Technology Enhanced Dimensions in e-Learning

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Abstract:

Complex learning tasks may be exhausting, tiring and sometimes even frustrating. Learners do need assistance. This is particularly true in technology enhanced learning where learners are frequently missing personalized guidance by some human teacher. There are two key terms: adaptability, i.e. the possibility to adapt a system to varying needs and context conditions, and adaptivity, i.e. this system's ability to adapt its appearance and behavior to identified current needs autonomously. Among many others, the central necessity is to meet a learner's goal(s). Multi-dimensional adaptivity is introduced, studied, implemented, and tried out towards better assistance to a large variety of learners under manifold circumstances in meeting the users' respective learning goals. The paper presents the concept of dimensions in adaptivity, illustrates the usefulness of the approach in an existing e-learning application, and explains several techniques in some more detail. Emphasis is put on novel opportunities enabled by innovative technologies. The DVDconnector technology, for instance, allows for the integration of large-size media like full-screen movies into online services. The content drawn from the DVD can be sashayingly dovetailed with online e-learning. DVD script programming makes even DVD content dynamic; it may be assembled and presented in dependence on learner needs. The aim of the paper is to provide a little contribution to the community's common endeavour to make our e-learning systems and services considerably more adaptive.

1 Technology Enhanced Learning from an AI Perspective

Computer systems underly a tendency of growing complexity, thus, becoming more and more complex tools. This does apply to the class of e-learning systems as well. As a result, users need to put more emphasis in learning about how to operate and use their tools. This, for sure, is the wrong way. We do need a paradigmatic shift from computer tools to computer assistants. The research and development area of Artificial Intelligence (AI) deals with the creation of computer systems assisting human users in a variety of tasks including academic studies, professional training and individual activities of life-long learning. 'ITSs [Intelligent Tutoring Systems] are a class of Artificial Intelligence systems that act as assistants in the teaching-learning process.' [14]

Every human being knows about the importance of assistance provided by other humans in literally uncountably many situations. We all appreciate help in doing routine work, but assistance is of the greatest importance to us when we are facing difficult, complex, time-consuming and exhausting tasks. In those cases, co-operative support by an assistant is the best we can get. The better we understand each other, the better we can do the job together.

Clearly, the importance of human learning to us can hardly be overestimated. The many ways in which humans learn are quite diverse and not yet fully understood [2, 3]. Ambitious learning tasks usually require a lengthy engagement and may easily get rather boring, exhausting or even frustrating. There is abundant evidence of the need for assistance in learning. Consequently, e-learning systems are, perhaps, the type of computer systems where we are facing the by far greatest demand of 'intelligent computer assistance'.

Assistance to the learner may have many facets including a system that acts as a 'co-learner' [4] accompanying the human learner. Another assistance concept is addressed by [12] which seems to be more an extended tool equipped with extra components to support the teacher in technology enhanced learning. Others like [5] see assistants very much as assistants to the teacher: 'The teaching and the evaluation process could be shared between real and virtual assistants in order to deliver an adapted teaching'. Quite similarly, [1] work to supplement a human instructor within distributed collaborative learning by a computerized assistant. All those approaches are highly appreciated, but the crucial task still is to equip the electronic teacher with some kind of intelligence.

There still seems to be a very long way until computers are turned into proper assistants to humans. There are open problems galore in many areas ranging from intuitive interfaces allowing for an expressive and easy communication between humans and computers via the fact that a system nowadays is very limited in the way it can track a user's behaviour up to the computers' internal reasoning mechanisms enabling them to understand the users' needs and desires. The present work on adaptivity is deemed a small step on this long way.

2 Learning Goals, Machine Intelligence, and Adaptivity

The e-learning systems' adaptivity is the key issue to perform the ambitious step from complex tools to intelligent assistants. There is a large variety of potentials of why, when, and how to perform adaptively. We need to compensate for the students' remoteness. Adaptive presentations should serve to uphold the learners' motivation and attentiveness. Learning variation aims at fostering comprehension, but has to take care of minimizing floundering. The authors have been contributing to the development, implementation and application of an e-learning system named DaMiT (Data Mining Tutor, available under `http://damit.dfki.de`) for the domain of knowledge discovery and data mining.

Data mining is both a science and an art. The ultimate goal of data mining is generating expressive models over given data such that these models are of valuable predictive power on future data. There is no complete formalization that can predict in advance which approaches might be successful and which might fail on unforeseeable future information. Consequently, studies of data mining require both formal studies and extensive experimentation. DaMiT is a tutoring system for studying the science and experiencing the art.

For an appealing content presentation and for a flexible didactically motivated dovetailing of different approaches to the art and science of data mining, the DaMiT system offers rich combinations of presentation variants (section 4.2). Naturally, the DaMiT approach and system can provide only a little contribution to the community's overall endeavor toward the next generation of e-learning systems.

Among the inventions, there is an own learning goal concept. Learning goals are finite lists of elementary goals which are 7-tuples. The core component of an elementary goal consists in some concept from the underlying domain ontology, some purpose of recently learning and some intensity of the anticipated learning activities. Expressive learner modeling is a crucial step toward 'system intelligence'.

The present submission builds upon these prerequisites and focuses ways of exploiting the available concepts and techniques for attractive multimedia presentations that adapt to user needs.

3 Dimensions of Adaptivity in e-Learning

So far, we have discovered an urgent need of substantially differing presentations of learning content[1] to learners with different goals, wishes, needs, and the like in varying contexts.

Clearly, there are also many cases in which a manifold of presentations is inappropriate [10]. When, for instance, the one and only goal is to read and memorize a certain text (some legal regulations to be followed in practice, for example), the best way might be to read the text linearly. A one-dimensional presentation of content will do.

However, the research, development and experimentation reported here focus ambitious technology enhanced learning endeavors which are usually complicated by a large variety of materials available, by several didactic approaches usually under controversial discussion, and by an urgent learners' desire for substantial support. The crux is that an effective learner support needs to take lots of parameters into account. This is a call for high adaptivity – the focus of the present publication.

Next, we are trying to motivate and stepwise introduce a certain perspective at dimensions of adaptive content presentation.

Trivially, adaptivity needs the system and the learner to have the choice between different alternatives concerning the form and/or the content to be presented by the system or to be selected by the user, respectively. Alternatives are, for instance, to follow the progressing content flow or, alternatively, to take a detour through a couple of additional illustrations. Under different circumstances, such an alternative may be either to do an exercise[2] or not. Sequences of exercises of a different complexity may allow for a deviation into a proper new dimension. In the DaMiT system, so-called competitive exercises usually require a sequence of human-machine interactions, thus, properly opening a longer way into another dimension.

[1] We do not go into the exciting discussion about what 'content' truly is. From a didactics point of view (following [7], among others), the 'material' presented is not the 'content' learned. Unfortunately, computer science terminology, in general, and knowledge management terminology, in particular, is bringing in some confusion.

[2] In systems where exercises are fixed at a certain position within a sequential content presentation, doing an exercise does not really mean a step into another dimension.

Quite ambitious and technically exciting tasks arise from the use of high quality video material[3]. The DaMiT approach uses high resolution video of full-screen size for different purposes. Following a video stream is seen as a one-dimensional activity. There are many cases where stepping from the video dimension into another one is offered for didactic reasons. For instance, videos may be left to consult the conventional e-learning content in pursuit of background information.

Motivated by their own conceptual work, their work on didactic design, implementation and by their experience in using e-learning in higher education, the authors did arrive at a certain perspective at dimensions to be explained briefly.

Let us try an a posteriori approach, first. When learners navigate through the material offered by a certain e-learning system, they frequently meet branching points where they have the opportunity to either follow the stream of activities as before or they may get engaged into activities of a different type. There are examples galore. For instance, sequentially reading text on HTML pages can be interrupted by consulting a glossary or looking into references to the literature. Engagement in solving a sequence of exercises may be interrupted by visiting a chat for consulting other learners. Videos may be either watched continuously to the very end or exit points may be taken as an opportunity of getting explanations for what is ongoing and what are the underlying scientific concepts. A posteriori, the learner's activities may be seen as movement through a multi-dimensional space.

However, in many cases, the steps actually performed can be seen as a path through a space of lower dimension. For illustration, going through a sequence of HTML pages and every once a while having a look at some illustration is somehow two-dimensional in character.

Conceptually, the dimension concept is impressed on the authors' description of e-learning activities, for the sake of some systematization. One may adopt different positions, but for the time being, one viewpoint might do. The conventional text pages of an e-learning system form one dimension. Passive illustrations form another dimension. Interactive applets for exploratory learning form a third dimension. A fourth dimension is given by exercises and tests. Another dimension may come in when social communication (e.g. chat) is enabled.

Different approaches to dimensions in e-learning come up with different goals. In [11], dimensions relate to learning goals as illustrated by the explanation that 'basic arithmetic might have two dimensions, namely *Addition* and *Subtraction*'. Particular approaches to simulation based discovery learning like in [5], e.g., lead to specific content and presentation forms. From the perspective of the DaMiT approach, this may be seen as one particular dimension.

The authors are aware of the difficulty that there may be a lot of different perspectives at dimensions. What is appropriate in one application domain may be useless in another one. What describes adequately the choice you have in one system, may be simply absent in another one. This is the authors' first publication about the issue of dimensions of adaptivity; it is far too early for generalizations.

[3]It is the authors' intention to show such a video during their conference presentation and demonstrate the change of dimension practically. Videos are provided on DVD based on the DVDconnector^{TM} technology by micronomics GmbH, Berlin. This technology allows for a smooth dovetailing of online and offline content without any interruption of the learning process. Videos are played from DVD and navigation from the offline media into the online media and vice versa appears sashaying.

4 Didactic Concepts and Dimensions of Adaptivity

The key motivation for adaptivity of a higher dimension ist not simply to have a fancy appearance of a system which, thus, attracts more attention than other systems do. Truly, the key motivation lies in didactics where changes of dimension within the learning process may be of substantial importance to the learner. As the paper puts more emphasis on technologies than on didactics, the authors are going to exemplify the didactic reasons and extend the discussion toward more technological approaches and their exploitation for adaptivity.

4.1 The Case of Motivation and Overviews vs. In-Depth Studies

For the DaMiT System, several motivating videos have been produced. This material may be deeply nested with the online content of the DaMiT system. The table below surveys the case of a video which describes information extraction from semi-structured documents by means of the LExIKON system (cf. [6]). This video is used to motivate algorithmic learning studies by means of an attractive application.

File Name	File Size [KB]	Duration [min.]	Short Description	Anticipated Interaction / Steps into Other Dimensions
`01n.vob`	22 432	0:24	System Intro	6 invisible Hotspots linking to Internet pages
`01x.vob`	43 118	0:47	System Intro	6 invisible Hotspots linking to Internet pages and a transpararent HTML page linking to AEFS content
`02n.vob`	28 703	0:31	Overview	
`02x.vob`	48 863	0:54	Overview	
`03n.vob`	34 256	0:38	Task Description	
`03x.vob`	61 382	1:08	Task Description	
`04a.vob`	45 148	0:50	Preparation	
`05a.vob`	19 142	0:21	Setting Params	
`06n.vob`	81 869	1:31	Learning I	
`06x.vob`	112 093	2:04	Learning I	visible Hotspot around AEFS (video stop) linking to DaMiT content about AEFS
`07a.vob`	81 748	1:30	Wrapper Concept	two subsequent transparent HTML pages, linking to AEFS and Formal Language Learning, resp.
`08n.vob`	91 026	1:41	Learning II	
`08x.vob`	122 474	2:16	Learning II	
`09a.vob`	71 236	1:19	Inform. Extract.	
`10a.vob`	55 556	1:01	Summary	

There are 15 video snippets of altogether appr. 900 MB. The running numbers indicate the order in which video sequences are to be combined. The names' final letter is used to distinguish variants, where 'n' stands for the 'normal' presentation, whereas 'x' denotes a more extended presentation of the same stuff.

Usually, a learner gets a full video of approximately 10 minutes in length composed of 10 subsequences. Theoretically, 32 different appearances of the video under consideration might be assembled, whereas in practise only 6 versions are used. In the following diagram it is depicted how the `.vob` files can be connected to form a possible sequence through the video. Here, the dotted lines mark junctions to other dimensions. In dependence on the adaptively generated video version, the learner gets offered between 3 and 6 branching points to step into another dimension of presentation and learning activity. In the column 'Anticipated Interaction' you find a brief description of the possible switches into another dimension.

$$\begin{tikzcd}
& \vdots \\
& \mathtt{01n} \arrow[dr] & & \mathtt{02n} \arrow[dr] & & \mathtt{03n} \arrow[dr] & & & \mathtt{06n} \arrow[dr] & \vdots & \mathtt{08n} \arrow[dr] \\
{} \arrow[ur] \arrow[dr] & & {} \arrow[ur] \arrow[dr] & & {} \arrow[ur] \arrow[dr] & & \mathtt{04a} \arrow[r] & \mathtt{05a} \arrow[ur] \arrow[dr] & & \mathtt{07a} \arrow[ur] \arrow[dr] & & \mathtt{09a} \arrow[r] & \mathtt{10a} \\
& \mathtt{01x} \arrow[ur] & & \mathtt{02x} \arrow[ur] & & \mathtt{03x} \arrow[ur] & & & \mathtt{06x} \arrow[ur] & & \mathtt{08x} \arrow[ur] \\
& \vdots & & & & & & & \vdots
\end{tikzcd}$$

This illustration will be completed by some look into the techniques that allow for interleaving the offline video and the online e-learning material smoothly for traversing the multi-dimensional space of learning activities.

From the DaMiT system's perspective at its contents, the video snippets on the DVD are treated like 'chapters'. In particular, there are the two video variants number 06n and 06x, resp., in the table before. Their corresponding chapter numbers are 06 and 16. The extended video version, but only this one, is getting overlayed a visible hotspot. The corresponding XML metadata

```
<contentextern>
<general name="chapter16"/>
<technical format="dvd_video" location="chapter16.script">
<additional>
<param name="chapter" value="16"/>
</additional>
</technical>
</contentextern>
```

relate the DVD content to a script located within the e-learning system itself. Treating scripts as server-based content allows for dynamic adaptivity of offline videos, as well. Further operational details will be discussed in chapter 5 below.

4.2 The Case of Introduction to and Support for Learning by Doing

For the sake of experimentation, DaMiT offers a large variety of applets for *explorative learning* and for *learning by doing*. Experiments are sometimes complex. The potentials of explorative learning are frequently hidden behind the enormous freedom the learners have in operating an applet. Advice is of great value. There are videos intended to explain the behaviour of an applet and to exemplify the way in which exploration leads to new insights.

For example, in the context of decision tree induction, DaMiT offers an applet for learning decision trees over patterns from a list of positive and a list of negative examples.[4] The user may understand the nature of the initial data mining problem and the algorithm for its solution much better if he can test the algorithm himself. For that purpose, the applet allows the user to generate and change the input data of the algorithm and to view the resulting decision trees. Besides the textual explanation of the algorithm within a lecture, this applet constitutes a second dimension for learning about the induction of decision trees. A further dimension is implemented by the additional supply of several videos for this applet. These videos guide the user in operating the applet, illustrate specific phenomena of the given data mining problem, or explain the crucial ideas of the underlying algorithm. But what is most important is the fact that DaMiT implements multi-dimensional learning by linking the different dimensions and allowing the user to change dimensions whenever it may make sense.

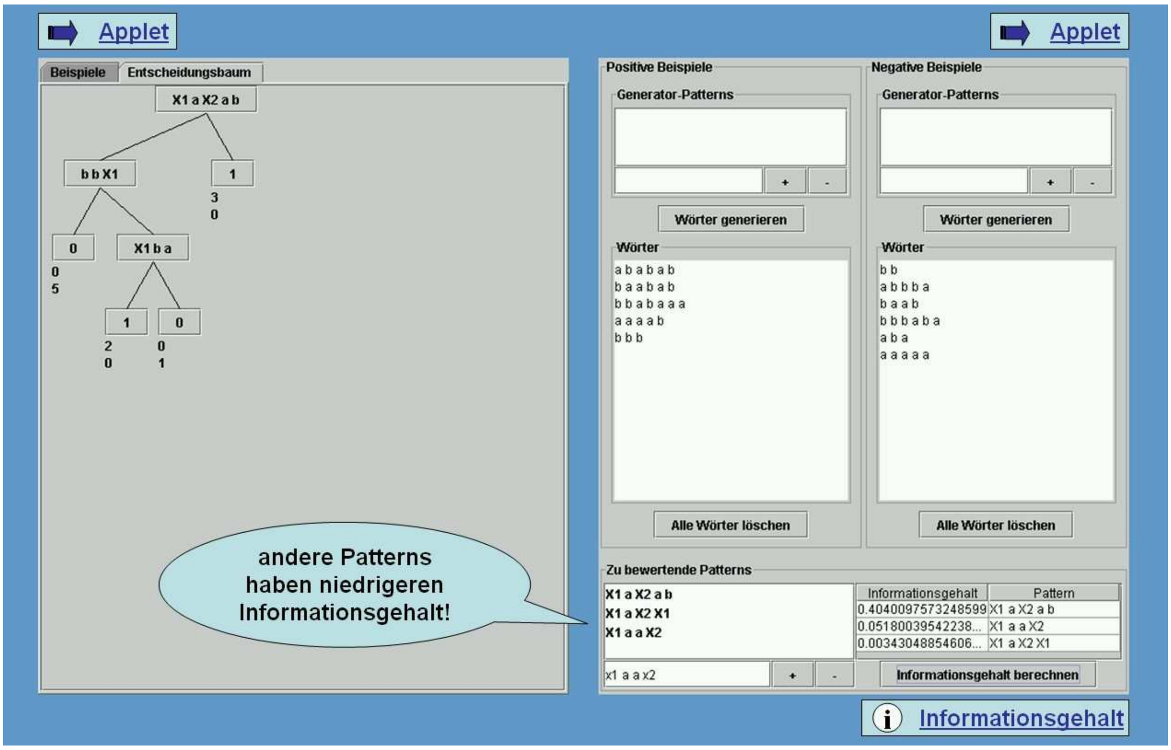

Figure 1: Snapshot of a Video for the Introduction of Applets (with Overlays)

Let us consider for example the video explaining the underlying algorithm; figure 1 shows a snapshot of it. In the video, a set of input data and the corresponding induced decision tree is displayed. The root node of the induced decision tree is, by the instructions in the algorithm, labeled with a pattern allowing for the maximal possible information gain for classifying the input examples. On the video snapshot, you find this tree in the left window.

[4] A decision tree over patterns is a binary tree in which each none-leaf node is labeled by a pattern (that is a string consisting of variables and terminals) and each leaf is labeled by a class name. An input example is constructed to pass the test associated to a non-leaf node, if and only if it matches the corresponding pattern. The classification of an example is determined by the label of the leaf reached when, starting at the root, its path through the tree is determined only by the results of the tests in the reached nodes.

To explain the functioning of the applet, the video displays a second applet (see right window in figure 1) which is used to calculate the information content of a pattern given a set of labeled input data. In the video demonstration, the data used in the first applet are fed into the second applet and the information content of the pattern in the root node of the decision tree is compared to that of other patterns. Several balloons like those used in comic strips notify the user of the most important facts.[5]

To allow for multi-dimensional learning, the video is equipped with several links enabling user interaction (and dissection of the video). These links constitute junctions to several dimensions (e.g., to applets, textual lecture parts, and further videos). In figure 1, you can find three links: link 1 and 2 at the upper corners which lead to the corresponding applets and link 3 in the lower-right corner linking to textual content, namely the explanation of the term information content (German: 'Informationsgehalt').

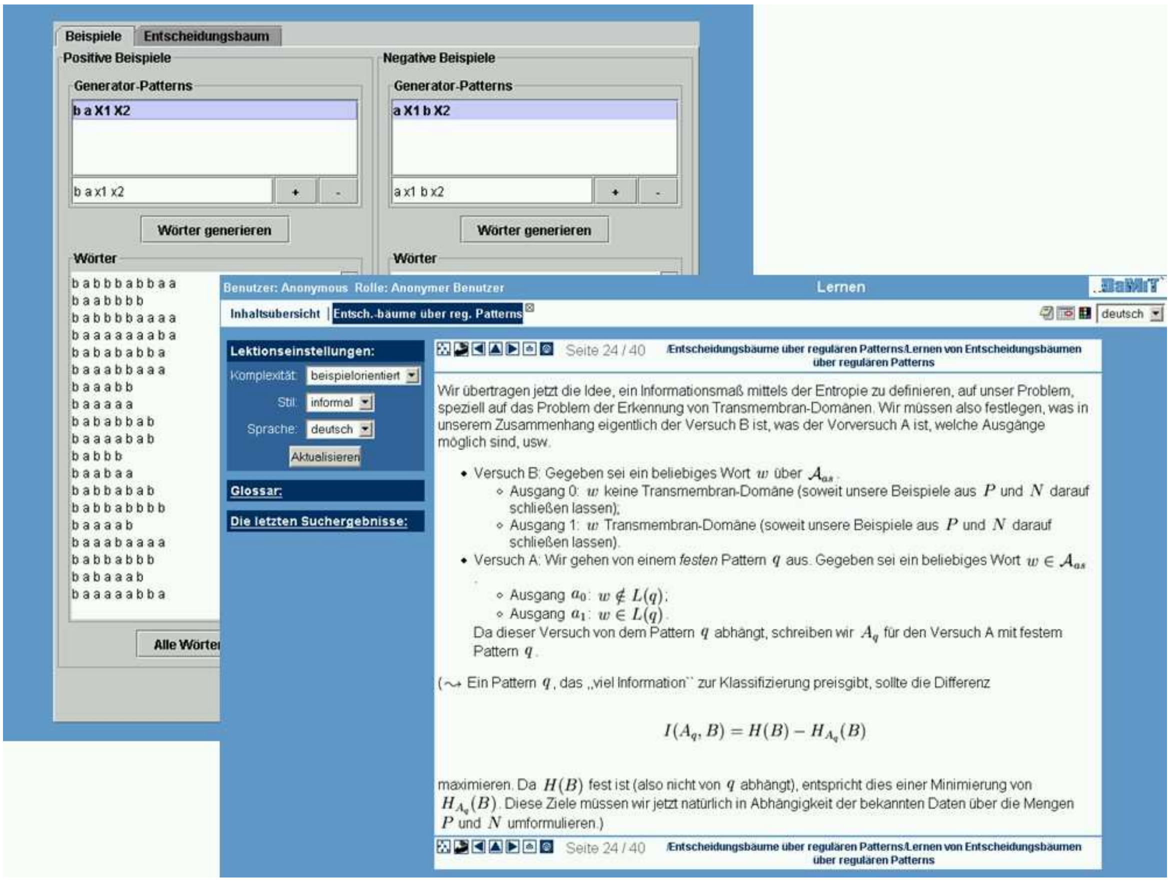

Figure 2: The Interaction Appearance after leaving the Video into Different Dimensions

Figure 2 shows the targets of the links 1 and 3. By following link 3, one leaves the video and arrives at the textual lecture depicted in the right window. This link might make sense for a user who needs background information about the definition of information content.

The target of link 1 is shown in the left window of figure 2. This junction to another dimension (an applet) might make sense for a user who would like to make experiments with the

[5] In figure 1, e.g., the german text in the ballon is saying that other patterns do have a lower information content.

applet itself. In particular, via such a link the video again provides a *learning by doing* component. The videos not only allow for accessing different dimensions, but can themselves also be accessed from different dimensions.

5 Technologies for Unfolding Presentation Spaces

Implementing ambitious didactics, meeting high expectations of media quality, giving birth to machine intelligence, ...: all this does require some technological decisions and their subsequent implementations. This chapter permits a glance at the DaMiT technology.

5.1 Content Modularization and Annotation

An adaptive presentation of content can be generated in various ways. On the one hand, the system may decide which content to present, and on the other hand, it may determine how to arrange the content. Thus, the system's content needs to be fragmented into more or less small elements, called *learning objects*. To enable the system to deal with these learning objects, they have to be annotated with metadata. This includes general information like author and date, technical information about requirements (e.g. need for a certain plug-in), educational information like presentation style and difficulty, a classification of the object, information about relations to other objects and so on. The example displayed here illustrates the metadata information of the overall video introduced in the preceding chapter.

```
<unit multi="embedded,illustrated">
<general name="mot_LExIKON" description="A Motivation Video for
               Information Extraction and Algorithmic Learning"
keyword="information_extraction,wrapper_induction,aefs,
         formal_language_learning"/>
<lifecycle author="SB_KJ" status="final"/>
<classification type="dvd_illustration"/>
<contentextern variant="embedded">
<general name="chapter1"/>
...
</contentextern>
...
</unit>
```

In DaMiT, a derivative of the IMS Metadata Standard[6] is used to annotate this information. Some parts of the IMS Standard were left out, and some substantial extensions turned out to be neccessary.

5.2 Interfaces and Functions for Presentation Generation

In the process of the content generation, there have been a lot of database operations invoked. Therefore, the main part of content generation logics was implemented within the

[6]See `http://www.imsproject.org/`, Primer for the IMS Learner Information Package, 2001, and `http://www.imsglobal.org/metadata/`.

database itself by using stored procedures that take the user data and his learning preferences as input parameters and generate corresponding XML structures. These XML structures being generated serve as interface between the database layer and the application layer of the system [13]. The application layer parses the XML structures and generates the object representation of the content hierarchy. Such representation allows to divide content into pages, resolve references to several other content elements within the application layer, change the content presentation style and so on.

The downside of such an approach is possible performance loss in the case of vast content hierarchies. In such cases, the utilization of caching [15] techniques could provide possible solutions to the performance problem.

5.3 Dovetailing Online and Offline Content

By means of the above-mentioned DVDconnector^{TM}, the DaMiT consortium was able to extend its service of a server-based e-learning system towards an attractive variant based on DVDs in every client's computer. The way in which a certain part of an offline video is overlayed with dynamic navigation information is exemplified here.

```
BEGIN_PLAYLIST(16)                          # playlist for 06x.vob
  BEGIN_EVENT("AEFS in DaMiT")
    TIMECODE(00:02:34:00)
    BEGIN_HOTSPOT
      RECT(100,100,300,300)
      LINK("http://neumann.dfki.uni-sb.de/damit/servlet/manager?
            command=goobj&name=DA_AEFS&session_id=%SESSION%&
            MODULE=COURSES","DaMiT")
      ACTION("PAUSE")
      OPTION("PAUSE_ON_CLICK")
    END_HOTSPOT
  END_EVENT

  BEGIN_EVENT("PLAY 07")
    TIMECODE(00:02:37:00)
    ACTION("PLAY(7)")
  END_EVENT
END_PLAYLIST
```

The video snippet '`06x.vob`' (see table in section 4.1) gets some visible hotspot at the time point 00:02:34:00. The location of this hotspot is given as a rectangular in pixels. When the hotspot occurs, the video stops. Clicking the hotspot brings the learner into the DaMiT system according to data from his current learning session.

This technology is setting the stage for truly dynamic adaptivity to the learner, to his progress in learning, to his needs and desires (including even unarticulated goals [8]), and over changing context conditions, though the building blocks for the adaptivity are located on seemingly static DVDs.

6 Conclusions

In technology enhanced learning, it makes a difference whether you simply turn pages or whether you may alternate between text studies and looking at illustrations of what you are reading. This is the tangible difference between moving along one line, i.e. only within a one-dimensional space or navigating through some literally two-dimensional space. If another type of media is offered in addition (opportunities of exploratory studies with interactive applets, for instance), you really sense the third dimension which makes your studies more enjoyable. Those dimensions are really present in e-learning. The present publication intends to make these dimensions explicit toward their intentional investigation, design and usage. Approaches to storyboarding [9] are drawing benefit.

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