

Adaptive Web-Based Portal for Effective Learning Programming

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ABSTRACT

In this paper we describe a framework dedicated to evolving methods supporting adaptability in e-learning applications with the use of current Semantic Web technologies. Adaptability based on user's characteristics (personalization) requires mechanisms that can work with meanings and uncover consequences based on the user's (learner's) behavior during studying. Our goal is to design and verify methods and techniques for the presentation of and navigation in knowledge presented for learning purposes utilizing ontologies for content representation. The design is validated in a domain of learning programming with program examples. We describe a web-based portal that enables the creation, personalized search and recommendation of program examples.

Categories and Subject Descriptors

H.3.3 [Information Systems]: Information Search and Retrieval – *Selection Process*; H.5.4 [Information Systems]: Hypertext/Hypermedia – *Navigation*

General Terms

Algorithms, Design, Experimentation.

Keywords

Learning programming, personalized web-based portal, Semantic Web, domain model, user model.

1. INTRODUCTION

At present time, there exist many web-based systems indented for support education. It is a consequence of an evolution of the field and of a related advancement of commercial systems in this area. Consequently, several interesting research directions have emerged in this field what makes it appealing also to the research community. Despite the progress, a “filling up” the content in a way resulting in knowledge being effectively presented to the

user – ideally according to his current needs and comprehension, i.e., with the use of personalization, still remains.

The importance of adaptive behavior of web-based applications intended for learning purposes increases mainly due to the extensiveness of e-learning systems' information spaces. In comparison to other systems that provide content, most of today's educational systems have an advantage in terms of their information space size, which stays relatively small and closed. Nevertheless, attempts for dealing with an open information space appear in the field of education. This means that even though we know the structure of the information space, we automatically gather (unknown) content from various sources (connected by knowledge presented to a learner) from the Web, and thus we cannot speak about closed space any more (see example in [8]). Without further support, a user (learner) can get easily “lost” in the information space. That is not only caused by the extent of the information space in quantitative terms in mind (number of text lines, pictures, etc.), but mainly due to its intellectual comprehension requirements, which often do not directly depend on the quantity of the presented material.

Orientation in study materials has a significant outcome on the effectiveness of the learning process. A possible solution can be based on defining paths in the application domain's model in advance [11, 18]. However, some students prefer his/her own order of lectures (e.g., based on his/her level of knowledge, style of learning, time s/he has available). Improvement can be achieved using methods and techniques of adaptive hypermedia, which provide instruments for dynamic adaptation of the presentation, content or navigation according to the current user's characteristics or according to the environment in which information is provided.

The information space, which is presented to the user (learner) by educational application, is in an adaptive web-based system represented mostly by a concept-based domain model¹. The information space containing study material is usually divided into information fragments. In adaptive web-based systems an information fragment is a web page or its part. Separation of the application domain model from the actual content benefits from a simplified model, because different content variants of concept

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¹ In educational applications a concept represented in the information space is knowledge, so the information space is called also the knowledge space.

(e.g., alternatives for beginners and intermediate users) are represented separately in the information base, and thus it is possible to utilize reasoning independently for the concept selection and independently for the fragment selection process.

The creation and maintenance of the information content is one of the most difficult tasks and therefore building open information spaces for e-learning is a challenge for both teachers and researchers in this field. This is the reason why people seek ways how to use new semantic Web technologies for automated information processing in a large, distributed and heterogeneous space of the Web and also for the adaptive web-based systems for education. That implies questions such as utilization of ontologies for model representation [1], creation of information content in a way that it can be reused in several educational systems [7], effective personalized navigation in open information spaces [17].

Current systems merely support creation of models at different abstraction levels. They are based on their representation and enable filling of particular structures directly or by means of forms. Research in this field is open with a gap in exploration of various models and abstractions of the information space, and also in new approaches to the user interface, which make effective creation and reuse of educational materials possible.

The filling up of the content itself has at least two aspects. One of them is the creation of study materials – content presented to a learner. Although it is a difficult task, it is the easier part since there exist rather many study materials and their creators – teachers – are usually prepared to create new content or alter an existing one that is to be presented to students.

The second and probably more difficult problem is describing the created study materials (i.e., metadata definition) and defining relations among individual knowledge pieces in the information space that are needed for automatic reasoning and adaptation. Defining, categorization and association of terms to particular knowledge materials is a non-trivial task.

In this paper we present a design of an adaptable web-based portal intended for learning programming. Its goal is to utilize methods and algorithms for automatic information processing, and are aimed at more effective access to its content. The portal combines tools, which realize particular tasks related to intelligent search, recommendation and filtering of information. These make use of a metadata layer according to standards defined within the Semantic Web initiative. The goal is to support the creation of information content for e-learning in a way that makes it possible to utilize methods of reasoning and to intelligently recommend or filter information depending on user (learner) preferences. In context of the defined portal we deal with the following fields: methods and techniques of adaptive navigation in an information space aimed at learning programming, and the design of adaptive web-based application models in a way that manipulation with large information spaces of knowledge, including their reuse, can be made more effective (or often even only made possible).

2. WEB PORTAL FOR PERSONALIZED NAVIGATION IN KNOWLEDGE

A challenge in the field of e-learning domain model creation is mainly the support of metadata definition and revealing of relationships among individual information fragments or metadata

themselves that mutually interconnect presented knowledge. Without having relationships defined, automatic personalized recommendation is not possible. Therefore in a well-linked information space, it is possible to make use of well known and well-trying adaptive hypermedia techniques.

We have designed a framework for producing adaptive web-based solutions for the Semantic Web [2]. The basic purpose is to experiment with particular new approaches and at the same time to have the possibility to realistically verify the designed methods and algorithms (by users – university students in our case – during the educational process) as well as their mutual collaboration using cooperating software tools that execute tasks within the educational application. The proposed portal solution offers a flexible, configurable and adaptable user interface. Its purpose is to make the services provided by the software tools, which carry out methods for obtaining study materials, their analysis, clustering, annotating, discovering of relationships and methods for navigation and presentation accessible to the user. The portal itself provides functionality such as management of the knowledge metadata lifecycle (a realization of the *CRUD* – *Create Retrieve Update Delete*² pattern).

One of the significant features of the portal in connection with the *CRUD* pattern realization is its flexibility towards changes in the domain ontology. The solution is based on utilization of naturally existing metadata in the ontology. Those are applied in the automated generation of JavaBeans class forms that are used as the internal data representation of the application layer. A part of the portal is an ontology-object mapper, which enables to transform data stored in JavaBeans class instances into an ontological form and vice-versa. The described approach improves the possibilities of using the portal with other domain ontologies. The dynamic generation of forms and JavaBeans classes moreover contributes to robustness and improves maintenance, since the portal can automatically react to certain types of changes in the ontology.

Architecture of the portal is based on a development framework that realizes the *MVC* – *Model-View-Controller* pattern. We have used a freely available Apache Cocoon framework³, which provides resources for dynamic document generation through defined chaining (*Pipes and Filters* architectural pattern)⁴. The chaining is defined centrally while data in each one is produced by the generator. Afterwards, the chaining is transformed by a series of transformers. Finally, it is provided to the output in the desired format by the serializer.

Fig. 1 contains a view of the portal's architecture, which extends the functionality of the Cocoon framework by additional software components with the aim to enable [2]:

² The *CRUD* pattern organizes the application's persistent operations by creative, retrieval, updating and deleting operations that are implemented in the layer for manipulation with persistent data.

³ The Apache Cocoon Project, <http://cocoon.apache.org>

⁴ There exist several *MVC* based frameworks that can be used; our selection is influenced by results of previous research projects where this framework has been used successfully.

- Adaptability of the information space content's presentation;
- Automatic user modeling based on the recording of his/her behavior together with the used context;
- Reusability and a general design suitable for multiple application domains;
- Domain and user models flexibility (considering changes).

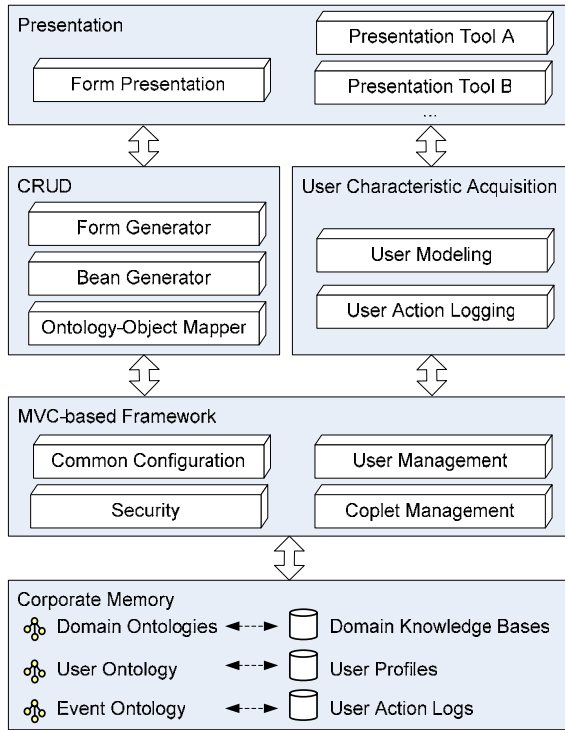


Fig. 1. Architecture of the adaptive portal framework.

The information space of the adaptive portal is represented by ontologies (domain ontology, user ontology and event ontology). User ontology is derived from the domain ontology in which we define domain-specific user characteristics. Event ontology is being used for recording semantics of user's actions taken during his/her work with the system, which enables to record user activity in current context.

An important part of the design is the realization of the CRUD pattern that supports the generation of forms from ontologies, which enables automatic creation of forms for various domains. The realization of the CRUD pattern in the portal comprises mainly the generation of form descriptions for the MVC framework (in our case Cocoon), generation of particular JavaBeans components together with the mapping and persistence support for JavaBeans components based on the ontology-object mapper in the ontology storage.

We are currently using the described framework in two research projects that are oriented at job offer domains⁵ [13] and

publications⁶ [6]. The particular tools that realize automatic user modeling, adaptive presentation and organizing the information space integrated in the portal are designed in a two-layer architecture. Each tool is divided into a domain-independent and a domain-specific layer. The domain-independent layer contains an implementation of an information and knowledge processing method on which the tool is based on. The domain-specific layer is indented to prepare the input for the tools and interpret the output of the particular information domain's tools. Therefore, each tool has a wrapper in the domain-specific layer. The described architecture enables reusability of software tools in multiple application domains.

Another domain in which we experiment with methods for working with large information spaces is the domain for support of learning programming with focus on learning by program examples. The domain ontology is based on the domain model created for learning programming using the AHA! system [3] and the domain model of the ALEA system [5] which is being used for teaching functional and logical programming at the Slovak University of Technology in Bratislava. The domain-specific layer of the tools is connected with various aspects. For the educational domain (also in comparison with the job offer or publication domain), specific needs are required, such as:

- Methods for user modeling consider different extent of the content (study materials vs. information about publication) which has an influence on rules concerning the tracking of time spent on particular information fragments; since we are talking about the process of learning, we apply the proposed method of estimating user's level of knowledge also including the forgetting model which we have verified in the AHA! system [4];
- Methods for analysis use general clustering algorithms to further navigate in clusters. Besides that, they have to consider the specific semantics of information fragments, relations among them that need to be considered, e.g., when mining relationships that is based on content analysis of particular information fragments and mapping content to knowledge ontology;
- Methods for adaptive presentation present multimedia information in contrast to metadata for job offers or publications; in this situation, it is more usable to annotate document segments and use the references directly among individual information fragments;
- In the phase of adaptive behavior specification, it is suitable to utilize knowledge from psychology or teaching didactics;
- It is appropriate to use adaptive features also in the process of knowledge testing, either for tests during learning, or examinations; we have proposed the method of inserting questions directly into study materials while suitability for the insertion of questions is evaluated according to an existing CAT (Computer Adaptive Testing) method that is based on the IRT (Item Response Theory) theory [14].

⁵ Methods and Tools for Acquiring and Presenting Information and Knowledge in the Web, <http://nazou.fiit.stuba.sk>

⁶ Modeling, acquisition, processing and exploiting of knowledge about user activities in the hyperspace of the Internet, <http://mapekus.fiit.stuba.sk>

3. ONTOLOGIC MODEL FOR THE PROGRAMMING LEARNING DOMAIN

Present approaches increasingly prefer representations of web-based application models that support automatic processing of information (in our case metadata on knowledge) aimed at their effective presentation and navigation. This leads to a representation by metadata and by ontology languages such as RDF/OWL [10]. While designing the domain model, we have utilized our previous design, which is being used by the AHA! system [3].

Domain model of adaptive education portal is divided into two interconnected parts: the *knowledge space* and the *concept space* [16]. The knowledge space defines individual knowledge by means of fields and keywords. As the field for learning programming, we have chosen the ACM software classification (www.acm.org/class/1998/D.html). The second part of the domain model consists of concepts that represent metadata regarding study materials. They are linked to particular information fragments representing the presented knowledge (study materials, in our case, e.g., program examples, texts explaining program structures).

The metadata are interconnected by relationships. These play a key role in the process of adaptability definition. In the field of education, it is primarily about the prerequisite relationship among individual knowledge (which is in our model extended by a weight resembling the relevance of the relationship). Prerequisite can be interlinked by the AND or OR logical operators, with the meaning that the learner has to know at least one (OR) or all (AND) knowledge prerequisite. An example of the knowledge space including its interconnection with the concept space is shown in Fig. 2.

Particular concepts define characteristics that are important for the adaptability and recommendation of study materials for study. The proposed concept definition is shown in Fig. 3.

We recognize four types of fragments for the programming learning domain that belong to the *ProgrammingConcept* type: program example definition, aid, note and solution. The categorization is based on representation in ALEA [5]. The fragments are defined in these concept types used for learning programming: example, explanation, program schema and test question.

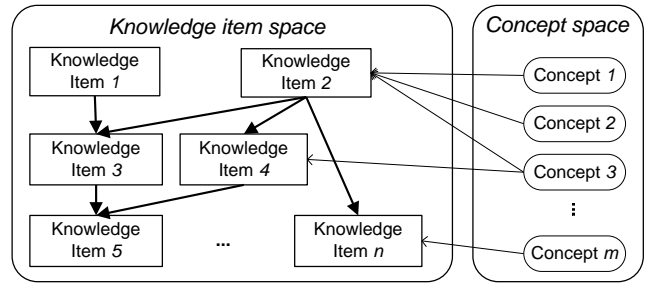


Fig. 2. The domain model.

4. RELATED WORK AND CONCLUSIONS

In this paper, we have described a design of an adaptive web-based portal for experimenting with methods for defining metadata and relationships in a knowledge information space. The methods refer in particular to analysis, organization and adaptive presentation of study materials. Creation of a web-based portal is not a new idea. Today, there are rather many commercial solutions in this field. These solutions have many interesting characteristics, however they are oriented mainly to directly usable standard solutions and features resulting from them, rather than to conceptual innovative solutions (also in connection with approaches utilizing the Semantic Web). A different approach is to use methods based on model-driven development of web-based applications such as HERA, WebML, SHDM/OOHDM or UWE, which distinguish particular application models. However, these solutions do not take into account the integration of several possible independent web-based application aspects that would be integrated just like in portal solutions.

The summary of available solutions would not be complete without mentioning solutions that originate in research projects utilizing the Semantic Web and comprising some characteristics of portal solutions. Projects such as OntoPortal (www.ontoportal.org.uk), AKT (www.aktors.org/akt), SEAL [15] or OntoViews [12] serve as examples. These projects utilize frameworks for the development of tools aimed at work with information using its semantics. They use ontologies for describing domain. Nevertheless, the support of personalization is not based on automatic acquiring of user characteristics or derivation of relationships in the information space, but is using metadata created in advance.

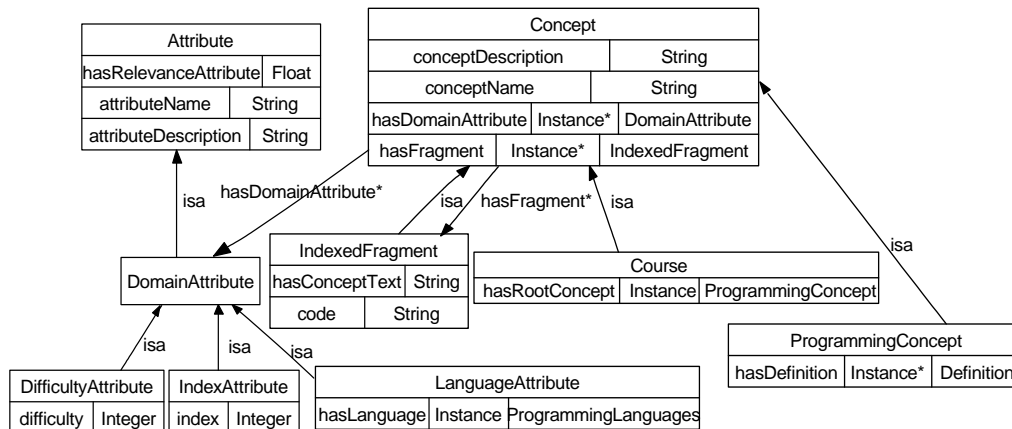


Fig. 3. Concept definition in the domain model.

The proposed solution is not limited to the field of e-learning. The first versions of the portal originated in two previous projects in the domain of job offers (the project NAZOU) and in the domain of publications (the project MAPEKUS). The portal tends to be a solution for a family of web-based information systems. The goal is to develop individual software tools at an appropriate level of generalization in a way that maximizes their reusability part for other similar domain areas.

The domain model that we have described in this paper serves as a suitable base for methods aimed at automatic discovering of relationships among concepts and subsequent deriving (analysis, categorization, annotation) with the goal to recommend suitable study materials. The division of the model into two parts enables to define the process of recommending study materials in two steps: the selection of the knowledge and the selection of the concept along with the corresponding information fragment. The domain-specific part of the user's model, which is inevitable for adaptive behavior, is being derived at the same time. The ontology representation enables not only to derive, but also to transform the models between several applications. Among the open questions to investigate is the interconnection among e-learning standards with initiatives in the field of the Semantic Web.

5. ACKNOWLEDGMENTS

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