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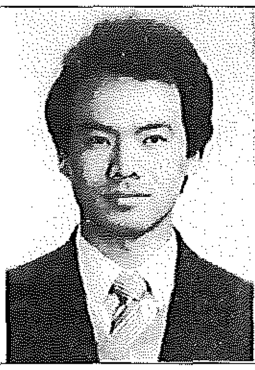


A Conceptual Model for Supporting Collaborative Authoring and Reuse

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This paper discusses some problems encountered in hypermedia-based collaboration and reuse, and presents a conceptual framework to resolve these problems. Three suggestions are made based on the discussion: 1) extra organizational structures are necessary in shared hypermedia to support collaborative interactions; 2) an abstract schema is a key to capture the dynamic nature of the shared hypermedia; 3) an integration of the schema evolution approach and the workflow approach is recommended for an open system hypermedia teamwork support. The whole authoring environment is divided into several component spaces with particular respect to the Dexter Hypertext Reference Model. Not only can this separation reduce the overall complexity of working within such an environment, but it also conforms more closely with human cognitive needs in collaborative authoring and reuse activities. (Author)

1. Introduction

Hypermedia systems are widely used as single user systems for browsing of extensively linked document material. This paper highlights the role of hypermedia systems in support of collaborative authoring and reuse of linked material. A large number of existing commercial and research computer-supported systems for collaborative work are related to hypermedia or hypermedia systems.Hypertext systems have been used to facilitate a variety of tasks involved in a collaborative process (2, 7). In collaborative work, tasks may include brainstorming and planning at early stages of the work. One of the fundamental issues that collaborators must face is the coordination of individuals' activities with respect to the workflow of teamwork. The conceptualisation of a shared workspace for group collaboration has been frequently used in an attempt to alleviate the problems of dealing with a complex and dynamic work environment.

Time and space are commonly used to classify the scope and functions of a computer system for collaboration. For instance, some systems could be used by a group of geographically distributed users at the same time, whereas some systems could be used by a group of people across a period of time. Important examples of the latter one are shared knowledge bases, which accumulate and maintain knowledge for a group of users over months or years. Coauthoring systems are also found in this category. Recently, some cooperative hypermedia systems are developed to support a wider range of collaborative activities across different time/space modes. This paper particularly discusses the following issues: how the evolution of shared hypermedia, or collaborative hypermedia, can be effectively dealt with by a computer support system and how the dynamic nature of the organization of collaborative hypermedia is related to individual collaborators' work and associated communication patterns.

Empirical evidence suggests that when users navigate through non-linearly organised material in hypermedia, cognitive overhead involved in navigation is the most frequently complained problem. Multiple users interacting with shared hypermedia are expected to encounter even more problems for them to capture the changing structure of knowledge, to maintain mutual understanding among collaborators, or to incoporate with others' work cohesively.

This paper focuses on the macrostructure of a shared and evolving knowledge base. Collaborative hypermedia systems are particularly discussed as a special type of knowledge representation and argumentation systems. Supported collaborative authoring and reuse with such hypermedia-based systems are discussed based on two sources of our experiences of developing and using collaborative hypermedia systems.This paper is organised as follows. Section 2 introduces the experiences in developing and using collaborative systems, and discusses problems pertinent to collaboration and reuse with these systems. Section 3 analyzes the open systems approach and the Dexter Hypermedia Reference Model to highlight the support needed. Section 4 discusses issues related to reuse in dynamic hypermedia. Section 5 summarizes the interrelationships among the components related to dynamic knowledge organization systems. Section 6 includes the conclusions drawn from our experience and the related discussion.

2. Interacting with Collaborative Hypermedia

Collaborative hypermedia are dynamic hypermedia systems used by several users. Collaborative hypermedia share some common characteristics with multiple user database management systems. Collaborative hypermedia systems emphasize the role of a system in facilitating human collaboration with the system, whereas multiple user database systems aim to schedule individual users' work to minimize interactions among users with mechanisms such as concurrency control and system transparency.

A Multiple Use Collaborative Hypertext system (MUCH) has been developed to support collaborative writing (11). The MUCH system is a collaborative hypermedia system in that the MUCH system draws users attention to coordination among concurrent users. The MUCH system has been used to explore problems encountered in its normal use. The MUCH system maintains a network of nodes and links. Users can use the MUCH system over a network of workstations. Many users can use it at the same time, for instance, in a class. A system monitor maintains dynamic information, which is available to each user, on the current user group. Users can also work on the same part of the hypermedia network at different time. The data structure of nodes allows the modifications to a node being recorded and attached to the node, with the identification of the responsible user and the time stamp when it happens.

Using the MUCH system in practice has revealed several problems which are related to the coordination of collaborative work and to the management of the shared workspace as a whole. These problems fall into two categories: 1) retrieval-related problems and 2) problems of understanding the evolving organizational structure of knowledge. Problems in the first category largely affect the use of shared hypermedia at microlevels. Problems in the second category can increasingly undermine the communication and coordination among the collaborators. While retrieval-related problems are relatively easier to cure by employing traditional information retrieval techniques to the hypermedia system, for instance, a full-text search facility across hypermedia entities, it is more difficult to solve the second class of problems within the standard framework of hypermedia.

The Open System for Collaborative Authoring and Reuse of multimedia courseware (OSCAR) project aims to develop a system for supporting collaborative authoring and reuse of multimedia training materials (i.e. courseware). A pilot test of the resulting system is arranged in the aerospace sector for producing collaboratively authored training courses. The key provision in the OSCAR system for collaboration is a Common Information Space (CIS). Facilities which help users interacting with the CIS are grouped as services. In the CIS, several heterogeneous bodies of knowledge are incorporated together, such as instructional strategies, domain structures and content material. One of the objectives of the OSCAR system is that the CIS is intended to supply the information and knowledge needed for a number of projects. The organizational structure of a CIS largely relies on associative relationships as well as inheritance relationships in the object-oriented paradigm. The lifetime of a CIS probably spans several years. It is a crucial requirement to keep the evolution of the CIS under control such that the organizational structure of the CIS remains easy to understand.

Hypermedia paradigms have obvious advantages over the traditional information systems in meeting the needs for collaborative work. For instance, hypermedia-based coauthoring systems allow coauthors to annotate each other's work. Hypermedia systems fit coauthors' interaction more closely to the context of the work at hand (12). On the other hand, hypermedia systems must overcome some problems in order to supply more effective and efficient support to collaborative work as a whole. The following issues identified in (1) are directly related to collaborative authoring and reuse:

Search and Query in Hypermedia

Access to information stored in a hypermedia network requires query-based mechanisms in addition to navigational facilities. This issue becomes prominent in fields such as authoring involving a large information space and collaborative work. Incremental solutions such as the fisheye view facility, which aims to balance the local details and the overall structure of a hypermedia network for the display, may not be essentially sufficient. Note, however, the latest development in fisheye views employ advanced techniques, such as the multidimensional scaling method, to address the problems with a large knowledge base.

Virtual Structures for Dealing with Changing Information

A hypermedia network cannot reconfigure itself in response to changes in the information it contains. A suitable mechanism is required to facilitate the incremental evolution of the hypermedia network. A related development is in the object-oriented database management, known as the schema evolution. A schema can be viewed as a kind of meta-thesaurus which defines the underlying relationships among the classes in the database. A schema of a set of templates will be disscussed in the following sections in this paper.

Support for Collaborative Work

A shared hypermedia network provides a natural basis for collaborative work. In order to provide integrative support for collaborative work, hypermedia systems need to accommodate facilities for three types of tasks:
a) organizational work: real-time tasks concerning social interaction and organization, such as discussion and decision making;
b) substantive work: tasks carried out by collaborators independently, such as drafting and editing;
c) annotative work: social construction of the substantive work in the form of collaboration, such as commenting and questioning.

Extensibility and Tailorability

Hypermedia are not directly well suited to any specific task or style of use. Thus, hypermedia users are faced with a tool that is clearly useful but not yet well adapted to the specific task at hand.

Collaborative authoring is a complex activity. Collaborative authoring involves different stages from planning outlines, preparing drafts, revising, to editing.

An authoring process has been modelled as a problem solving process (4, 5, 6). In the early stages of writing, authors gather material from their long term memories and external sources on a chosen subject domain. Then, these materials are arranged into a hierarchy, usually in their short term memories or on a personal notepad. Finally, the hierarchy of relevant information is delineated as a linearly structured document. This model is originally built to describe singular authoring processes.

When the model is applied to a collaborative authoring process with a shared hypermedia network, users of the hypermedia system will have difficulties with several problems. The most serious problem seems to be related to organizing the obtained material cohesively in a shared workspace. The problem of organizing and re-organizing the structure of the knowledge base is not inevitable if the knowledge base exists for a long term. The changing structure of collaborative hypermedia must be easy to capture by the collaborating users in order to incorporate effectively the work of an individual into the work of a group. In the next section, the information and organization needs for collaborative authoring and reuse with collaborative hypermedia are further discussed in respect to a hypermedia reference model, known as the Dexter model.

3. Dexter Model and Open Systems Approach.

The Dexter Hypermedia Reference Model aims to provide a basis for comparing of hypermedia systems in terms of functionalities and organisations (2, 3). The Dexter model analyzes a hypermedia system in three layers. The storage layer describes how the nodes and links are connected as a network. The run time layer describes the mechanisms supporting the users' interaction with the hypermedia. The within-component layer addresses the content and structures within hypermedia nodes. The within-component layer is of particular concern of hypermedia versus hypertext systems. In the following sections, we will focus on the storage and run time layers and their interrelationships.

The storage layer and the run time layer are connected by presentation mechanisms. The support needed for collaborative authoring and reuse processes corresponds to these two layers and the interrelated mechanisms of presentation. As discussed earlier, one of the key problems of working with a collaborative hypermedia system is to keep up with the evolution of its underlying knowledge organization and to present the dynamics in an easy-to-understand form to the users in collaboration. The evolutionary changes ultimately take place in the storage layer and the component of tracking these structural changes also resides in the storage layer. In dealing with evolving hypermedia, the information provided by the component must be effectively presented to the collaborating users through the presentation mechanisms and the run time layer.

According to the Dexter model, the purpose of the presentation layer of hypermedia is to present information or knowledge organized as a collection of nodes and links in a way that suits the need of a particular task or purpose. The basic notion of hypermedia does not provide particular operational semantics to authoring activities Several additional components are needed for a collaborative hypermedia system.

Additional components are needed for monitoring and controlling the evolution of knowledge organization, for incorporating the work of an individual work into the shared knowledge base, and for reusing existing knowledge stored in the common information space. In terms of the Dexter model, users interact with the hypermedia through the run time layer. Three types of task in collaborative authoring and reuse, as identified earlier, can be mapped onto different layers. Performing substantive tasks by each individual takes place at the level of the run time layer. An activity space for this type of task is conceptualized as an authoring space. Users solicit their interactions with the hypermedia from their authoring spaces embedded the run time layer. These individual authoring spaces stratify the shareness of the collaborative hypermedia. Users outside authoringspaces take a common view of the hypermedia. Users working in an authoring space have access to views which are particularly related to the incorporation of the work of an individual into the workflow of the group. Organization and coordination of tasks, sometimes known as procedural activities, involve both the run time layer and the storage layer. An abstraction of the macrostructure of the knowledge organization is known as a 'schema' in object-oriented database management terms. The classification of descriptors at higher levels of abstraction in layered hypermedia is sometimes known as a 'meta-thesaurus' or as a 'hyper-thesaurus'. A schema is also stored in the storage layer. The storage layers are divided into some conceptual spaces. The indexing space contains the schema, or the meta-thesauri, of the underlying hypermedia. The objective of the indexing space is to keep track of the evolution of the hypermedia's macrostructure.

Comparing with the Dexter framework, the OSCAR CIS corresponds to the storage layer. The CIS accumulates knowledge and training materials which will be used, or reused in subsequent courseware development projects. The CIS browser uses the schema of the CIS as a filter to control the information presented to users. The OSCAR system provides users with authoring spaces in its desktop module. Currently, the OSCAR system only provides limited functions and services to facilitate the schema evolution. The MUCH system maintains a semantic network and this network corresponds to the storage layer in the Dexter model. The component related to the structural evolution in the MUCH system is based on a special type of links, known as thesaurus links. These thesaurus links constrain the evolution of the semantic network as an acyclic directed graph. In the next section, we will discuss the relationship between reuse and the evolution of collaborative hypermedia.

4. Reuse in Evolving Collaborative Hypermedia

Sharing and reuse of knowledge stored in collaborative hypermedia is to improve the quality and the productivity of a collaborating group. A process of sharing and reuse involves several steps: retrieving, selecting, modifying and incorporating. The following issues are regarded, for example see (8, 9, 10), as some of the most important factors to be considered in a reuse process:

Component Suitability concerns the overall suitability of a component being considered for reuse.

Context Dependencies should be estimated in terms of the cost-effectiveness for the additional work and the associated component suitability.

Readability evaluates the reuse process on a particular component with respect to the overall development lifecycle, regarding its relationships with other development activities.

Availability of Knowledge Structure directly affects the complexity involved in a reuse process.

All these issues are directly related to the understanding of the underlying knowledge structure. In dealing with dynamic, or evolving collaborative hypermedia, this understanding becomes even more crucial for the success of a particular reuse process and, ultimately, for the success of collaboration. For example, in Figure 1, there are two levels of the organization of knowledge. The top level is a thesaurus, or a schema, which is an abstraction of the organizational relationships used in the lower level. In a general sense, the schema defines the form of the hypermedia unit of storage and its interface with the forms of other units. The contents of these units are stored in the second level of the organization of the knowledge base. The simplest form of the relationship between the two levels is one-to-multiple. A variety of contents can be abstracted and represented by a single form. The provision of the schema, or a thesaurus for evolution, reduces the cognitive load for users to understand the structures of the shared knowledge base. It is particularly desirable for interactions with evolving collaborative hypermedia over a long term. In Figure 1, the requirements for a task are represented as the node B. The node B may come from an authoring space at the run time layer, or it may be related to some nodes at the second level of the storage layer. The form and its interrelationships in the storage network are included in the requirements. This part of the requirements is related to a point in the schema in the top level storage network. Following the one-to-multiple relationship from the schema to the storage level for concrete materials, the system can provide the user a collection of legitimate candidates for sharing and reuse regarding the original requirements in the node B. This functionality would be difficult to achieve with navigational facilities to the hypermedia. What is needed in this situation is the power to address the macrostructures of the hypermedia and the schema in the indexing space is added to meet this need.

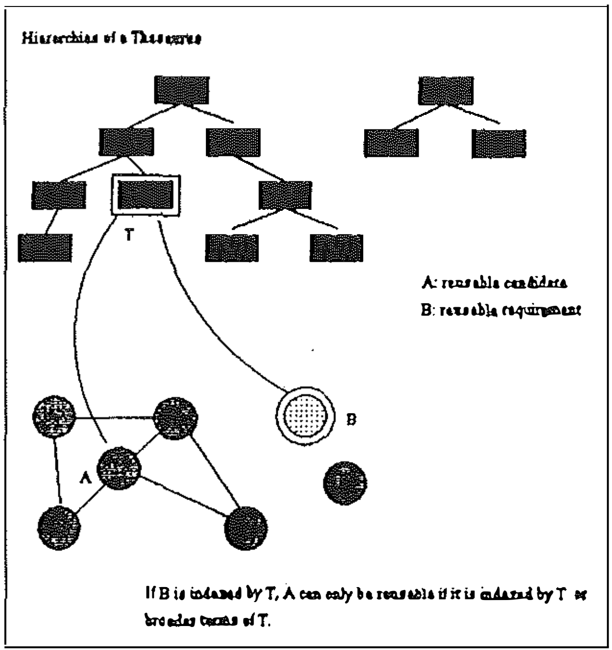

Figure 1. An example of using the schema, or the meta-thesauri, for reuse. The template T in the meta-thesauri chacterizes a reuse request B. The existing component A is indexed by the same template. The structural similarity between A and B suggests that the component A should be considered for a possible reuse. If the schema organisation remains unchanged, the overall organisation of the shared hypermedia should be regarded as static at this particular time.

It is worth noting the differences between reusing software and text. Software reuse is likely to gain more from the schema evolution approach, whereas reusing text in a collaborative hypermedia could involve some extra tasks for its effective use. It is impractical to make a clear cut in written text as separating functionalities and implementations in software engineering. The pragmatic meaning of a piece of text may need several relevant keywords for represention at higher levels of abstraction. The additional indexing work involved, manually or automatically, is a factor which must be considered in the design of collaborative hypermedia systems. Our experiences of using the MUCH sytem over the past few years and the insights obtained from developing the OSCAR CIS indicate that the schema evolution approach is indeed a cost-effective solution even when the extra index work is taken into account.

5. Interrelationships among the Components.

We have discussed a few system components, in the light of the Dexter Hypertext Reference Model, for supporting collaborative authoring and reuse. These components are conceptualized as spaces embedded into the layers of the Dexter model. The indexing space contains the schema of the underlying organisation of the hypermedia. The schema evolution is a key to the collaboration and facilitating reuse over evolving and shared hypermedia. More structures are added to organize procedural activities in users' interaction with hypermedia. Individual authoring spaces are used to provide organized views from the run time layer to the storage layer. Accumulated knowledge and information stored in the storage layer are conceptualized as in a common information space. In essence, the common information space is organised as a dynamic hypermedia network.

Individual authoring spaces are provided in the run time layer. There are two ways to access the storage layer of the underlying hypermedia (See Figure 2). One is from the run time layer without using any authoring space, the other is from within a particular authoring space. These two ways of access are associated with two different views of the hypermedia network. The first way is associated with a global view of the hypermedia and all the work that has been completed should be visible in this view. The second way results in a local view of the hypermedia focusing on some work being developed. The work being developed is usually not visible for the global views or some views from other authoring spaces.

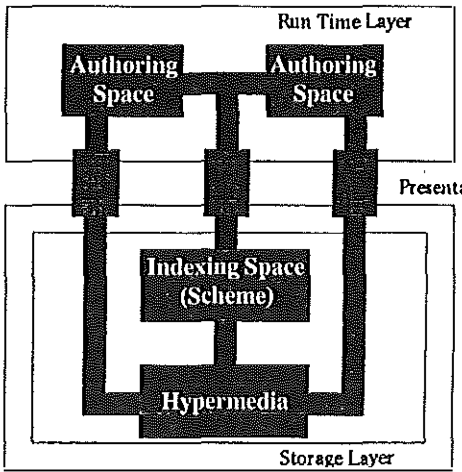

Figure 2. The interrelationship among the component spaces. Three ways are provided for interactions between collaborating users: 1) direct communication links between authoring spaces, 2) communication links at the macrostructural level, via the indexing space, and 3) indirect communication at the microstructural level, via the shared hypermedia.

Communication between co-authors are supported in two ways in the shared hypermedia system. They can communicate indirectly via the storage layer where they must share their associated views accordingly. They can also communicate directly using the communication links between individual authoring spaces. They can choose different communication modes according to their needs, which are within the scope of the structural contingency theory. The theory basically says that the mode of communication to be selected by users depends on the user's view of the situation. Users may decide to discuss or to plan in a face-to-face meeting, or they may choose to use indirect communications via the storage layer of the hypermedia for revising and evaluating tasks.

The role of the indexing space in developing collaborative hypermedia is to provide an intermediate level of knowledge representation between the run time layer and the detailed knowledge and content materials stored in the storage layer. The knowledge representation of the indexing space can be viewed as a part of the storage layer, whereas the mechanisms associated with this space correspond to the presentation mechanisms in terms of the Dexter model. The schema provides a dynamic template for the evolution of its knowledge organization. The conceptual space containing knowledge and information in the hypermedia is called the common information space. The indexing space is embedded in the common information space in that the knowledge stored in the indexing space is a hypermedia network.

In order to illustrate how the collaborative hypermedia system could help coauthors in their collaboration, coordination, and cooperation, let's consider a scenario of using the system. This scenario is generated from our experience of using the MUCH system for collaborative writing. A research team is working on a deliverable of a refined model of courseware development. First, participants in the team would clarify the objective to be achieved and decompose tasks for each member. Then, individual authoring spaces are created to accommodate independent work of individuals. Knowledge and information stored in each individual authoring space are usually not visible to users in other authoring spaces. Information hiding at this stage reduces the complexity of understanding the dynamic nature of the ultimate shared common information space. For instance, a chapter, or a subnetwork of the hypermedia, which is registered with an individual authoring space implies the dynamic status of this chapter. In this way, the communication patterns are determined by the decomposition and allocation of tasks. Once a chapter is completed, the responsible users would release it to the common information space. The released version of the chapter therefore is accessible to all the collaborators in the team. When a task is allocated to an individual authoring space, the authoring space is linked to a template in the indexing space. The template registers the logical structure used and associated attributes such as content descriptors, keywords, classnames, and interface functions. Releasing a chapter or a module to the common information space invokes a corresponding update in the indexing space in terms of the template, or the microstructure of the shared knowledge hypermedia. More precisely, a template of chapters could include several section templates and linear relationships to previous and subsequent chapters. A template of a software project could involve modules, associated relationships among modules, related documentation on source code, debugging, and configuration requirements for software and hardware.

Using templates in this way is essentially similar to using a schema of classes in the object-oriented paradigm. Our experiences in collaborative writing and reuse indicate that the extent to which the schema evolution approach could be useful varies from software engineering to more general hypermedia development. The provision of the indexing space with an evolving schema of the underlying shared hypermedia provides a level of abstraction, at which the organizational structure of the hypermedia could be easier to capture, understand, and monitor. The role of this schema, or a set of templates, to reuse is obvious. A template could supply a rich descriptive framework for a reuse process. Some early hypermedia systems request users to determine the organizational nature of nodes and links at the time of creation, causing an additional cognitive overhead for users. Transformation from one template to another allows users to refine their work incrementally. Further development would make it easier to manipulate templates as storage units in the common information space.

6. Conclusion.

The experiences of using an existing collaborative authoring system and of developing an open system courseware coauthoring system highlighted some problems to be addressed in the context of collaboration and reuse. The Dexter Hypertext Reference model is discussed to point out the limitations of hypermedia systems and possible improvements with respect to the identified problems. The conceptualization of the support for collaboration and reuse is analyzed with respect to the Dexter model.

The key component of supporting collaboration and reuse in shared hypermedia is the schema of the underlying hypermedia. The schema evolution approach is adapted from the object-oriented database management systems. A schema specifies a set of templates and associated interrelationships. Individual authoring spaces are provided as a mechanism to coordinate and incorporate individuals' work into the shared hypermedia with respect to related macrostructures conceptualized in the indexing space. Using descriptors at higher levels of abstraction in layered hypermedia is sometimes known as using a meta-thesaurus or a hyper-thesaurus. The present discussion of knowledge organization in shared and evolving hypermedia emphasizes the integration of meta-thesauri and conceptualizations of coauthoring and reuse activities. The integration is based on connecting the evolution of the underlying hypermedia with that of the abstract schema.

Previous experience and the analysis suggested that the usability of the schema evolution approach may have some substantial dependence on the subject domains being applied. Further work is needed to investigate the order and the magnitude of the difference, in particular, between developing an object-oriented database and generating a shared knowledge base over a long period of time.

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