Context-sensitive and Personalized Concept-based Access to Knowledge for Learning and Training Purposes

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Abstract: Educational objectives in the 21st century require efficient teaching and learning processes and enhanced learning environments. Focusing on knowledge-centered issues, an important aspect is, that learners need information that helps students developing an understanding. Our former experiences have shown that in addition to the simple provision of learning content further background information can support the learning process in school and university education as well as for vocational training. Therefore, in this paper we propose and describe a system, which allows teachers and trainers to manage background knowledge on a concept level for the learning process with less effort and enables learners to access effectively relevant additional information. In addition practical experiences and findings gained by two sample application are summarized.

Introduction and Motivation

It is well documented that the increasing amount of knowledge and its dynamic requires efficient and improved learning activities at any learning situation, such as in school, university and vocational education. According to (Bransford et al. 2000) over the last 100 years the objectives and expectations for the learning process have changed dramatically from repetitive learning to learning with understanding to become independent in the learning process, strengthen metacognitive skills and link knowledge acquired in cultural context. In order to meet the requirements of educational goals for the 21st century, aspects of learner-centered, knowledge-centered and assessment-centered environments have to be taken into account.

To narrow down to knowledge-centered environments, one important aspect is, that learners need information that helps them developing an understanding (Bransford et al. 2000). According to our former experiences, nothing but knowledge transfer by face-to-face lectures and the provision of course content in e-learning systems do not meet the requirements of modern learning activities. Learners are tending to use additional information in their learning process, as discussed in (García-Barrios et al. 2004). This former user survey, focused on learning activities at university level, has shown, that lecture notes and text books are most frequently used, but subjects also stated the usage of timely online information, web sites, Internet recherché, summaries of lecture notes, test examples, literature references, and lecture notes from other universities. It is obvious and may be backed by our daily-life experiences, that such a demand on additional information in the learning process is generally present in school and university education as well as in vocational training.

In order to find relevant information within the learning process, learners might apply search services on the internet. However, a significant number of users are faced with problems, such as lacking skills to successfully operate the search services, finding proper keywords for search queries, and selecting documents form trustworthy information systems. (Baeza-Yates & Ribeiro-Neto 1999; Pollock & Hockle 1997; Beavers 1998) In addition, such search activities take the users' attention off the actual learning process. To overcome that, technology-supported learning environments provide for each learning course or lecture access to mainly static repositories of physically copied and compiled background knowledge. However, such an approach causes continuous efforts to update relevant background documents, otherwise the repository becomes outdated. In addition the creation of such a repository is laborious and ties up human resources. (García-Barrios et al. 2004) Another important issue is, that learners' needs for additional information vary significantly and they are influenced by facts, such as pre-knowledge, knowledge acquisition, learning task and context. (Kramer et al. 2000) Consequently, the selection and maintenance of proper background information for each learning situation and course content increases dramatically. Therefore, a new solution approach is required, which allows teachers and trainers to manage background knowledge on the concept level for the learning process with less effort and enables learners to access effectively relevant additional information.

The situation stated so far motivated us to develop a running prototype which enables a context-sensitive and personalized concept-based access to knowledge for learning and training purposes. In the remainder of this paper, based on some illustrative application scenarios our solution approach and the system implementation is presented, followed by the description of two sample applications and the discussion of experiences and findings.

Application Scenarios

The objective of this section is to describe some application scenarios in different application domains to illustrate various user needs and to identify the specific requirements for context-sensitive and personalized concept-based access to knowledge.

Miriam is associated professor at university level and she has to give a course about a very specific topic for graduated students. The course includes face-to-face lectures, e-learning and group work activities. Her former experiences have shown that students' pre-knowledge significantly varies and to overcome that, additional knowledge for different knowledge levels is helpful within the learning process. Therefore, Miriam decides to offer students personalized references on concept level to additional knowledge available in various knowledge repositories. Consequently, students can access them in the e-learning system.

Nicholas is project manager of a new project which is very complex in terms of technology aspects. The project team members have diverse pre-knowledge in this new subject domain. Because of a tight timetable, project team members can not be educated and trained in advance. Thus, Nicholas made the decision to apply a learning-on-demand strategy. Therefore, he identifies relevant concepts of important subjects for the project and assigns various learning material and documents from the corporate memory (the intranet information system) and the selected internet resources. As a result project team members can access task-dependent and personalized information from the intranet information system.

Mona is head of the quality management department and responsible for modeling the business processes of the company, which are made available for the employees by the process management system and instantiated for concrete projects. Her former experiences have shown that in addition to task descriptions further information supports the efficient processing by employees. Additional information needed depends on various facts, such as on the project role, process and domain knowledge and frequency of processing specifics tasks. This led Mona to specify task-dependent topics (concepts) and link them to relevant documents for different roles and skills, such as example documents from finished projects, detailed task descriptions, best practices documents and domain knowledge.

Solution Approach and Implementation

In the light of users' needs discussed so far and illustrated by application scenarios in the previous section we have decided to develop a system which enables a context-sensitive and personalized concept-based information access applicable for knowledge transfer and learning activities. Our solution approach dates back to and is inspired by our former research work on the *Dynamic Background Repository* (see for further information García-Barrios et al. 2004) and its enhancements with a *Concept Modeling System* (see for details Safran et al. 2006). The main idea is to manage background knowledge and make it personalized accessible on the concepts level. Unlike most other solution approaches which statically link resources, we follow a flexible approach by dynamically linking topical resources by means of requesting or querying diverse information systems. As various information needs are caused by situations or activities of specific contexts, our system can cope with this requirement, which we call context sensitiveness. The main part of the solution approach is given by the *Context-sensitive Concept Modeling System (CsCMS)* with capabilities for personalization. The CsCMS and its integration in an overall architecture are outlined in the remainder of this section.

In general, the Context-sensitive Concept Modeling System enables to manage various contexts, such as courses or projects. For the purpose of a more fine-grained structure, a specific context can be composed by various sub-contexts which are modeled by different context items. In order to assign sub-contexts to a given information structure, context items can be linked to one or more content pages, such as learning objects, knowledge assets or workflow tasks. To illustrate this, for example the context item 'idea stage' is part of the context 'lecture project management' and it is assigned to the first three pages of the learning content. In the next step, for each context item in a specific context the background knowledge can be modeled by a set of concepts and corresponding synonym phrases. Each of the concepts can link dynamically to topical resources of various information systems by applying specific requests or queries. For further simplicity we will for short name both terms ('requests' and 'queries')

queries in the remainder of the paper. For the purpose of a flexible support of various information systems, the CsCMS allows to manage (add, edit and remove) arbitrary instances of information systems by creating corresponding sets of query templates. By query template we mean a kind of predefined query by applying a flexible placeholder mechanism. Placeholders can be defined to replace parts of the query, such as to fill in a query term by a concrete concept instance or to enrich the query with user group or user information. Each concept managed by the CsCMS can be initialized with the default set of information systems and predefined query templates, and some of them can also be deselected or rewritten. If appropriate the template-generated query for an information system can be partly adapted or wholly rewritten. To give an illustrative example, concepts such as ‘creativity training’, ‘brainstorming’ and ‘think tank’ are assigned to the concept item ‘idea stage’ and the default set of information systems (Wikipedia, Answers.com and Scholar Google) are selected. In order to get more relevant results, the search query for Scholar Google was adapted to ‘think tank’ AND ‘project management’. For representation purposes, concepts and query instances for specific concepts can be logically clustered by structure elements and displayed by proper titles.

The system described so far addresses the generic, non-personalized level of the context-sensitive concept modeler. In order to enable personalization capabilities, the system can also deal with concept modeling on the group and user level. The same functions as described for the generic level above are also applicable on these two levels. This means that specific information systems and proper query templates and also concepts can be managed for groups and even for individual users. In addition, data from generic level can be wholly or partly inherited and overwritten to the group and further to the user level. To illustrate the added value and the functions of this part of the system, imagine a group of students who are student members of ACM and they are interested in also receiving background knowledge from ACM portal. They can specify the ACM portal and proper query templates on the group level and can easily get access to additional background knowledge without any further effort. On the individual user level, for example, in their learning process students may also need additional concepts, which can easily be added and linked to helpful resources.

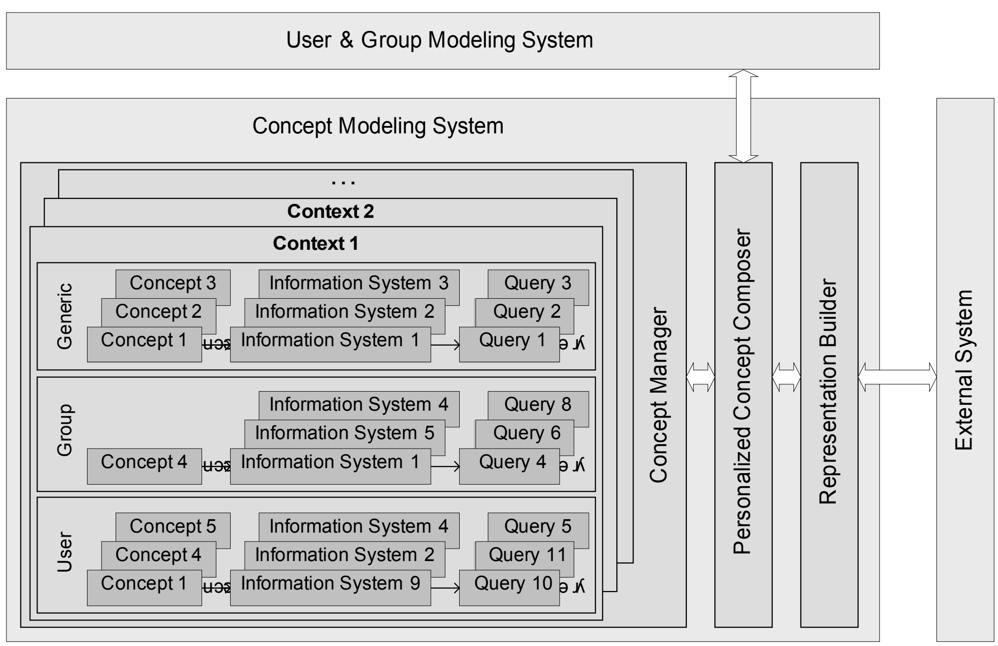

Figure 1: Context-sensitive Concept Modeling System with personalization capabilities.

Figure 1 depicts the conceptual architecture of CsCMS and its interaction with other systems. External systems send requests, which include information about the context, the specific context item, the user ID and the result representation. It is worth mentioning that a secured communication is also part of the overall architecture for privacy and security issues. The CsCMS returns a set of concepts and corresponding queries either in XML or XHTML for further processing and presentation. By narrowing down to the CsCMS architecture, concepts as well as logically linked information systems and their queries are managed on the generic, group and user level by the Concept Manager Unit (CMU). The Personalized Concept Composer (PCC) is basically responsible for merging concepts, linked information systems and queries from generic, group and user level. For the purpose of personalized merging and replacing place-holder with group and personalized information, the PCC communicates with the User & Group Modeling System. The Representation Builder (RB) compiles the results and delivers them to the external systems in accordance with their information requests.

The CsCMS is built on Openwings, a JAVA-based open source platform (see fur further details Carpenter & Bieber 2003 and OPENWINGS), and the software development follows the service oriented approach (Gütl et al. 2004). It is accessible for other systems by a standard interface. Figure 2 shows the graphical user interface of a JAVA application, which enables users to manage the CsCMS by connecting the same standard interface. The active tab 'Concepts' allows adding, editing and removing concepts as well as assigning them to a context item and specifying and rewriting query terms. This example refers to one of or example courses, a course about Graz and Styria (Context ID 'course01'). For the page 3 of the sample course the more fine-grained information about the context is defined by the Context Item 'instruction03'. One of the concepts for the content page 3 added by the teacher addresses the sign of Graz, the Schlossberg. In this example, the teacher has selected as one of the external information systems the Google Image Search and specified the search query 'schlossberg+graz'. The remaining unselected tabs enable to manage context details as well as context items and information sources in such a context.

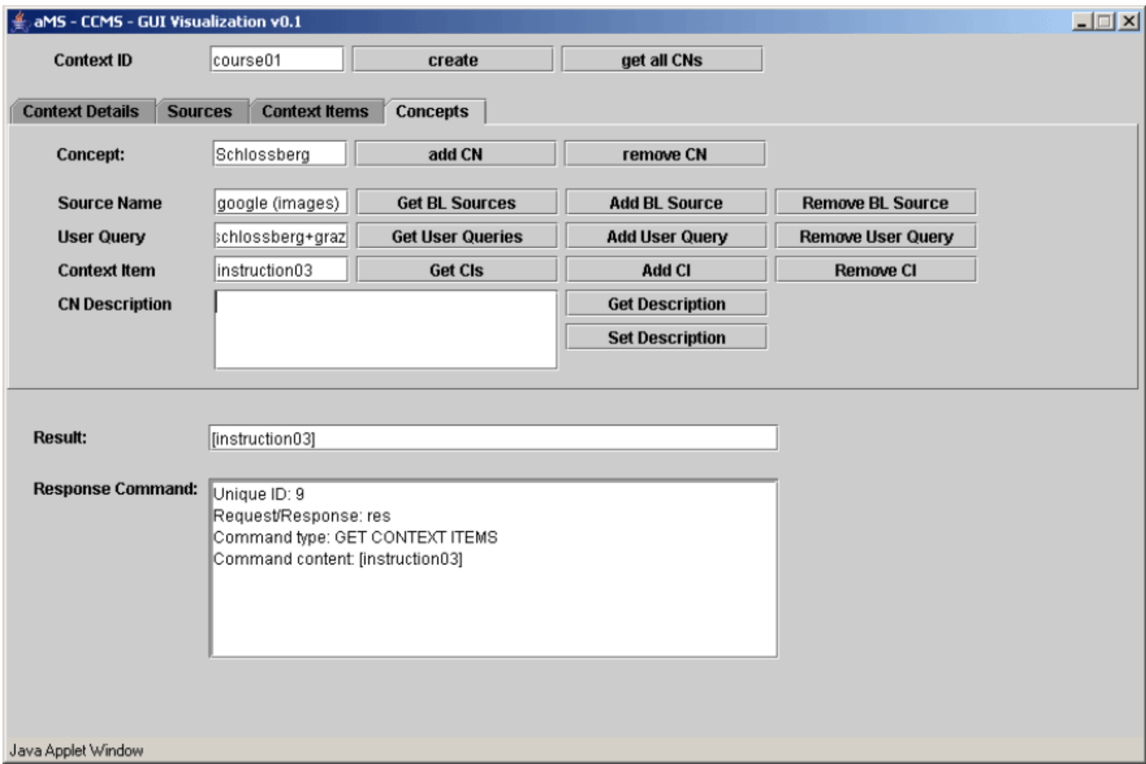

Figure 2: Example of the CsCMS's graphical user interface for managing concepts.

In Figure 3 an overall architecture is outlined for the purpose of linking context-sensitive and personalized topically background knowledge to learners' daily learning and training activities. In order to be flexible our solution approach enables an easy integration in various types of information systems, such as *Learning Management Systems (LMS)*, *Knowledge Management Systems (KMS)* and *Work Flow Systems (WFS)*. Information about the user (such as user record information, expertise, user roles in project and user behavior) and information about user groups (such as specific topics for group learning activities or project specific information for project groups) are managed by the User & Group Modeling System (for details see Gütl & García-Barrios 2005a and García-Barrios 2006). Such user and group information are fed and accessed by the information systems as well as by users' interaction with them. Specific user and group information are used by the CsCMS, such as user roles and group-relevant topics. As explained in detail above, CsCMS enables the personalized access to various repositories. Thus, any trusted information system can request personalized information for specific users by sending information about the context, context item (more specific context information) as well as information about the user and the representation format. Results can either be delivered in XML or in XHTML for further processing and rendering by the information system, such as embedding them in the content or in navigation and control sidebars. Finally, the user can follow personalized and semantic information requests in order to receive topical background knowledge from various knowledge repositories, such as Wikipedia and Answers.com as well as learning repositories, knowledge management systems and meeting recording information systems.

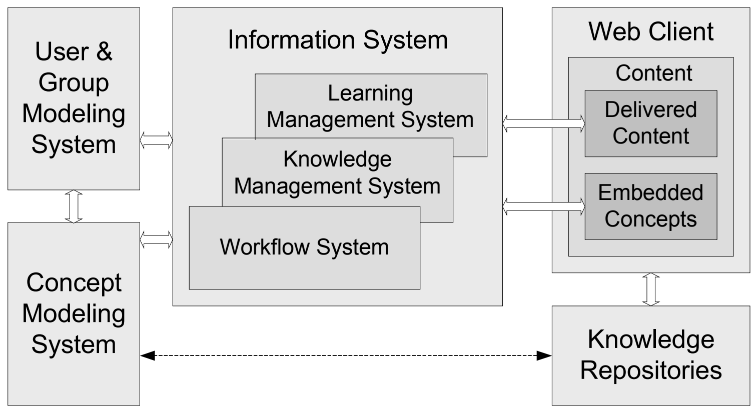

Figure 3: Overall architecture for personalized concept-based access to various knowledge repositories.

Sample Applications

In order to gain findings in various sample scenarios and to prove the flexibility of the overall architectural approach, the Context-sensitive Concept Modeling System (CsCMS) has been applied for getting access to background knowledge in two research projects, the AdeLE projects (see AdeLE) and the MISTRAL project (see MISTRAL).

Access to Background Learning Material in the AdeLE Project

The objective of the AdeLE project is to carry out research in order to develop an enhanced adaptive e-learning system. A main issue is to improve the learning process by well tailored learning activities through the usage of a fine-grained user profile. This is gained by real-time processing of user behavior tracking and content tracking. At this stage of the project, the user interaction (mouse and keyboard events) with the learning platform and gaze tracking is processed and mapped to the content rendered and delivered to the user. Another main issue is to build up the AdeLE architecture of strong separated client-side and server-side systems. On the client-side, a Web browser renders the delivered e-learning content and also provides control and navigation elements for interacting with the server-side located e-learning system. The *Real-time Eye-Tracking System (ES)* reads the eye movements and computes gaze pattern in order to describe characteristics of the user behavior. To gain valuable insights for the learning process, gaze tracking information has to be linked with fine-grained content information of the learning assets rendered by the Web Client, which is processed by the *Real-Time Content-Tracking System (CS)*. Both, learners' interaction as well as eye-tracking and content-tracking information are sent to the server side to build up and manage a fine-grained user profile. The communication between the server and Web server is handled by HTTP requests and synchronous RMI is applied for the other information exchange processes. On the server-side, AdeLE's architecture is divided into three main systems: *Modeling System (MS)*, *Adaptive System (AS)* and an *adaptable Learning Management System (LMS)*. The LMS is built on the SCORM reference implementation (see for further details ADL) and enhanced with adaptive features. It compiles the learning content from the learning object repository, and provides the control and navigation interface. Adaptation of content, navigation and visualization is controlled by the AS by means of exploiting user information from the MS. (Gütl & García-Barrios 2005a)

A former user survey has shown that background information can provide added value within the learning process; for detail see (García-Barrios et al. 2004). This has led us to enhance the core AdeLE system by providing context-dependent personalizeable background information on concept level from various knowledge repositories, such us encyclopedias, digital libraries and dictionaries.

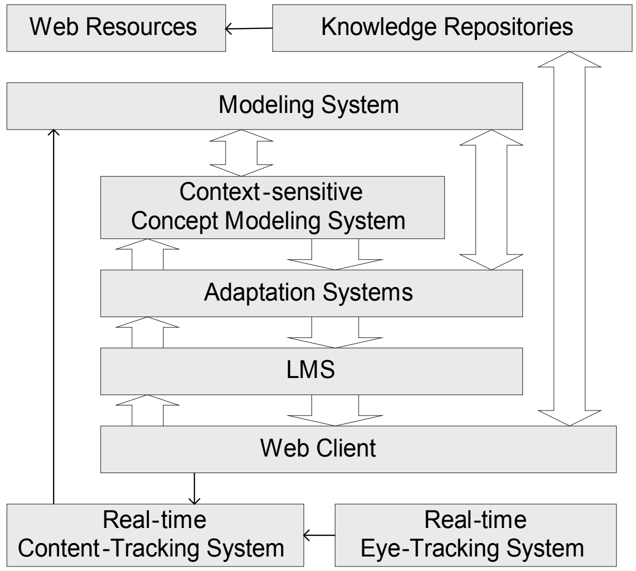

Figure 4: Overview of the enhanced AdeLE architecture.

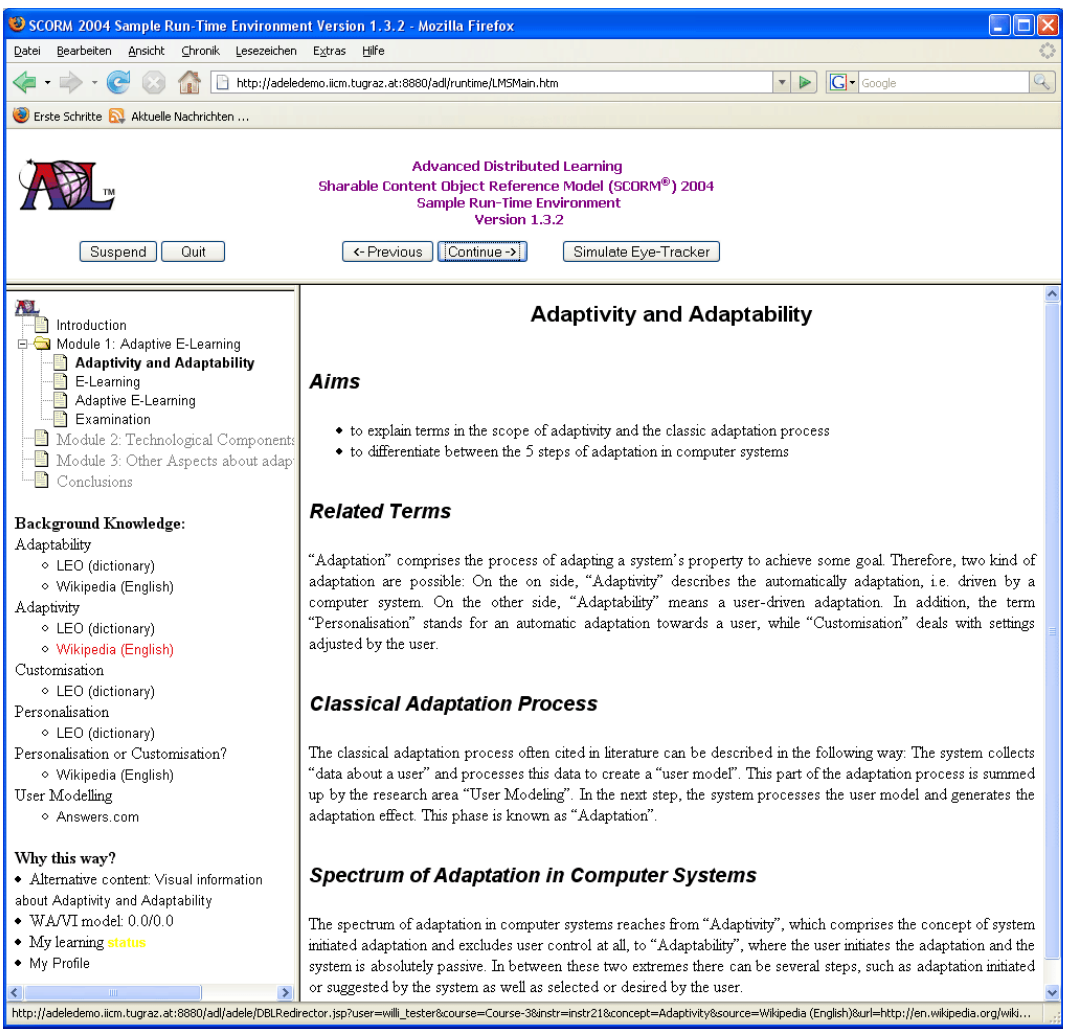

Figure 5: Personalized concept-based hyperlinks

The core AdeLE system has been enlarged by the CsCMS according to the proposed generic architecture depicted in Figure 3. A simplified architecture of the enhanced system is shown in Figure 4. The broad white arrows define the communication flow for delivering personalized concepts which link to topical background information of various knowledge repositories. A user's Web client requests a content page from the LMS. The LMS delegates the request to the AS in order to predict the appropriate tailored learning content by applying user information from the MS. Based on the selected learning content the corresponding learning context, or more precise the corresponding context item, can be determined. In the next step, a request including the user information and context item information is sent from the AS to the CsCMS. Based on that CsCMS selects the proper concepts and instantiates placeholders with actual values also retrieved from the MS to compile the corresponding set of queries. In the next step, the result is received by the AS and compiled with other information such as a navigation tree. Finally, the concepts and hyperlinks for requesting information from various knowledge repositories are rendered by the Web Client, as shown in the upper left browser frame in Figure 5. The user can request such background information in a separate browser window by following the hyperlinks rendered nearby the concepts.

For the sample application we have specified several query templates for the CsCSM for requesting information systems such as Wikipedia, Answers.com, Dict.Leo.org, Google Scholar and Google Picture search. Furthermore, the sample e-learning course was spited into several logical sections and linked to corresponding context items. For each context item a general set of helpful concepts were defined and instantiated with default queries for the pre-defined information systems. Based on the user information provided by the MS the actual set of concepts is selected from the general set of concepts and the queries are also adapted by user information by means of placeholder. As an first approach for tailoring the concepts to users' needs we have defined three knowledge levels (beginners, advanced, expert) and linked them to different groups.

Access to Meeting Information for Knowledge Transfer Purposes in the MISTRAL Project

The MISTRAL research project focuses at storing, processing and automatically annotating of multi-modal data streams in meeting scenarios. The meeting recordings consist of video and audio data as well as click-data streams of presentation interactions in meetings. In addition, relevant documents in digital formats assigned to meetings are also processed and taken into account. In order to gain automated semantic annotations from the multi-modal meeting recordings, four unimodal units process the meeting data: (1) The *Video Processing Unit* extracts information about meeting participants (participant identification and spatial location, gesture and facial expression). (2) The *Audio Processing Unit* processes acoustic-based information about the meeting participants (participant identification and spatial location, voice characteristics). (3) The *Speech-to-Text Processing Unit* annotates textual information from oral talks. (4) The *Text Processing Unit* processes speech-to-text data and meeting-relevant documents in order to provide additional information, such as topic classifications, summaries, concepts, and the like. All the information added from these units is called features. Based on the results of the unimodal units, the *Multi-modal Merging Unit* is applied in order to merge the extracted features of the unimodal units and the Semantic Enrichment Unit adds additional semantic information inferred by means of a knowledge base. The semantic information annotated by the core MISTRAL system is stored together with the meeting recording data in the MISTRAL data repository. Based on that, a meeting recording information retrieval system allows searching for relevant information which can be accessed and streamed by a meeting recording browser. (Gütl & García-Barrios 2005b; Gütl et al. 2006)

Results of an extensive literature survey has shown that there is still a gap in order to integrate meeting recording information in teaching and learning activities (for details see Gütl & García-Barrios 2005b). This motivates us to develop a prototype for vocational learning and training activities providing background information to meeting recording information on a semantic level. The prototype is based on the overall architecture depicted in Figure 3, including the CsCMS, a simple learning management system and the core MISTRAL system as knowledge repository. The right browser window in Figure 6 shows exemplarily one content page of a training course. The embedded background knowledge is rendered as a kind of sidebar at the lower left side of the browser window. A personalized set of concepts and related hyperlink queries enables users to request topical meeting recording information. The left browser window of Figure 6 partly depicts the result representation for the information need 'find speaker segments about the topic *speech recognition*'. The user request was initialized by clicking on the corresponding hyperlink at the background knowledge sidebar.

For the sample application described above, a set of query templates with proper placeholders (for concept replacement, group information and user information) was defined for querying the MISTRAL information system. Furthermore, a context for the training course was created as well as proper context items and linked concepts in accordance to the learning content pages were defined on the generic level and on the group level. For each concept the whole set of query templates was initialized, some of them were overwritten on the group level according to project roles. Based on that, the following information can be searched for each concept: (1) speaker segments, (2) relevant documents assigned to meetings, (3) experts, (4) meetings, the user being present or absent, and (5) projects the user is or is not involved in.

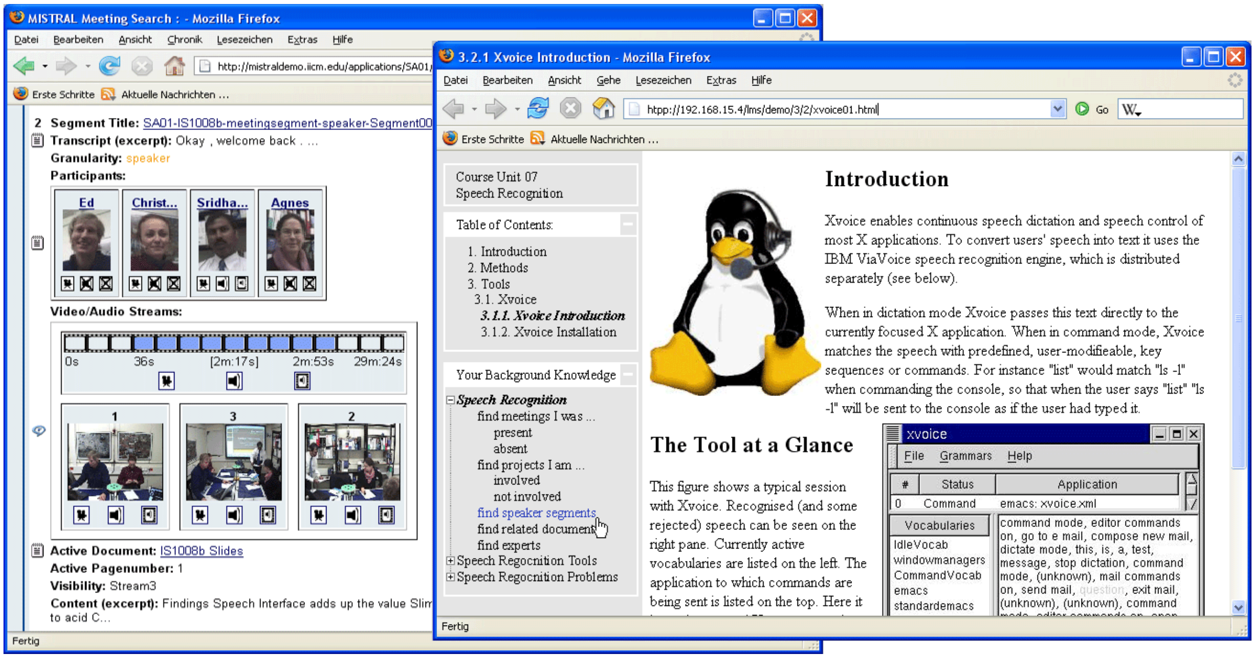

Figure 6: Personalized concept-based hyperlinks to background knowledge embedded in e-learning content (lower left sidebar of right browser window) and meeting recording search results for the predefined query 'find speaker segments about the topic *speech recognition*' (left browser window).

Conclusions and Future Work

In this paper we have shown that current educational objectives of our society requires efficient teaching and learning processes and adopted learning environments. For learning situation (such as in school, university and vocational education) in addition to the learning content additional information can support the learning process. Therefore, we have proposed a system, which allows teachers and trainers to manage background knowledge for the learning process with less effort and enables learners to access effectively relevant additional information. As a result a solution approach and the development of a running prototype was described which enables a context-sensitive and personalized concept-based access to knowledge for learning and training purposes.

Based on the experiences we have gained from the development and setup of the two sample applications described so far, our findings can be summarized as follows: (1) The proposed overall system architecture and communication interface seem to be flexible and applicable in different application scenarios. The architecture allows to integrate easily the CsCMS in existing systems (such as the core AdeLE system) or offer a guidance for the development and setup of new applications (such as the concept-based access to MISTRAL meeting recording information). (2) The service oriented architecture provides a flexible framework for efficient system adaptation and further development. (3) The proposed template mechanism combined with placeholders for specifying actual requests or queries for various information systems and the concept of rewriting such queries on general, group or user level allows to specify topical background information with less effort. However, the definition of a suitable concept structure for an entire course is still time consuming. Therefore, as future work a semi-automatic process will be developed in order to support teachers and trainers to identify concepts from course material. Additionally, we want to further enhance our system in order to provide a mechanism for students to easyly managing and sharing concepts as well as linking them with course content. (4) Adaptation functionalities on group and user level in combination with the concept of query templates allow to define highly customizable concept structure efficiently. However, the effort for specifying the provision of highly tailored information structures based on more than one adaptation criteria tend to increase dramatically. In the light of that we will enhance our template and placeholder mechanism with a rule-based approach in order to define more fine-grained adaptation rules. (5) The access to various background information systems on the abstract concept level can be easily tailored for different application scenarios and diverse needs. First experiences have shown an added value for users. However, in order to gain more experiences user surveys will be carried out for educational purposes on university level and for vocational training.

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