Towards Open Corpus Adaptive E-learning Systems on the Web

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Abstract. Development of conceptual knowledge is an important part of education. In individualized instruction this aim can be facilitated by concept maps interconnected with learning materials. Traditional adaptive web-based e-learning systems use a closed and static corpus, which is predefined in the design time. But there is plenty of learning resources publicly available on the Web, which provide a huge potential for learners. Obviously, it would be very useful to have an opportunity to choose for a particular context a suitable concept map that could dynamically access selected learning repositories and enable an intuitive navigation in both the concept and document layers, as well as between them. We have attempted to develop a solution that is based on the principles of open corpus adaptive educational hypermedia and at the same time can be part of a personal learning environment. The outcomes show that this may be a promising approach, but its usefulness is highly dependent on the usability and flexibility of the e-learning application.

Keywords: Adaptive E-learning Systems, Open Corpus Adaptive Educational Hypermedia, Concept Map, Ontology, Learning Repository, Reusability, Personal Learning Environment.

1 Introduction

Individualized instruction is a crucial requirement of the modern era and web-based leaning provides many approaches how to address this big challenge. From the pedagogical perspective one of the key learning theories is cognitivism [1], which aims to develop internal cognitive structure that strengthens synapses in the brain. One way how to technically support this approach is by means of interactive concept maps [2], which are graphical tools for organizing knowledge that represent it in graphs, showing the relationships among concepts. Concept mapping has been shown to help in learning, creating new knowledge, writing, and assessment. A concept map enables active acquisition of knowledge and can be also used as a network for navigation, allowing for discovery learning [3], which is a technique of inquiry-based instruction, based on the principles of constructivism. It is also a method of instruction through which students interact with their environment by exploring and manipulating objects.

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Context exploration can be supported by concept based navigation [4], when the learner can easily access a wide spectrum of the relevant concepts. This fosters an inductive way of learning relationships among concepts. Navigation in the semantic space can start from an occurrence of a concept in a learning material. Then the concept map can be accessed, showing correlated concepts as well as materials related to the concept, explaining its meaning. This concept map is an example of opportunities that web instruction provides to enhance learning, because information can be accessed in different ways, choosing always the preferred perspective. Students and teachers appreciate in the web environment what they cannot find in traditional classroom [5]. But going beyond the "no significant difference phenomenon" requires more attention for innovative approaches enabled by online instruction.

The positive outcomes from this approach lead us towards ideas about how to overcome its limitations related to the system closeness and how to generalize it. We see a challenge in exploitation of the huge amount of publicly available resources on the Web and their orchestration towards an open and flexible learning environment providing a new quality of experience. So instead of the traditional adaptive e-learning systems with a closed and static corpus predefined in the design time, the teacher or the learner could have an opportunity to choose an appropriate concept map in the form of an ontology and dynamically interconnect it with selected learning repositories in order to enable a flexible selection of learning resources and navigation on both concept and document layers, as well as between them. This kind of reusability and interoperability is also a main aim of open corpus adaptive educational hypermedia [6]. Here we aimed to integrate this approach with the personal learning environment interface, which is becoming popular.

In the next paragraphs we first introduce a theoretical background for this work. Then our conceptual approach is explained. In the following paragraph we describe the system architecture and its implementation. Afterwards the evaluation outcomes are presented. Finally we conclude the paper, summarizing its main results.

2 Theoretical Background

An adaptive system can react to certain circumstances and adapt accordingly. The process of adaptation is typically based on users' goals and preferences. These and other relevant properties of the user are stored in a user model, which enables the system to tailor its reaction accordingly [7]. In the context of e-learning, adaptive systems are more specialized and focus on the adaptation of learning content and navigation. An adaptive system intervenes at three stages during the process of adaptation – it controls the process of collecting data about the user, the process of building up the user model (user modeling), and during the adaptation process [7]. But traditional adaptive hypermedia systems take into account only a limited set of documents and relations between them that have been chosen at design time, i.e. closed corpus. Therefore a natural challenge is to exploit the huge potential of the available resources on the Web and to enable dynamic updates of the materials considered. An open corpus adaptive hypermedia system has been defined as "an adaptive hypermedia system which operates on an open corpus of documents, e.g., a set of documents that is not known at design time and, moreover, can constantly change and expand" [6]. Such documents can be enriched with annotations and relationships for the learning purposes.

As authoring of adaptive educational applications is quite a demanding task, the Semantic Web has been often leveraged to facilitate this process and to improve the efficiency of authors in this field, taking into account principles of reusability and interoperability [8]. Many solutions have been based on ontologies that integrate various learning standards in their implementation. Ontology can be considered as a network of concepts. Several network-based knowledge representation formalisms have been explored, including Concept Maps [9]. Representation of a domain model as an ontology enables usage of standard representation formats and publicly available inference engines, as well as access to a vast pool of technologies for ontology mapping, queering, learning, etc. The domain ontologies also benefit of such properties as intentionality and explicitness, which allows building unbiased and logically complete domain models.

Semantic annotation uses the Semantic Web technologies for knowledge discovery. In the process of ontology-based text annotation [10] the elements of the ontology are identified in the text and their presence is indicated, showing also the type of the entity. Several recent projects exploit the ontology-based annotation techniques for automatic indexing of textual Web-resources with semantic meta-data. One of them is COHSE (Conceptual Open Hypermedia Service) [11]. COHSE is based on the original idea of distributed link services [12] working as intermediaries between Web clients and Web servers and augmenting Web documents with dynamic links. The COHSE components apply ontology-based annotation technologies to associate automatically the pieces of documents with ontology concepts. Another approach is implemented in Magpie [13], which works on the client side as a browser plug-in. It analyses the content of the HTML document being browsed on-the-fly and automatically annotates it based on a set of categories from an ontology. The resulting semantic markup connects document terms to ontology-based information and navigates the user to the content describing these terms.

3 Conceptual Approach

As we have already explained, our aim is to represent the concepts and their relationships in one layer, the learning materials (documents) in the other, and then to interconnect them semantically in order to offer easy navigation in this open hyperspace for the user. Figure 1 illustrates the conceptual structure of our system. Learning objects are collected from the open corpus and the domain ontology is used to annotate and index these objects. Then user model, domain model (ontology), content model, and adaption model (specifications of adaptation semantics by adaptive rules) are exploited to perform the learning content adaptation. Finally, the adapted results are presented to the user. We aim at developing an adaptive application that applies semantic web technologies to analyze available information from open corpus.

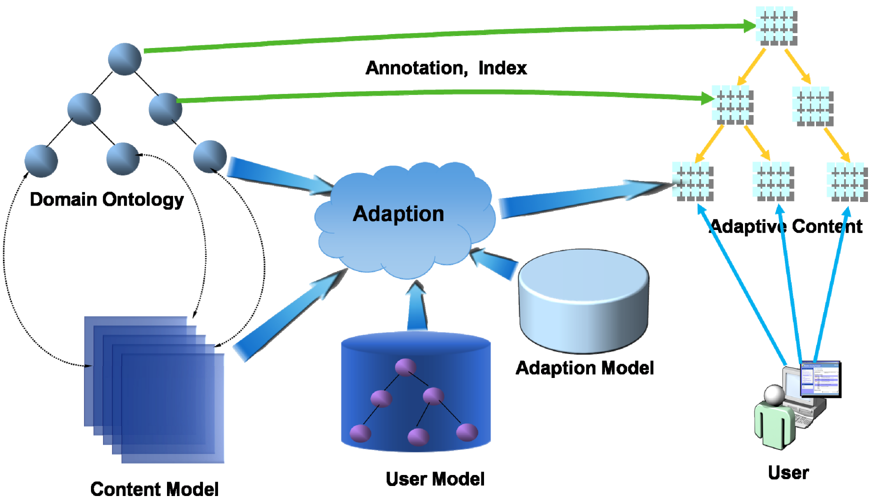

Fig. 1. The Conceptual Structure of System

The functionality of the system includes structuring the concepts network (knowledge space), structuring the hyperdocuments network (hyperspace) and connecting the knowledge space and the hyperspace. In principle, this procedure consists of the following steps [14]: content from open corpus extraction, meta-data generation, adaptive hypertext generation, and result visualization.

Content extraction: It is performed by means of federated search, which is an information retrieval technology that allows the simultaneous search of multiple searchable resources. The system can search multiple databases at once in real time, arrange the results from the various databases into a useful form and then present the results to the user. Federated search has been used to search distributed learning object repositories for e-learning [15].

Meta-data generation: The collected content will be enhanced with additional information through attaching various attributes to documents. Semantic annotation can speed up searching and help users to find relevant and precise information. It enriches the unstructured or semi-structured data with a context that is further linked to the structured knowledge of a domain and enables to find results not explicitly related to the original search.

Adaptive hypertext generation: This process analyses the harvested content and adaptively responds to the learner query. Learners can compose a query by selecting one or more keywords from a set of specific domain concepts. For users' queries, the system first performs concept adaptation using the domain model, the user model, and the adaption model. The result is the selection of concepts and relationships between them. Then content adaptation is performed with the selected concepts. Finally, a complete hypertext is generated for the user query. Figure 2 illustrates the process of adaptive hypertext generation, which includes four steps of concept, content adaption, hypertext generation, and presentation.

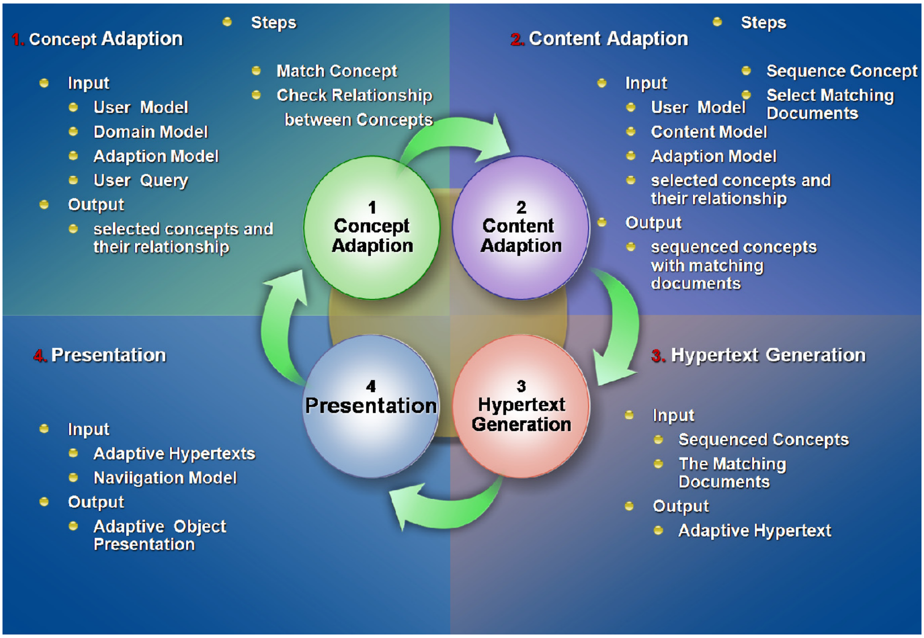

Fig. 2. The process of Adaptive Hypertext Generation

Visualization: This phase includes creation of the navigation part and user interface part. The navigation is based on domain concepts to reflect the relationship among concepts and documents so that learners can be guided in a rich context.

4 System Architecture and Implementation

This system has client-server architecture that consists of three fundamental interconnected layers as shown in Figure 3. The database layer consists of several databases, which store the data on users and collected learning content. The application layer builds up the adaption service logic. It runs on a web server and presents an ontology-based adaptation infrastructure. In this structure, the Data Manager, the User Manager, the Event Manager, and the Context Manager interact with the Adaption Engine, which aggregates their outputs into a single representation. The Session Manager keeps track of users' activities and responds accordingly. The presentation layer runs on the iGoogle gadget platform, which provides the user interface with widgets (small standalone GUI applications) that can be selected and designed by the user into a personal learning environment.

We divided the implementation of adaptation service into three phases: learning content extraction, semantic annotation, and learning object adaption. KIM platform has been used for text analysis and generation of semantic links [10]. We use Apache Tomcat as web server to publish our adaption service. AJAX and RESTful technology are used to realize the communication between client-side and web server-side. User interface and navigation models are implemented in the client layer. According to the navigation models, we use concept map to construct navigation space.

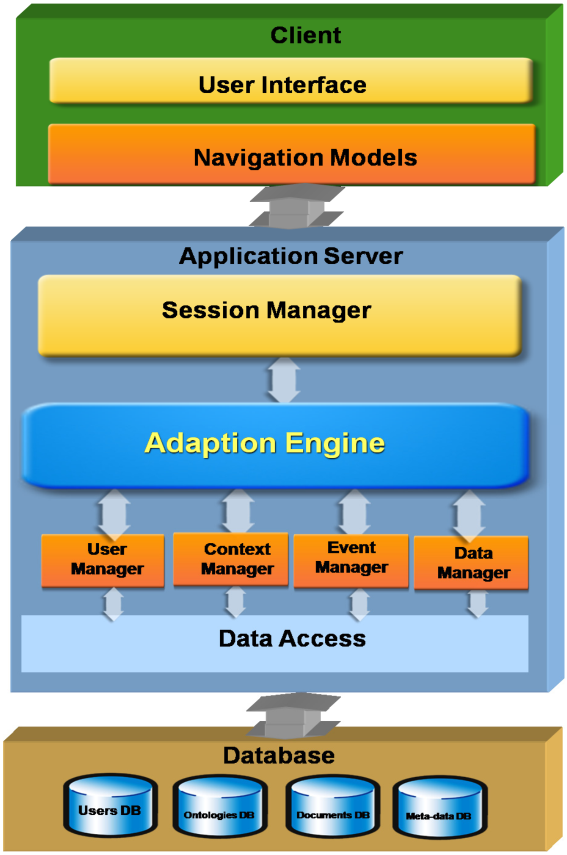

Fig. 3. System Architecture

As already mentioned, we realize the presentation layer in the iGoogle gadgets environment. iGoogle and gadgets can be used as platform to integrate various kinds of services [16]. We can deploy several gadgets in one screen on iGoogle. By setting up own iGoogle interface, the user can use different functionality gadgets collaboratively. It can provide an active learning environment. The user interface includes five widgets:

- User log in and profile data edition
- Keyword search
- Documents list
- Concept map
- Document semantic annotation

The realized gadgets have been published in iGoogle. The keyword search widget, the documents list widget, and the annotated document widget are shown in Figure 4. By query widget, users enter keywords for relevant content. Users can also use concept map to search learning content by choosing directly. The list of adaptive content is shown in second widget. In third widget, users can look through the annotated document, in which the entities are colored differently. The additional information based on domain concept and knowledge space can be seen by mouse over operations.

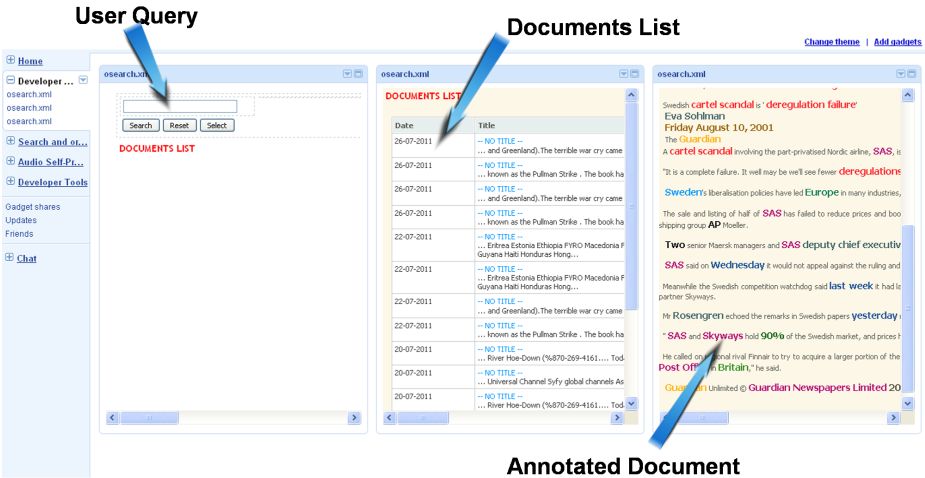

Fig. 4. User Interface Illustration

5 Evaluation

In the evaluation phase, we have surveyed 10 students. The first group consists of 5 experienced users and the second includes 5 non-experienced users. This number is inline with the outcome of usability research [17]: The best results come from testing no more than 5 users and running as many small tests as you can afford.

After a brief introduction of the system, the related knowledge of participants has been surveyed. Afterwards the system usability was tested and participants were asked to perform several tasks, like annotation of documents, searching in the list of relevant documents, or navigation. Most of the users could perform the assigned tasks successfully. Figure 5 shows the result of the usability test. The users could finish most of the tasks in thirty seconds. But several users could not understand the meaning of the ontology-based adaptive navigation correctly.

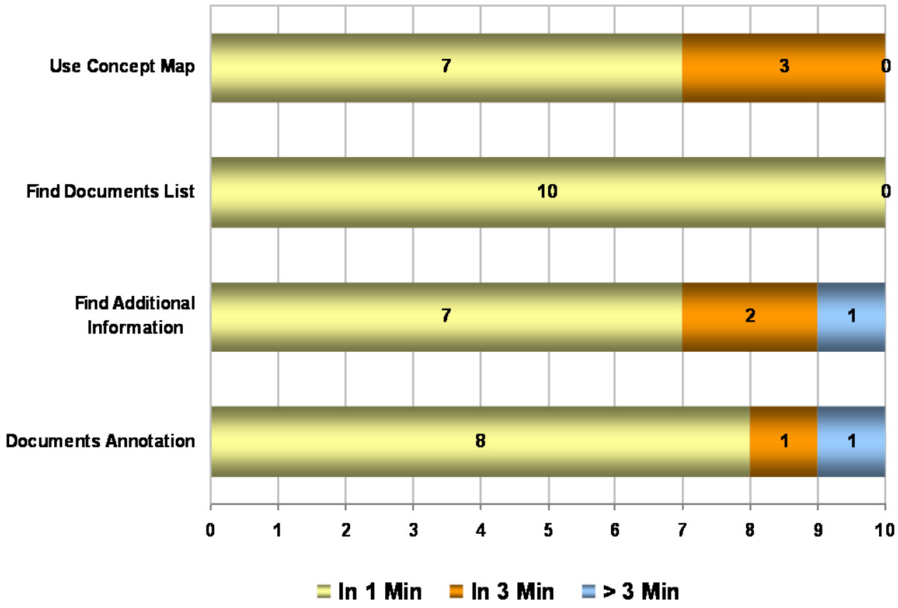

Fig. 5. Results of Usability Tests

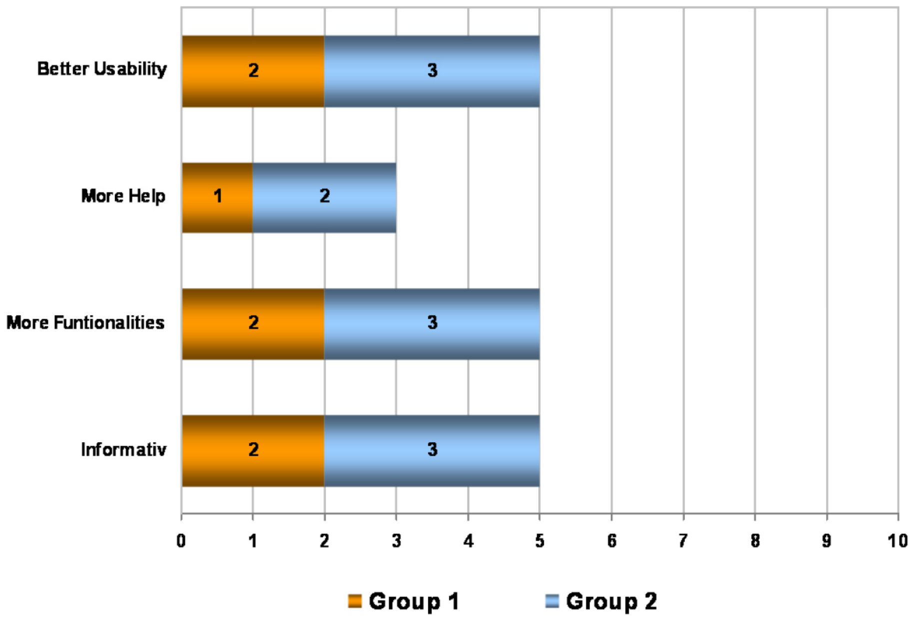

Fig. 6. Further Requirements of Users

When asked to rate the functionalities of the system the users rated the adaptive navigation more positively than the user interface and display style. They also estimated the quality of provided information in average as satisfactory, which is about the average. Regarding knowledge improvement, most students believed that they had extended their knowledge.

The evaluation results have revealed certain benefits and drawbacks of this system. On one side most users were able to perform the required operations successfully, even if some of them were not very experienced in this field. But the ranking of provided information as satisfactory is not very positive and indicates quite some potential for improvements, which was demonstrated also by further requirements of users (Figure 6).

6 Conclusion

The aim of this work was to design and implement an adaptive e-learning application that could exploit open educational resources, including domain ontologies and learning repositories. This idea has been inspired by the principles of interactive concept maps together with open corpus adaptive educational hypermedia. Open corpus adaptation is a challenging problem for modern Web-based systems in order to provide more flexibility for users as well as to improve reusability of available resources and interoperability of existing solutions.

In this experiment we have attempted to design and implement an e-learning system that would enable exploitation of existing domain ontologies as concept models and learning repositories as educational resources. Moreover, in order to enable flexible adaptation of the whole environment, the user interface was implemented in the form of widgets that can compose (a part of) a personal learning environment. The performed evaluation of the system has revealed both positive and negative outcomes, which can be used in the future in similar efforts. Especially the functionality of the system and its usability can be improved.

As interoperability plays an important role also in the area of serious games [18], this approach might inspire new activities also there. On one side serious games represent a special type of adaptive systems, but on the other hand standardization, reusability, and interoperability are rather limited in this area. So a general adoption of open corpus resources is a big challenge for serious games in general. Nevertheless, gamified learning is becoming more and more popular, which implies new opportunities how to stimulate motivation in adaptive educational applications.

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