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Coherence in the Learning System k-med

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Abstract. The advantages of a hypermedia learning system are the possibility to adapt the content to the learner and to maintain the content easily due to the modular structure. The disadvantages are the well-known problem of the cognitive overhead, and the less discussed problem of little local and nearly no global coherence. The k-med approach is to describe the resources of the system by metadata, connect them by relations and have an ontology containing all relevant concepts. These descriptions enable the system to generate dynamically individual guided tours and table of contents for orientation and navigation according to the preferences of the users. The relations are also used to add small pieces of static text between two resources to connect them.

1 Introduction

Due to the rapid development in scientific areas, the half-life of knowledge decreases rather fast, one of this areas is medicine. A permanent process of learning is required. That means, life-long learning conducted often by oneself is needed to remain up-to-date. This implies a change of paradigm in the field of education. The traditional way of teaching "once and for all" becomes obsolete. Students in the field of medicine have to learn less facts and more techniques to gain, sort and estimate relevant information by themselves, and therefore contrive independently their own knowledge (see Tsichritzis in [18]). Learning becomes individual and therefore the type of learning material has to change from "one size fits all" lessons to small and reusable components which can be combined individually. To support the latter approach, electronic tools are necessary. Information bases must be available for a heterogeneous audience, e.g. for physicians, medicine students, nurses etc. Learners with different background knowledge, learning aims, computer devices and personal means of learning have to be supported by these new tools. Another constraint for these

learning systems is the maintenance: pieces of information have to be added, modified, exchanged and deleted fast and easy to keep pace with the scientific development.
To meet these requirements, Darmstadt University of Technology develops together with medical and educational experts the system k-med. The fundament of this system is a modular knowledge base where the chunks of information (in k-med called media bricks) are attributed by meta-information. In chapter 2 and 3 we describe in detail the kind of knowledge base. The disadvantage of the modular approach is the missing coherence. Linguists distinguish between two kinds of coherence (see Dijk&Kintsch [4]). Local coherence establishes the relation between two subsequent sentences or – in the context of hypertext – between two nodes. Global coherence is the connection of larger parts or the whole text[1], the classification of one part to others. Readers can construct local and global coherence easier, if the authors assist them by giving the text a structure and means to see this structure.
In chapter 4 we show a possibility to compensate this by exploiting the metainformation of the knowledge base.

2 Modular Knowledge Bases

In this chapter we introduce the basic idea of modularity in a knowledge base of learning systems. We discuss the advantages and disadvantages. In chapter 3 we will show how the knowledge base has to be enhanced to counterbalance the drawbacks.

2.1 Characterization

A modular knowledge base is characterized by consisting of a media bricks. The media bricks can be connected to others or not. There is no order, no sequence given. Paths through the material can differ in content, length and order. The knowledge base as such has no linear order.
The best known example of a modular knowledge base is an encyclopedia. More relevant in the context of electronic learning systems is the concept of hypertext. In [10] Nielsen describes the characterization of hypertext as being nonsequential as the common and simplest definition.

2.2 Advantages

There are three major advantages of the concept of a modular knowledge base:
- it enables the system to adaptively offer material to the learner,
- it makes it easy to maintain the knowledge base and
- it permits both the contribution of several authors and allows for the re-use of single media bricks independently from the actual system.

A modular knowledge base can substitute a number of books without the effort of writing several ones. A modular knowledge base makes adaptivity possible. It can contain alternative material concerning one topic. Learners can get individual information on the level of single media bricks. These can differ in their data format, their level of difficulty, complex-

1. The usage of the words “text” and “hypertext” should not exclude documents with multimedia elements or hypermedia.

ity and so on. A learning system which includes for example audio files reading out the texts of the text files can be used by blind learners. When learners have the choice between a video and an image, they (or the system itself) can select the most suitable media brick with respect to their technical constraints. Also the personal preferences concerning the media can be considered. One user learning a certain topic might gain help from a lot of examples, another might be better off without them.

But also on a more complex level, a modular knowledge base is the fundament of an adaptive offer of information. The needs of learners with different background knowledge (e.g. a first year student and a Ph.D. student) can be met exactly. Additional information, probably a fairly big number of media bricks, can be read by learners with less experience. Some media bricks might be offered at the first reading but not at subsequent performances. This technique is realized for example in the AHA-based course 2L690: Hypermedia Structures and Systems at the University of Eindhoven [3]. The other way round, a very interested learner might be inclined to learn more details, probably a formula of a medicine or the biography of a mentioned person.

Different learning strategies can be supported, case-based learning as well as fact-based learning, an hierarchical approach as well as a problem-oriented motivation [11].

Learners with different learning aims are interested in different aspects of the same topic. A physician has to know how to diagnose tuberculosis, whereas a nurse needs information how to wait on the tuberculosis patient.

A learner might learn about the topic bacteria after reading something about the diarrhoea. In this case, it is not sensible to include detailed information of salmonella in the bacteria part, since he or she has learnt about it in the previous part about the diarrhoea. The other way round, salmonella should be learnt in the bacteria part, if the learner has chosen the reverse order.

An information system has to be current. The modular knowledge base allows for an easy modification of the content. Since there are no text-immanent cross links between the media bricks, only the media brick to be modified and its links are to be considered.

Due to the same reason, several authors can contribute to the knowledge base. It is not necessary to know the complete set of information to add a media brick. Authors can link their media bricks to others without changing them. They can modify their models independently of the context, since there is none.

2.3 Drawbacks

Normally, as mentioned above, a media brick contains less information than a book, an article or even a paper. The media bricks have to be written context-free: self-contained, semantically and syntactically discrete pieces of information (see Kuhlen [7]). Authors contributing to a modular knowledge base have to acquire new writing techniques. Some scientists consider this as an advantage: Baird&Percival in [1] and Streitz in [16] established the thesis that writing modularly prevents the author from linearizing his or her net-like structured knowledge and the reader from de-linearizing the information to build up a mental representation. Slatin in [12] states that especially student writers can better explore the basis of their thought by writing a linked hypertext system rather than a linear text.

We think that if it is really possible to transfer the mental representation of knowledge onto a hypermedia system, this might be on the contrary a disadvantage. For gaining knowledge

from information, it is necessary for the learners to find the context and relations of learnt information against the background of their already existing knowledge. This cannot be adopted automatically from someone else.
It is also questionable whether the link structure of a hypertext system matches the mental representation of the author and the reader. Conklin [2] doubts that it is easier to write a net-like structure instead of a linear text because of the cognitive overhead for the author.
Beside this problem, the authors cannot use their trained techniques for composing a good text (see Dijk&Kintsch [4]), such as stating the connection between two paragraphs in form of "As we have seen in chapter 2, …" or "Another approach is …"; it is not possible to continue an example, as the learner has not necessarily read the first part and so on.
A media brick has to be described in more detail than sections of consecutive text in order to find it and offer it at the appropriate place and to make it accessible for external users. The task of describing is the task of the authors. Publishing houses make the experience that traditional authors try to resist this.
Also from the learner's point of view there are problems: As Thüring et al [17] made clear, the readability of an hypermedia document is influenced by two factors: coherence improves, whereas the cognitive overhead due to the additional effort for orientation and navigation decreases the readability. Thüring et al concentrate on the cognitive overhead; they discuss the problem of coherence as easy to solve: authors should state the semantic relation between two media bricks in form of typed links and they should provide a context. This works for a relatively small hypertext system and a homogeneous audience. But as soon as the system is meant to provide relevant information for a broader group of learners, the number of the nodes and relations becomes too huge to overview them at a glance. This way, the cognitive overhead grows even more. Especially for learners who, by the nature of learning, do not know the area they want to get informed about, it is hard to differentiate between germane and unimportant media bricks.

3 Description of the Media Bricks in the Knowledge Base

In order to automatically create dynamic learning documents, k-med uses the Learning Object Metadata (LOM) approach of the IEEE Working Group P1484.12 [22] as metadata scheme to describe the media bricks. We are aware of the fact that many people from the Adaptive Hypermedia System community believe that the metadata provided by LOM is not sufficient to fulfill all requirements to use media bricks described with LOM inside an Adaptive Hypermedia Learning System. People argue that it is not possible to achieve the purpose "To enable computer agents to automatically and dynamically compose personalized lessons for an individual learner", which is specified in the Project Authorization Request (PAR) Form of the working group. One of the main prerequisites to accomplish this purpose, is supporting coherence between the media bricks. Learners usually tend to distrust working documents which were generated adaptively by computer systems. This will get the worse, the less coherence the system can provide between two subsequent media bricks in the document.

3.1 Metadata Attributing Single Media Bricks

LOM provides attributes divided in nine categories to describe a learning media brick. These categories include attributes to represent properties like copyright or utilization aspects of the media brick and attributes which express the “pedagogical properties” of the media brick. The problem with these properties is that different authors have different conceptions about the values of these attributes, even if there is a fixed vocabulary for the attribute value. Computer based agents however have to examine exactly these fields if they want to make decisions about the selection of a media brick from a pedagogical point of view. An agent for example, will tend to select media bricks with the same value of the property “semantic density”, if it has to arrange media bricks to form a document. If the authors of the media bricks had different meanings about these values, the generated document will neither be very useful for a learner, nor be a coherent document.
The question is, whether this problem can be solved with other attributes or other values for the existing attributes. As we will show with a small example, we believe that these will not lead to better results for the generated documents. To get a confirmation that people with different background have different opinions about the difficulty of a media brick a simple test was made: Fermat’s Last Theorem was formulated in two versions. The first one contained only mathematical expressions, the second one used no other mathematical symbols than “+” and “=”, but explained the problem in a natural language. Test persons (about 90% with a university degree) were asked to read these two versions and to answer the questions, which version was easier for them to understand and whether or not they have a mathematical or natural science background. The result is shown here:

	Version 1	Version 2
Mathematicians etc.	16	8
others	2	11

The figure suggest that there is no “easy” or “difficult” version. The example shows that it is unpromising to specify objective descriptions about the pedagogical properties of a resource. To decide whether or not a resource is appropriate for a user in a current situation, more information about the context, where the resource shall be used, is necessary. Furthermore the system needs more information about the background of the learner and also the criteria of the metadata author, who has tagged the resource. These restricts the effective use of algorithms to calculate values like the level of difficulty of a document to closed systems. Only in a closed environment, all informations to classify a resource can be controlled and managed. Additionally more “pedagogical” metadata about a resource can be collected to generate a coherent document. The main disadvantage of a closed system is obvious. The system is not able to use resources generated and described outside of the system. Furthermore not many authors of learning material are willing to provide enough metadata, because describing a resource with metadata can be a time consuming effort. Moreover the author is not always the best person to describe a media brick with metadata, because he or

she doesn't have the specialized knowledge to provide the pedagogical properties of a media brick.
As soon as material, which was built and tagged outside the system, is considered, the coherence of the generated document decreases. Therefore, it is more unlikely that the system will be able to produce documents which can be presented to the learner. As we have shown above, more metadata does not necessarily guarantee a better quality of the generated documents. Even if the document was generated of pedagogically fitting media bricks, the coherence inside the document can still be low.
In contrast to metadata schemes used in closed systems, the big advantage of LOM is, that it is very easy to find and (re-)use modular resources generated outside k-med. Having in mind how many resources described with LOM will soon be available, we decided to use this metadata scheme for our system, even if we have to accept some restrictions of LOM. As we want to show in chapter 4, we believe that it is possible to select appropriate media bricks described with LOM and some extensions we are using in k-med, to generate a coherent document for an individual learner.

3.2 Relations between Media Bricks

The second important aspect for generating coherent documents of modular resources is the possibility to express explicit relationships between media bricks. These relations can be used to consider methods from the instructional design, while selecting the media bricks. As an example, the system could first present a media brick discussing a problem. Starting from this media brick, the system could search for media bricks connected to the first one in a way, which represents that the following media bricks are examples or solutions for the problem treated in the first media brick. The proposed values for the relation category of LOM are taken from another metadata scheme for multimedia documents, Dublin Core (DC) [21]. The values are.

{isPartOf, HasPart, IsVersionOf, HasVersion, IsFormatOf, HasFormat, References, IsReferencedBy, IsBasedOn, IsBasisFor, Requires, IsRequiredBy}

Unfortunately, the bibliographical background of these relations is obvious. Furthermore the relations mix content-based and conceptual connections between the media bricks. The fact that a media brick is referencing another one, is an indication that the media bricks contain information about the same topic. It is not enough information for a computer based agent to decide, if these connected media bricks can be presented in a certain order. The relations "isPartOf/hasPart" and "isVersionOf/hasVersion" are not sufficient. These relations can be useful for organizing and managing generated lessons. To generate the lesson itself they are not helpful. The relation "Requires/isRequiredBy" is also inappropriate. If a media brick completely depends on the existence and accessibility of another media brick, the approach of independent and reusable learning media bricks gets completely lost. A media brick, which cannot be extracted from a system and used in another system, without also extracting all depending media bricks does not need to be described at all. Media bricks connected with the relation "isBasedOn/IsBasisFor" have the same problem. If this relation expresses a content based connection between two media bricks, there is no difference between a "isBasedOn" relation and a "isRequired" one. If someone wants to express the fact that a media brick is dealing with a concept, which is explained in another media brick, he or she shouldn't express this fact with connecting two concrete media bricks or, in other words, representations of the concepts. This kind of connection is independent of the actual media bricks and should therefore be modeled separately

From our point of view, relations between single media bricks should be restricted to didactic relations. These are for both a computer-based agent and a human learner useful to gain additional, more profound or explaining material. A short characterization of these rhetorical-didactic relations and how they are used to establish coherence is given in the next chapter.

3.3 Formal Representation of the Knowledge Domain

In k-med, the semantic relations of the concepts described in the media bricks are modeled separately from the actual content, the media bricks. k-med uses for this purpose an ontology, that is a networked structure to browse and navigate through medical termini. Moreover media bricks are attached to medical knowledge, which is independent from the media. A logical and consistent ontological design requires types of concepts to reflect the entities within the knowledge domain (i.e. medicine), relation types to model the relations between concepts, and axioms [13]. Axioms supervise the process of knowledge modeling logically, they come into play while building conceptual and relational instances. For example we use inverse relations, which are automatically fired, when a relation is drawn between two concepts. Another example is the maintenance of hierarchical relations. We have to formalize rules, which guarantee the establishment of a relation like „diarrhoea is caused by bacterium xyz" whenever we draw a relation „bacterium xyz causes diarrhoea". If we order concepts hierarchically, we want to avoid relations like „the skeleton is a part of the bones", if we already have the relation „the bones are a functional part of the skeleton" [19]. The media bricks are connected to the respective concept of the such constructed knowledge domain.

4 Coherence

A criterion of a text is coherence. As Kuhlen remarked in [7] there cannot be (and from our point of view should not be) coherence in a hypertext system as such. It is up to the users to create coherence for their individual path through the system. An educational hypertext system should support the learners at this task.

In the following sections we show how this support can be added to learning systems with a modular knowledge base.

4.1 Local Coherence

Traditionally, the authors assume the job of relating two subsequent sentences or paragraphs. The basic tool is the order of the sections. Phrases like "It follows …" or "Whereas, …" etc. state the kind of relation between the sections, the second sentences or paragraph is a conclusion resp. a restriction of the first one. By using a consistent vocabulary and a recognizable style, the authors can support the users at following their train of thoughts and hence at building up coherence by themselves.

With a modular knowledge base – probably originated by several authors – none of these instruments is available. In the following sections we show a possibility to add coherence to such a knowledge base.

Guided Tour. To re-establish clues for coherence, some systems introduce guided tours, especially for beginners. A guided tour is one linear path through the material. By following the path, readers are discharged of the decision making whether two media bricks are connected at all. They can assume that subsequent media bricks are related. But adaptivity and guided tour is a contradiction in terms. The "one size fits all" approach does not meet the requirements of life long learning with respect to individuality.

The solution we suggest in the project Multibook are individually generated guided tours [15]. Here, no pre-fixed sections of media bricks are represented to the learners. The lessons are dynamically composed according to the user profile. Statements explicitly given by the learners as well as the learning history and user behavior are considered. The information gained from the user profile is matched to the formal description of the knowledge base. For more details see [11]. In k-med, a human teacher takes care of this task since for medicine students the curriculum is rather fixed and the choice of the material in not completely up to the learners.

The learners are able to visit the neighbor media bricks which are not included in their guided tour. They can get a natural language list in a natural language with the names of links outgoing from the current media brick. This way, a deviation of length 1 from the selected path is possible.

Exploiting the Relations. Any link between two media bricks represents a relation. Untyped links are not really helpful to develop an understanding of the kind of relation. Typed links are fairly widespread and various. Some systems exploit the traffic light metaphor (see for example [5], [20]). Here, the links are dynamically labelled with a recommendation whether to learn the media brick or not, according to the individual learning history of the user. This helps the learner to find a useful path, but does not establish coherence.

Based on the Rhetorical Structure Theory by Mann and Thompson [8] we have developed a set of relations between media bricks. We call these relations rhetorical-didactic, examples are "explains" or "deepens" (for a more detailed list see [14}). The relations are used to realize the adaptivity for example to the level of difficulty and learning strategy. They can also be applied to give clues of coherence. The system adds in the presentation fixed short sentences between two media bricks according to the relation connecting them. An example of such a sentence is "The following will present deeper aspects." This way, we re-establish the textual clues for coherence. One rhetorical-didactic relation plays an additional role. If a media brick can be considered as a continuation of another, they can be connected by the relation "continues". It is not necessary that the two media bricks are deeply semantically related. They may be a continued example: a media brick being a graphic of an apple might serve as an example for fruit, another media brick showing a sliced apple might illustrate the structure of a stone fruit. By connecting these media bricks, the system can – if appropriate – present both to the learner and constitute a thread, else missed in this surrounding.

4.2 Global Coherence

Overview over the Domain. Clues for global coherence of a linear text can often be found in the way the text is presented. The knowledge whether the present document are proceedings of a conference or a course book is an indication of its context. Ideally, the users of an adaptive learning system should not be bothered by classifying this context, since they can assume that the information offered to them is adequate.

Normally, authors categorize their books by adding a blurb. Often here is stated the position of this book with respect to the knowledge domain. Articles or conference papers are specified with keywords.

In k-med, the learners are supported to classify the media brick or set of media bricks to a bigger context by showing them a simplified graphical presentation of the ontology where the media bricks are connected to. Up to about 30 nodes which can be atomic or subsumptions of several nodes are displayed to the learner. The relations between the nodes are not well-defined semantic, but more associative ones. The user can explore this representation by expanding the subsumed nodes. With this tool, the learners can get an overview of the domain.

Table of Contents. The mightiest tool for document-immanent global coherence is a table of contents. Tables of contents offer the readers an overview of the structure of the document. Authors manifest the order and hierarchy, and this way give clues of the position of the single parts in the document. Readers are always able to locate the present piece of information in the context of the whole document.

In Multibook, the documents are composed dynamically from the media bricks. There is no generally valid table of contents. Therefore, also the tables of content have to be created on the fly. We utilize the underlain ontology; concepts of the ontology serve as entries for the table of content. The selection, order and hierarchy is determined by rules according to the user profile [15]. In k-med, the table of content is generated automatically according to the media bricks chosen by the teacher.

Which parts the user has already seen and where she or he is at the moment is indicated by colors. The dynamically generated table of contents has the same functionality as in linear documents. Additionally, the learners can navigate on it.

5 Related Work

The problem of coherence in hypertext systems is well known. Different approaches to solve it are done. Probably the most radical one is the concept of dynamic hypertext. The systems PEBA-II and ILEX as described in [9] use natural language generation techniques to create the documents tailored to the users. This way, the systems can generate linking sentences helping the user to build local coherence. These sentences are based on the relations between for example the current document and the previous one. For gaining global coherence the systems support the users by using the discourse history and comparisons of known concepts with the new ones. The results of the systems are really excellent. But their goals are restricted to description of an entity and comparison. It is doubtful whether the technology works for texts of a more general character.

Some systems have as being a hypertext system a modular knowledge base, but are meant to be read in a prefixed order. Often they are the HTML version of a printed book. Users

may deviate from the given path, but it is not recommended. In these cases, coherence is no problem. But are these truly hypertext systems?
Since for establishing coherence, text-immanent indicators are essential, any other solution cannot offer more than compensation. Some systems concentrate on displaying the context of the actual media brick. An example for this solution is SEPIA [17]. SEPIA's presentation interface (SPI) is divided into four parts: The current document, the previous document, structural information about the current document and about the immediate predecessors. Hereby, clues for both local and global coherence are given. The disadvantage is the cognitive effort to watch four different parts of the window, the missing clarity of the interface. Other systems [5], [6], [20] offer static tables of contents. The learner can recognize their actual position. This does not help the learners to establish coherence, if they do not follow the order of the table of contents.

6 Conclusion

We have shown the necessity of a modular knowledge base to meet the requirements of life-long learning. Learners with different background, learning aims and methods should use the same knowledge base in order to spare the effort to produce many individual documents. Documents based on single media bricks have the disadvantage of lacking coherence. We have explained how the knowledge base has to be enriched by metainformation to provide means for building coherence. In the last part we described the concrete example k-med where rhetorical-didactic relations between the media bricks and the underlain ontology are used to re-establish both global and local coherence.
With the above described knowledge base and techniques we try to diminish the gap between adaptivity and good readability.

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