used (i.e. recalled). As a result, new additions to the top of the list cause the older record with the same header or partial match of search keys to be forgotten or to be harder to find. In our context, the records contain combinations of links and nodes that appear to suggest meaningful subgraphs, templates, and or trails. These may result from both popularity and analysis. The headers can be made up of many forms of information to allow rich search options and will include items such as semantic meanings and summary patterns found by the analysis tools. The key to the success of this approach is in the analysis algorithms that make up the encoder for forming new headed records in the list and the decoder for search matching on recall. This is where various analytical routines for partitioning and structural modeling promise to be useful, as well as the indirect voting algorithms based upon the activities of the involved individuals.

Hopkins (1987) provides a recent example of what is possible by such approaches and confirms statistically the experience of those who have worked with the Delphi technique (Linstone and Turoff, 1975). Given a complex problem, the nature of the relationships both proposed and examined by members of a collaborative group will differ significantly according to their degree of expertise concerning the problem. In Hopkins' example, complex models of the same situation built by different individuals are analyzed by scaling techniques that clearly differentiate the degree of expertise of each individual with respect to the problem. In any real life situation different individuals in the same project group or differing groups have different expertise to bring to bear on different aspects of a complex problem. Any method that can be employed to facilitate communication of an individual's expertise into a collaborative description (e.g. a CMC oriented Hypertext document) has a high potential payoff for the improved utilization of information.

It is the existence of an underlying general semantic morphology that makes possible the incorporation of such approaches as a "group memory" for Hypertext. This and other such approaches are needed to capture information on the users as an integral part of the Hypertext system. It is only be integrating such information that we can evolve systems that will support Hypertext as a collaborative process for the development and utilization of knowledge.

7. SUMMARY

A general morphology can provide the foundation for the construction of a general purpose set of tools which can be utilized to promote better cognitive understanding on the part of users of large, collaborative Hypertext databases. The complexity of such systems may arise from both the number of nodes and links, and from the alternative mappings of nodes and links, provided by different members of a collaborative group in forming and utilizing a body of knowledge.

In essence, we are attempting to provide a representation for Hypertext that will deal with the "equivocality" of information, rather than just uncertainty. As pointed out by Daft and Lengel (1986, p. 560):

> Rich media facilitate equivocality reduction by enabling managers to overcome different frames of reference and by providing the capacity to process complex, subjective messages.

Although retrieval has received a great deal of academic attention, the real challenge of Hypertext is composition and shared understandings, not retrieval. We believe that the composition of Hypertext should be a collaborative effort to produce collections of material useful to the group and for other related groups. From this point of view, Hypertext is not a static entity for retrieval only, but one that changes and adjusts to the group and its activity. Our current efforts include the formulation of a model which can be used to support collaborative composition, shared browsing, and iterative improvement of the knowledge, based upon feedback from the user.

Brown and Newman (1985) proposed the term "system opacity" as representing a major problem in interactive systems. System opacity occurs when the interface metaphor conveys no understanding to the user of the underlying implementation model for the system. We propose the term "functional opacity" to indicate a mismatch between the cognitive process of human problem solving and the interface metaphor. It is the elimination of "functional opacity" for Hypertext that is the main objective of the morphology proposed in this paper.

The true potential for Hypertext will be realized when it is created as a natural result of a collaborative composition process. Work teams in organizational settings are groups function over long periods of time and persist even with changes of membership. As a result, they create large bodies of material which are continually evolving and being modified. For example, the planning of a single new product may involve the creation and specification by a group of over a thousand separate tasks that need to be accomplished. New members of a group should be able to see if their ideas and concepts have been explored in the past by the group. It is this type of large scale task that Hypertext within a CMC system must be able to accommodate.

The approach to Hypertext suggested in this paper offer the opportunity to create a "collaborative intelligence" system (Hiltz and Turoff, 1978). This is one in which the group can obtain a far more intelligent result than the most intelligent member would have acting alone. This is a far more desirable objective and higher pay off than the hidden assumption behind AI and Expert systems, which strives only to do as well as the best member.

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