Information Structuring For Intelligent Hypermedia: A Knowledge Engineering Approach

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ABSTRACT

The next generation of hypermedia systems will undoubtedly incorporate many concepts and techniques taken from the field of artificial intelligence and knowledge-based systems, in order to add more intelligence to the basic hypertext model. In this paper, we discuss where this need for more intelligent hypermedia systems comes from, by looking at the major authoring and reading problems characteristic of hypermedia. We then point out the similarity in system architecture which exists between expert systems and intelligent hypermedia systems, and discuss how a knowledge engineering approach to hypermedia information structuring can help us address these authoring and reading problems. Finally, we describe the use of such an approach in our implementation of IKON, a prototype third-order hypermedia system, based on the so-called Model-Map-View-Praxis or MMVP conceptual system architecture.

The need for intelligent hypermedia systems

The flexibility in the structuring and presentation of diverse types of information that is offered by hypermedia is at the same time hypermedia's greatest asset and its greatest shortcoming. It is hypermedia's greatest asset, since this flexibility allows information to be represented and accessed in very diverse and natural ways. It is hypermedia's greatest shortcoming, since this flexibility makes the information space of a hypermedia system so rich and malleable that its authors have difficulties structuring it, and its readers have problems navigating through it. This imperfection of the basic hypertext model has become apparent in the last couple of years, during which hypermedia grew from a research subject into a commercially viable technology. Moving from small research prototypes to large commercial hypermedia systems has confronted researchers with the limitations of an approach which simply tries to scale-up present solutions to authoring and reading problems.

The challenge now facing hypermedia researchers is to shift from hypermedia systems which offer *unguided access* to *static, undifferentiated information* to hypermedia systems which provide *directed access* to *changing, specific information*. As Halasz [1] has convincingly argued, this requires the development of a next generation of more intelligent hypermedia systems. In this paper, we discuss how we can address this challenge by following a knowledge engineering approach to hypermedia information structuring.

Authoring problems: premature organization and system maintenance

During the last three years the MIPS group, in cooperation with Elsevier Science Publishers b.v., has built the *Active LibraryÒ on Corrosion* (ALC), a CD-ROM based hypermedia system for materials and corrosion engineering [2]. The final system, which went on sale in April 1992, contains well over 3·000 nodes of multimedia information and more than 15·000 links. As such it is one of the largest commercially available hypermedia systems. During the design and development of the ALC, the two most important authoring problems we experienced (see also [3]) were problems of premature organization and system maintenance. The *premature organization* problem consists of the fact that as a hypermedia system is being built, the topology of the underlying hypertext network will necessarily have to alter frequently, to reflect changes in the information contents or in the author's ideas about the desirable link relationships in the network. The *system maintenance* problem consists of the fact that each time changes have been made to the hypertext network, all the nodes and the links between these nodes have to be checked for internal consistency. The present generation of hypermedia systems offers little or no support for this authoring-in-the-large.

Reading problems: cognitive overhead and navigational disorientation

Amongst hypermedia usability researchers it is now generally accepted that cognitive overhead and navigational disorientation (the "lost in hyperspace" sensation first described by Conklin [4]) are the two major reading problems facing hypermedia users. *Cognitive overhead* arises when the reader is faced with too much information

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at the same time, while *navigational disorientation* arises when the reader looses his grasp of the hypertext network's overall topology. In our usability testing of the ALC, we have found that the very nature of hypermedia connectivity leads readers to expect purposeful, meaningful relationships between nodes. As a result, readers tend to get very confused when there is an apparent lack of consistency in node presentation and in navigation possibilities. However, the present generation of hypermedia systems offers no standard techniques or tools for maintaining this consistency.

The similarity between an expert system and an intelligent hypermedia system

Our discussion of the authoring and reading problems leads us to the conclusion that the two big challenges facing the next generation of hypermedia systems are *managing complexity* and *managing change*. Other authors [5,6] have already argued that the best way of addressing these challenges is by incorporating more knowledge into the basic hypertext model. Present research prototypes of intelligent hypermedia systems follow basically two distinct approaches to this problem:

(1) knowledge is *expressed within* the hypertext network itself: knowledge about the nodes and links is represented through node and link typing (along a continuum from weak typing [7] over relaxed typing [8] to structured typing [9])

(2) knowledge is *expressed on top of* the hypertext network: knowledge about the nodes and links is represented separately from the hypertext network (see e.g. [10])

Since a hypertext network is in itself already very analogous to a semantic network, most researchers follow the first approach to the development of intelligent hypermedia systems. We believe that the second approach offers a greater promise of integrating knowledge-based concepts into hypermedia. Indeed, when we look at the corresponding architectural components of an expert system and of what would be an intelligent hypermedia system, we discover a striking similarity in function.

Expert System	Intelligent Hypermedia System
user interface	user interface
inference engine	navigation engine
knowledgebase	link structures
database	node contents

Corresponding architectural components of
an expert system and an intelligent hypermedia system

In the same way as an expert system's inference engine can execute the inference procedures specified in the rules in the system's knowledgebase, using the data in the system's database, an intelligent hypermedia system's navigation engine could execute navigation procedures on the basis of the knowledge represented in the system's link structures, using the information in the system's node contents. In this way, an intelligent hypermedia system could maintain the same necessary separation between *data* and *knowledge about that data* as is maintained in a knowledge-based system. We have recently [11] proposed a conceptual system architecture, the Model-Map-View-Praxis or MMVP architecture, for such a so-called *third-order* hypermedia system, which can support three different types of semantics: the *contents semantics* (how information is usefully related to each other), the *navigation semantics* (how information is to be meaningfully navigated) and the *presentation semantics* (how information is to be meaningfully presented) (for a discussion see [12]).

A knowledge engineering approach to hypermedia information structuring

We have discussed how the basic hypertext data model is fragmentary and static in nature, and as a result has problems dealing with complex and rapidly changing information. These problems can be overcome by exploiting the parallels between expert systems and hypermedia systems, i.e. by following a knowledge engineering approach to the structuring of hypermedia information. Indeed, the two principal characteristics of knowledge engineering information structures are:

(1) information structures are *intensionally defined*: information structures are not hard-wired, but are specified using a general, abstract formalism (frames, objects, etc.)

(2) information structures are *dynamically expressed*: knowledge represented in the information structures is expressed dynamically at run-time (through inference, CBR, etc.)

This results in information structures which are both extensible and adaptive, since both their definition and their expression can be modified independently of the underlying data.

Using hypermedia data primitives which have these same characteristics of being intensionally defined and dynamically expressed can help us address both the authoring and the reading problems which we have discussed before. We have argued elsewhere [11] that the basic information structures that have to be extended for intelligent hypermedia are nodes, links, and navigation procedures. Nodes can be defined intensionally by specifying in an abstract way their information contents and their semantic relationships to other types of nodes. The contents of a given type of node can then be changed without having to alter the underlying information. Similarly, links can be defined dynamically by specifying which type of node has to be connected to which other types of nodes. Changing the topology of the hypertext network then consists of redefining links, and the network is able to dynamically reconfigure itself. These intensional definitions have to be based on a separate knowledge-based domain model of the information contents, where the existence of hierarchies, similarities, causal connections, etc. between the data fragments in the system is explicitly represented. Expressing these intensionally defined nodes and links is then done through navigational procedures, which perform a kind of rule-based navigation. These navigational procedures can be considered as specifications of *which* node can be meaningfully displayed *when* and *how*.

Intensionally defining nodes and links helps us to alleviate the authoring problems of premature organization and system maintenance by supporting a more *active topology* for the hypertext network. This means that the nodes and links are not permanently "frozen" at the time of their creation, but are defined as virtual structures laying on top of the data included in the hypermedia system. As a result, the author(s) can change nodes and links more easily and more frequently. Also, several node and link templates can be predefined so that new information is automatically incorporated into the system, maintaining all the internal structural regularities in the network's topology. Dynamically executing navigation procedures helps us to alleviate the reading problems of cognitive overhead and navigational disorientation by achieving greater *presentation consistency* and *navigation coherence*. Having the presentation of the nodes remain consistent makes it easier for the readers to perceive the different components of a node, interpret them, and make a decision about what to do next. And making navigation from one node to another node remain coherent (i.e. meaningful in a given context) allows readers to remember where they came from and predict where they can go to next. Both can be achieved by turning the navigation engine into a more active computational component that uses the knowledge stored in the system about the information, nodes, and links, to execute intelligent scripts specified in its navigation procedures. These navigation procedures could e.g. adapt the nodes' presentation and the allowed link navigation to the reader (reader-related presentation) and to the task he is trying to accomplish (task-related navigation).

Following a knowledge engineering approach in the IKON prototype

The MIPS group is at present developing a prototype intelligent hypermedia system, called the **I**ntelligent **K**nowledge **O**bjects **N**avigator (IKON). IKON is used primarily as a test-bed for the integration of knowledge-based techniques into hypermedia systems and for validating the MMVP architecture. For details about IKON's system architecture and basic design principles, we refer to [12].

In IKON, the information structures necessary for representing the domain knowledge and for intensionally defining nodes and links are built by extending the standard knowledge representation possibilities which are available in Intellicorp's KEE™ 4.1 (**K**nowledge **E**ngineering **E**nvironment). Domain knowledge is represented using a set of KRYPTON-like, semantically coupled thesauri of domain concepts (for more details see [13]). Nodes are represented using a multiple inheritance frame formalism, where the slots contain deferred references (i.e. references which are determined at run-time) to the actual information content and links to other related nodes. This allows the system, when it is in a given consultation state, to adapt to the reader the contents and the availability of the links of a node. Navigation procedures are represented using a single inheritance frame formalism, where the slots contain navigation scripts which specify the next nodes to be displayed, and the next navigation movements to be enabled for activation by the user. This allows the system to display information in a specific node with only certain buttons active, so that the reader can only perform those navigation movements to other nodes that are relevant for his task at hand.

Future research

In this article, we have shown how a knowledge engineering approach to the structuring of hypermedia information can help us address major authoring and reading issues. We discussed in detail how in this evolution of hypermedia from a more syntactic to a more semantic approach, the hypermedia data primitives used to capture and represent these information structures will also have to reflect this change. In the IKON prototype, this requires the use of knowledge representations which have already proven their value in the field of artificial intelligence. Our own research efforts are now directed towards the formulation of a methodology for so-called *semantics-compliant* hypermedia information structures modelling.

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