A Concept-based Context Modelling System for the Support of Teaching and Learning Activities

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Abstract: The goal of the Concept-based Context Modelling System (CO2) is to facilitate accurate background information resources, and thus assist users in their teaching or learning activities. The presented solution approach is based on the experiences made at IICM with dynamic background libraries (DBLs). Thus, the CO2 can be seen as an enhanced version of our first solution. Users may define relevant concepts and assign them to specific information spaces. Each concept is linked to a specific search query in order to supply learners with context-relevant background information. A service-oriented architecture allows the CO2 to offer reusable, extensible and flexible components, transforming the underlying idea towards a multi-purpose system, allowing the modelling of arbitrary contexts (information structures) by means of concepts and their linkage to various search and retrieval services. In practice, the CO2 is applied within the AdeLE and the MISTRAL research projects at IICM.

1. Introduction

Past research projects at the Institute for Information Systems and Computer Media (IICM) led to long-term experience within the field of e-learning. This experience indicates e.g. that within the learning process the sole application of a static course repository is not sufficient (see Dietinger et al., 1998). As a result, the first prototype of a dynamic background library (DBL) has been developed (for details refer to García-Barrios et al., 2002).

The target of this development is to facilitate knowledge transfer by providing a dynamic approach to background information resources. In a world of constantly changing and increasing knowledge, this dynamic approach is more advantageous than a static one due to the flexible adaptation to new or changing information. Beside the advantage for learners to be presented always context-relevant and up-to-date knowledge, teachers also profit from the aggregation of topical and accurate information resources to their courseware. Another aspect addressed by a DBL is the occurrence of dead nested links within static courseware. This problem can also be amended through our dynamic approach. The access to background information is enabled by querying one or various search services. Queries are defined by teachers according to the nature of the course or to their didactical goals, i.e. according to a specific context or to a specific didactical intention. Another important aspect is the adaptation towards the user, i.e. to cope with different pre-knowledge levels of learners as well as personal preferences and learning styles, personalization of context and concepts is also desirable.

Evaluations of the issues stated so far showed that additional improvements were necessary to maximize the use for both learners and teachers. Along the lines of the development of an enhanced DBL, the applicability of concepts in teaching and learning has played an important role. Further, evaluation results showed that the use of a DBL system counted with general acceptance among the test subjects. Nevertheless, from the feedback of the evaluated subjects, potential of improvements could be also identified, and this fact was the main motivation to begin working on a new, more flexible solution. (Gütl & García-Barrios, 2005)

In order to establish a common understanding of the terms concept and context, let us firstly refer to (Gütl & García-Barrios, 2005), and secondly state our interpretation within the scope of this paper. Concepts are the elements stored in human brains in order to understand things, i.e. concepts represent thoughts, ideas, senses, notions, believes or entities describing some semantic within a knowledge domain. Further, the practice-oriented view of a domain is said to be a context and is build through concepts and the relationships among them. E.g., considering the scope of e-learning, the didactic-specific arrangement of courseware represents an individual context, which in turn is valid for a specific domain. In general, from the identification of a context as the space in which a set of concepts occur, it becomes obvious that not only e-learning courseware, but any structured information space divisible into concepts can be interpreted as a context. Based on this idea, a Concept-based Context Modelling System (CO2) was developed as an enhanced multi-purpose DBL; more details are given in the next sections.

From the technological viewpoint, in order to solve the drawbacks of the initial version of our DBL, a service-oriented architecture (SOA) was chosen for the CO2. This software architecture - based on the usage of flexible services - increases the reusability and extensibility of software, and consequently, multi-purposefulness.

After a first introduction into the basic applicability of dynamic background libraries (presented from the viewpoint of specific user requirements), this paper offers a detailed description of the CO2 by means of its functionality and architecture. Further, it introduces two examples for its application into research projects at IICM. To conclude the paper, some general conclusions and some remarks on future development are presented.

2. Applicability of Dynamic Background Libraries for E-learning

The first idea of a dynamic background library (DBL) goes back to the GENTLE project at IICM, as described in (Dietinger et al., 1998), and aimed at the enhancement of the learning process through the provision of so-called *dynamic information* in order to supplement the static content of an e-learning course with additional resources from external systems, in this case from the WWW. These resources are called dynamic, because they are not statically referenced directly by hyperlinks within the content but reached dynamically through context-dependent queries for different search services. The first implementation of this idea is described in (García-Barrios et al., 2002) and first evaluation results can be found e.g. in (García-Barrios et al., 2004a).

Our experiences in the field of dynamic background libraries led us to the perception that learners require additional background information on relevant concepts related to the course content. Thus, based on the findings from our implementations and evaluations, this additional background information should be incorporated into the learning process through the use of *concept definitions* (i.e. textual words or phrases, called *DBL items* within our previous implementations). Next, these concepts should be linked with context-dependent queries for different search services, both together describing *dynamic up-to-date background knowledge*. Thus, the access to dynamic background knowledge can be provided by the chain "course content → concept definition → context query → search services". Simple examples for this mechanism as well as for the visualization of DBL items can be found in (García-Barrios et al., 2002 and Mödritscher et al., 2005).

Having given a brief overview over the basic functionality of the DBL, let us explain its applicability within e-learning environments by means of some needs of the main types of system users, learners and teachers. It is important to state at this point, that in the context of this paper and for the purpose of simplicity, no specific distinction is needed and made between teachers and course authors, because the courseware is supposed to be given and the construction of the DBL might follow the didactical goals of authors or teachers. The purpose of the next paragraphs is only to show some requirements, which are fulfilled by our CO2 implementation.

From the point of view of learners, the DBL facilitates the process of knowledge acquisition, as it assists them by their making-up of representations of context-relevant concepts in their minds. The main didactical goal is to enable a *free* exploration of dynamically accessible resources, for which topicality and accuracy is maintained by the search services. Thus, the quality and type of the reached background information depends on the used search service (e.g. a domain-specific database retrieval system, the search functionality for an external learning object repository, a commonly used search engine, and the like). Another possible requirement for learners might be the access to translations. This is mainly interesting in the case of e-learning courses which are not in the learner's native language. Here, translations for the concepts (i.e. DBL items) can be provided by the use of queries for online dictionaries. Moreover, a learner can apply the DBL to search for images depicting the concept (here, image retrieval engines can be applied). To give a last example, consider the use of specific digital libraries in order to provide scientific background material related to some concepts linked to segments of the course content.

From the teachers´ viewpoint, the DBL provides user interfaces for defining the DBL items (in order to build up a set of course-relevant concepts), assigning them to segments of the course content (in order to span the context of the concepts), and linking the concepts to different search services (in order to enable access to purpose-dependent background resources). For the purpose of personalizing the results of the DBL according to the learners´ level of knowledge expertise, different queries can be also defined for the same concept.

As can be concluded from the observations stated so far in this section, the provision of accurate and up-to-date background information is not only defined by its *context-dependent semantics* (given by the assignments of concepts to segments of courseware), but also by its *pragmatic value*, i.e. the intentions behind the need of following a "concept query". The latter statement is the most relevant issue, because on the one hand, a learner should have the freedom of choosing which "search engine" to use, and on the other and, a teacher can restrict the number of visible "concept queries" in order to force learners to visit specific external repositories. The specific functionality of the CO2, which explains these mechanisms, is depicted in the next section.

3. A Concept-Based Context Modelling System

Based on the experiences made form earlier DBL implementations and on the findings from evaluations of these implementations, an enhanced system has been designed at IICM to facilitate the provision of dynamic background knowledge. From the point of view of knowledge transfer (which is not restricted to the field of e-learning), this new system, called *Concept-based Context Modelling System (CO2)*, represents a first implementation step towards a multi-purpose DBL, which should be utilized for various applications areas. From the technological viewpoint, the CO2 is based on a Service Oriented Approach (SOA) in order to ensure as much modularity, flexibility and reusability as possible. This chapter aims at giving an overview over the development steps and functional architecture of the system.

Concept Modelling

The core elements of the CO2 are *concepts*, which in turn are arranged together spanning a conceptual space. This conceptual space can also be interpreted as a knowledge structure for which concepts are used as atomic entities describing the semantic area of a specific domain. For details on *Concept Modelling* refer to e.g. (Gruber, 1993) or (Gütl & García-Barrios, 2005). For the purpose of this paper, the following statements describe our interpretation of concept modelling for its applicability in building arbitrary knowledge structures. A concept defines a semantic entity within a knowledge domain and is represented by a symbol or term, i.e. a concept is mainly represented in a symbolic or textual way. Concepts and their interrelationships among each other are applied (i.e. created and used) by individuals or groups of persons. Thus, different concepts and relationships represent different meanings and perspectives on different domains for different persons or groups. Our CO2 enables the definition of concepts and their linkage to nodes within a knowledge structure, in this case, within the contents of a course.

The 'problem' describing the fact that each knowledge domain has various applications areas, is represented and solved through the use of *contexts* (Gütl & García-Barrios, 2005). Thus, a context can be defined as the interrelated conditions in which something exists or occurs. While domains offer a more global view on concepts, a context offers a specific scenario-based view on a conceptual space. For example, a context may be a workflow, an e-learning course or any information space that can be spanned with concepts; in turn, these concepts within a context may belong to one or more domains. Likewise, a concept from one domain may be applicable in different contexts. Ordering domains and contexts as orthogonal axes, it can be generally stated that a concept may find validity in various domains and contexts. This perspective is depicted in Figure 1.

Further, the CO2 enables the definition of so-called *matching patterns*, which are textual definitions tightly-coupled to concepts. On the one hand, matching patterns are used to identify alternative terms beside the symbolic description of a concept. These alternate terms can be used to identify references to the concept within any text, i.e. in an instruction of a course. On the other hand, they enable the application of synonyms, e.g. in order to implement multilingual support.

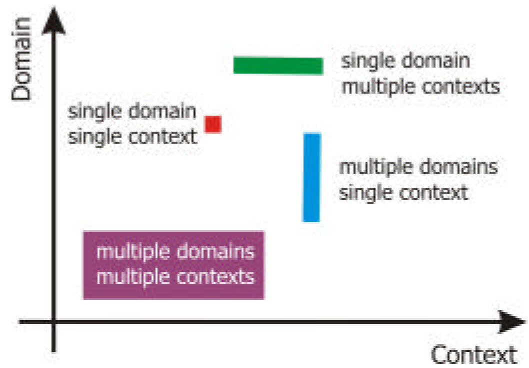

Figure 1: Validity Regions of Concepts within Domains and Contexts

As an enhancement for previous DBL implementations, the CO2 provides the possibility to assign a set of queries from various Information Search and Retrieval (ISR) systems to each concept. These ISR systems are the *sources* for the background information provided by the CO2. Each source is defined by a Uniform Resource Locator (URL). In order to utilize the sources for the individual concepts, a query is defined for each concept and each source. These queries may contain placeholders, for example for context or concept names. Two types of queries can be discerned. *Default queries* resemble the most likely query for a source. One such default query must be defined for each source. *User queries*, in contrast, are queries that have validity only for a single concept.

Beside the concepts, structures of information resources can be modelled by *contexts*. In the latest version of the CO2, such a structure is a sequence of interrelated terms, which we call *context items*. In the example of an e-learning course, context items are the linkages to instructions of a course. Within this scope a context represents the e-learning course per se, but from a general viewpoint, it may also be used to represent a folder structure on a data medium or the document collection of an IR system. In turn, each concept within the CO2 might be associated to one or more context items in order to represent the relevance of a concept in the individual elements of the information resource's structure. In summary, the CO2 can be used for arbitrary context-based information retrieval issues with the goal of assisting explorative tasks through background information resources.

Considering the applicability and user needs described in the preceding chapter, this core functionality can be explained from the user's point of view. A teacher usually starts the process of modelling concepts by defining a set of concept definitions (e.g. single terms or phrases, which span the semantic space of a course) and a specific number of interesting sources, which are available for all concepts. The definition of each of these sources requires at least the URL of the ISR system and a *default query*. Next, queries are assigned to concepts and subsequently adapted to the specific context of the e-learning course. By default, each source is queried with the *default query* for any given concept. These queries might return unsatisfying results in some cases. The teacher will then adjust the query for a concept by defining a *user query* which leads to more "adequate" results. In other cases, querying a given source will not be necessary for a given concept; thus, the teacher can mask the source by adding it to the list of so called *blacklist sources* for the concept (i.e. these sources will not be visible for the learners).

In addition, the teacher must map the structure of the course into a sequence of *context items*. Each of the existing concepts can subsequently be assigned to be valid for one or more context items. This allocation to context items represents the relevancy and semantic value of the concepts regarding the instructions of the course.

From the learner's point of view, the appearance of the individual concepts depends highly on the integration of the CO2's output into the e-learning framework. Independently of the presentation, a list of hyperlinks to suitable sources is provided for each concept. When the learner requires additional information for one of the concepts, the learner selects a suitable source from the list. The type of query applied depends on the individual concept. The *default* query is only used if no *user* query was defined. No difference between *default queries* and *user queries* is discernable for learners, but as "free exploration" is given due to the fact that the learners reach the UI of an external ISR system after following a concept-hyperlink, they might refine their search results according to personal needs.

A Service Oriented Approach

From the technological viewpoint, the main goal of the development of a new version of the DBL was, among others, to provide a flexible application to be used in various application areas. Moreover, it is aimed to provide standardized interfaces and openness for easy extension and integration of external systems. This can be achieved using a *Service-Oriented Architecture (SOA)*.

Services provide standardized interfaces and are independent of the state of other processes. (Bieber & Carpenter, 2001) defines a service as 'a contractually defined behaviour that can be implemented and provided by any component for use by any component, based solely on the contract'. This results in highly reusable and flexible components. The *Openwings Framework*[1] was chosen as the underlying technological basis for the designed CO2 services.

Additional advantages of a service-oriented approach in the Openwings Framework include the mobility and 'deployability' of the services. Service objects and associated code may be delivered over the network and installed into specified platforms or spaces. Protocol- and environment-independence are also provided by the Openwings Framework. Moreover, services can be aggregated to perform new tasks. Finally, due to the fact of being based on the Java language, interoperability is provided.

Architecture of the CO2

Drawing from earlier experiences with an advanced modelling system in a service-oriented approach (Gütl & García-Barrios, 2005a), a strict separation between profiles and models is held. The simplified layer-based architecture of the CO2 is depicted in Figure 2. External systems access the functionality of the CO2 via the *Manager* component. Depending on the kind of requests, these are forwarded to the corresponding components of the system for further processing (i.e. to the *Profiler* or the *Modeller*).

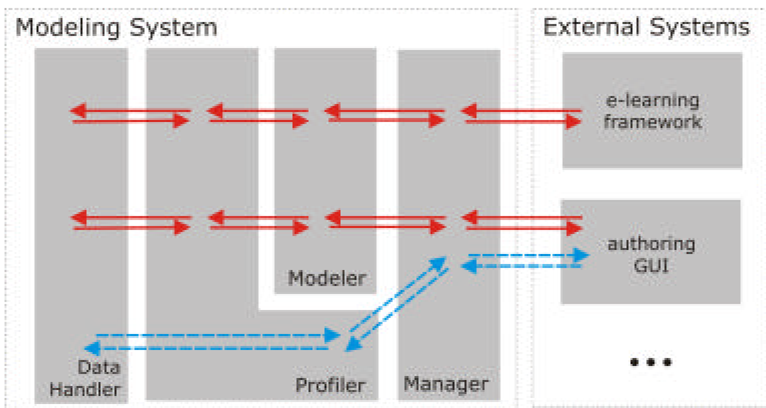

Figure 2: Layer-based Architecture of the CO2

In order to create and maintain *context profiles*, the Profiler component might be accessed form the outside by external systems, like an authoring GUI or an adaptive engine, via the Manager. Context profiles contain the raw information about contexts and concepts. They are maintained by a context author. In the case of the application in an e-learning environment, these authors are mostly the teachers or course authors responsible for a course.

Context models, in contrast, consolidate and expand and the basic information from the profiles by means of assumptions and inferences. These are provided by the Modeller component for further use in external systems. The Modeller accesses the Profiler component in order to fetch the basic information about the context and performs specific processing steps to infer semantically richer information. Regarding the topic of this paper, a Learning Management System (LMS), or its corresponding Adaptive Engine, accesses the Modeller component in order to retrieve either (a) models of whole contexts or (b) individual context items or (c) concepts descriptions, which were previously assigned to the course content, and consequently, might be used to "provide" background information.

Further, the *Datahandler* component is responsible for storage and retrieval of the profiles managed by the Profiler. In the current version, the profiles are stored in XML files. In order to allow easy exchange of profiles and to extend the functionality of the system in future development, a separate structure is maintained for general context information, for the available sources, for the structure of the context items and for the individual concepts.

Each of the components depicted so far in this section is implemented as a single service within the Openwings Framework. This *macro-service approach* was chosen based on our earlier experiences with the service-oriented approach for the implementation of user models within the context of the AdeLE research project (see

[1] http://www.openwings.org

AdeLE, 2005). Due to its service-oriented structure, the CO2 is easily modifiable and extensible. Furthermore, the individual services can be deployed onto different Openwings platforms in order to increase performance. The next section gives a brief introduction to the current practical applications of the CO2 at IICM.

4. Application of the CO2 at IICM

As already stated in the previous section, the design of the CO2 was chosen to provide a flexible system for the application in various areas. One of these areas is the application as a dynamic background library within an e-learning environment. Generally speaking, the CO2 can be applied in any area where a concept-based modelling of knowledge structures or a delivery of context-based background information is desirable.

Regarding the research activities of the Institute for Information Systems and Computer Media (IICM), the CO2 is currently integrated in two projects, *MISTRAL* (*Measurable intelligent and secure semantic extraction and retrieval of multimedia data*) and *AdeLE* (*Adaptive e-Learning with Eye Tracking*). For details on these projects, refer to (Mistral, 2005) and (AdeLE, 2005).

Within the MISTRAL research project, the CO2 is applied in the Semantic Meeting Information Application (SMIA). This application aims to provide different context-dependent views on conceptual spaces as well as to merge them into personalized structures according to the notion of concept connotation and denotation (see Gütl & García-Barrios, 2005). The *contexts* in SMIA are applied to the area of semantic annotated features extracted from multi-modal meeting data streams.

Further, the CO2, as described in the previous sections, is applied as a dynamic background library within the AdeLE research project. The overall AdeLE architecture is shown in Figure 3, where the CO2 is represented by the 'Concept Modeller' module on the bottom left side of the figure. In this adaptive e-learning environment, course creators and teachers use the CO2 to define concepts and resulting contexts (one such a context corresponds to the structure of one e-learning course). Thus, each instruction within a course is represented in one individual context item. Further, teachers and course creators may define arbitrary sources as basis for background research activities within a given context. As stated previously in this paper, a source represents an ISR system. For each source, a default query needs to be defined. These may contain placeholders, such as for a concept definition. For each concept, such a default query may be overwritten (i.e. user queries are defined). Typical sources in an e-learning environment include Web search engines or online dictionaries. Aiming to provide high quality information, ISR systems should be favoured which allow the administration of white lists of sources.

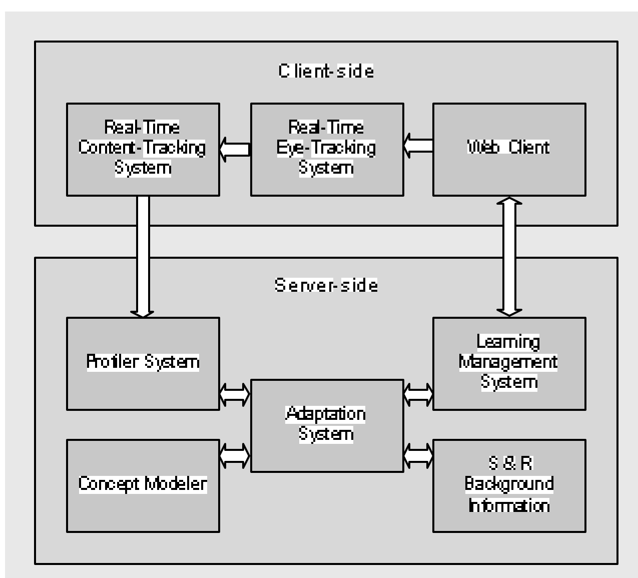

Figure 3: Overview of the AdeLE Framework (Gütl & García-Barrios, 2005a)

For the Adaptation System of AdeLE (see middle module at the bottom of Figure 3), the models for an individual concept or instruction, or the model of the whole course, can be returned by the CO2 as XML (eXtensible Markup Language) structure or as an XHTML (eXtensible Hypertext Markup Language) fragment for further use.

In the case of AdeLE, the XHTML models are mostly retrieved, integrated into the adapted course page and passed to the LMS, where their layout can be rendered via CSS (Cascading Style Sheets) according to the LMS-dependent Web design requirements. To give an example of this mechanism and its result, see "Background Knowledge" on the left frame of the screenshot in Figure 4. In the figure, the additional window has been opened after a learner followed the query labelled "google (images)" for the concept "Clock Tower".

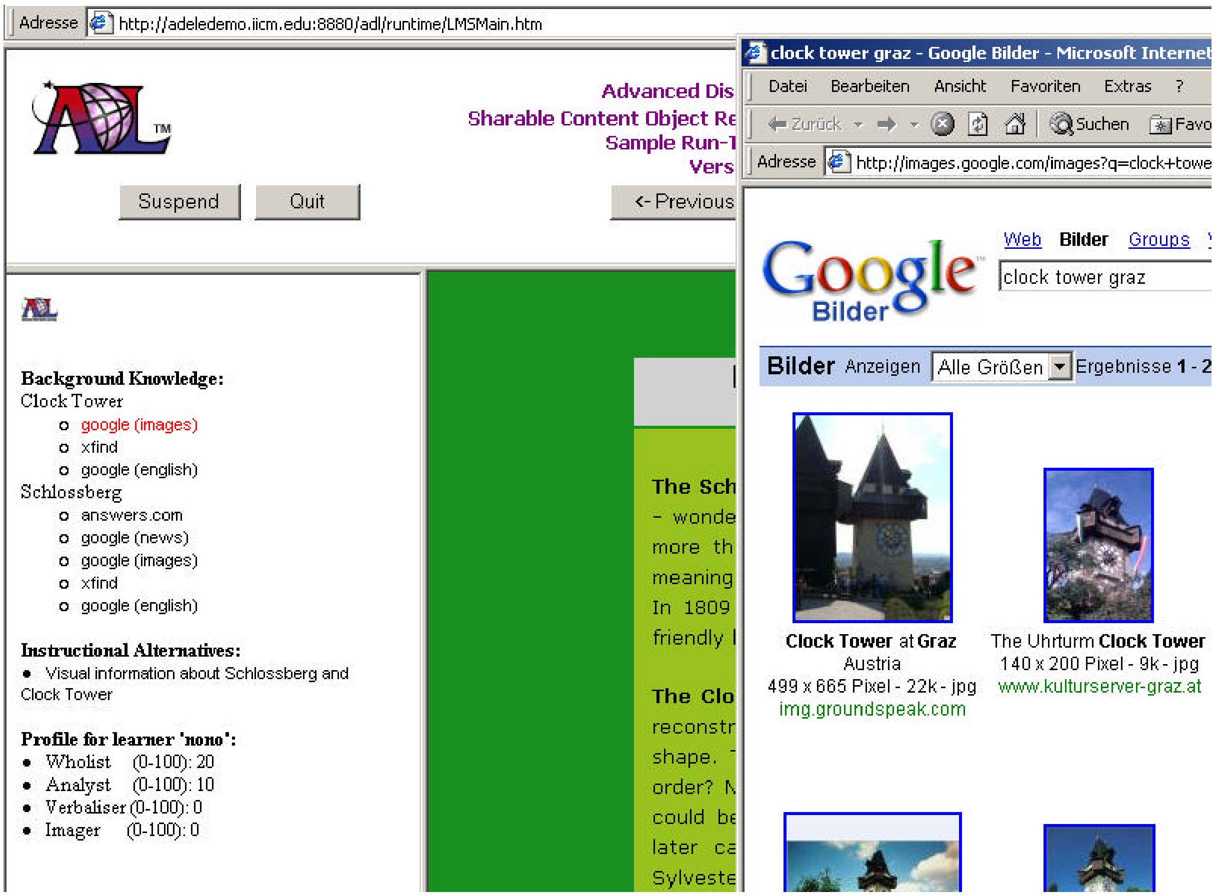

Figure 4: AdeLE e-Learning System: Visualization and Usage of Concepts from the CO2

5. Conclusions and Outlook

This paper presented the development steps and functional issues regarding a Concept-based Context Modelling System (CO2), driven by the desire for an enhanced version of a dynamic background library. The CO2 was designed as a multi-purpose solution for a broad range of application areas. The main goal of the system is to assist users in explorative tasks through dynamically generated, context-dependent, background information spaces.

In the area of e-learning and focusing on the teaching process, targeted information retrieval is offered by providing teachers with the possibility to define *single concept – multiple queries* pairs for various information search and retrieval systems, and thus, the CO2 supports them to reach various context-dependent didactical goals. Following this principle, learners can *pragmatically* choose which type of background information they need to better comprehend a specific concept, e.g. if their intention is to find sample images (via a multimedia search service), translations (via an online dictionary) or definitions (via an online encyclopaedia). The CO2 is applicable for these specific needs, but also for other possible Web-based scenarios, due to the facts that arbitrary information structures can be modelled as contexts and arbitrary background resources can be reached through information search and retrieval systems.

An additional relevant goal of the use of the CO2 is represented by the need of *personalization* of the learning process during explorative tasks. Various interaction functions with a user modelling system are already provided in a primitive way, but future research and implementation activities will bring the inclusion of advanced features in this topic. Other issues for further development of the CO2 include an enhanced ability to represent *complex structure of contexts* (e.g. workflows or graphs). Another focus of our ongoing research efforts in the area of "applicability of concepts in learning and teaching" will be the management of more complex representations for *concepts*, i.e. multi-dimensional concept modelling should be possible. Finally, *evaluations* of the system solutions with a large number of users are taking place and the results will be published in a near future.

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