Knowledge Representation and Reasoning in Personalized Web-Based e-Learning Applications

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Abstract. Adaptation that is so natural for teaching by humans is a challenging issue for electronic learning tools. Adaptation in classic teaching is based on observations made about students during teaching. Similar idea was employed in user-adapted (personalized) eLearning applications. Knowledge about a user inferred from user interactions with the eLeanrning systems is used to adapt offered learning resources and guide a learner through them. This keynote gives an overview about knowledge and rules taken into account in current adaptive eLearning prototypes when adapting learning instructions. Adaptation is usually based on knowledge about learning resources and users. Rules are used for heuristics to match the learning resources with learners and infer adaptation decisions.

1 Introduction

E-learning applications have been introduced for two reasons:

- to aid learners in the learning process,
- to simplify access to education for people who cannot physically attend classic education

The Internet enabled distance education by providing electronic tools to support the above goals. On the other hand, increasing variability in learning style, culture, knowledge, background of learners has fostered research about methods which addresses these differences in learning.

Traditional teaching is very adaptive. Human teachers adapt to learners when lecturing, tutoring, and guiding learners. They adapt their interaction in more collaborative exercises.

User centered adaptation (or personalization) of electronic learning follows a similar idea. Personalization can be seen as a set of particular decisions about variable information sources fitting the context of learners. In order to allow for making informed decisions, information intensive applications should on one hand collect and maintain knowledge about information resources and context of their usage, and user information on the other hand. Reasoning on the knowledge can then be applied to adapt access, presentation, and navigation in the information resources.

Electronic learning on the web recently is connected usually with self-directed learning by exploring a learning material. The learning material is accessible as other information sources on the web, i.e. information access on the web is realized through the hypertext paradigm. Hypertext interlinks related pieces of information (pages) and allows the user to browse through the information space. The links are provided either explicitly, encoded by authors of the pages, or they are generated automatically, for example based on the results of a query.

Guidance of a learner and support of his orientation in learning, so natural for teaching, can be at least partly realized through a personalized access. Personalized information access in this context is concerned with user-centered bias of the hyperlinks to support better the current user context. Generating links automatically taking user profiles into account is a very attractive option. However, it creates challenges as well. Solutions based on semantic web techniques to realize personalized access on the web seem promising. Key aspects of these solutions are ontologies and reasoning techniques. Ontologies represent shared and agreed upon conceptual models in a domain, which describe the main concepts of the domain and their relationships. Ontologies can thus serve as reference models for generating links in this domain, and represent hypertext, content and user information. Reasoning techniques can then work on metadata based on these ontologies, and generate links based on content, user context and user background.

2 Knowledge Representation

Semantic web technologies allow to link information objects thus moving from document centric idea of current web to more fine grained semantic structures [2]. The information objects may be media items used in learning. The metadata provides facts about the media items forming a knowledge base used for inferring personalization decisions. However, with the object paradigm we can go even further and see the objects on the semantic web as little agents which act on behalf of information providers. In learning domains these may represent for example peer experts on particular topics, tutors able to advice and train on particular skill or environment agents, where one can acquire a skill through an interactive game.

2.1 Learning Resources and Content

Besides generic metadata known in digital libraries, in learning we should be able to determine more learning oriented attributes such as learning goal of a media item, particular activity presented by a media item, intended audience of the media item, etc. Such attributes from the knowledge representation point of view can be seen as binary predicates which bind particular learning media item with a semantic information about it. The predicates can link the media items as resources also to other resources or complex objects. A set of such predicates can be seen as a story about a media item and serve for reasoning about its possible usage. Resource Description Format (RDF) [12] is well suited for predicate/property centric metadata linking objects treated as resources on the web.

Several open specifications or standards have been proposed to represent facts about learning objects: Dublin Core and Dublin Core Terms standards [1] and Learning Object Metadata (LOM) [10] among the most used provide vocabularies for the predicates.

Structural properties like composites or learning prerequisites (background required to understand particular learning resource) are also important in inferences for personalization. The composition of learning units can be for example used to chose appropriate granularity for a learner if he realizes difficulty or is to advanced in the study [5, 9].

If a media item provides learner with knowledge on more than one topic, a semantic network of roles (importance of a knowledge item in a learning material) [6] can be used to determine appropriateness of the learning material for the learning goal posed by a learner.

The roles and types can enhance adaptation possibilities for construction of learning sequences based on user profile, annotating the position of a user in the learning resource structure, helping to identify main outcomes of a learning resource based on roles and level of concept coverage, and so on.

Furthermore, additional sequencing or relations on knowledge items can reflect different pedagogical approaches to guide a learner [9].

2.2 User

User interests, user performance in different courses, user goals and preferences, and other user features are important when searching for appropriate learning resources for particular learner and his context.

Similarly to the knowledge representation for media items, user features are represented as predicates connecting learner with semantic information about him or his classification to particular stereotypes. Open specifications serve with vocabulary for the predicates as well (e.g. IEEE PAPI and IMS LIP with some specific extensions for the ELENA project [7, 8, 3]).

The knowledge background and competencies of a learner are indexed similarly to the learning material; i.e. concepts from domain ontologies are used to classify a learner and his knowledge and skills.

3 Reasoning

Reasoning for personalized eLearning systems is based on matching learning material offers described in metadata with the descriptions of a learner. According to the level of matching, it infers whether particular resources are suitable and how they are suitable. The inferences take place at two levels: queries from a learner and queries placed in web guides for the learner. The idea is that learner first specifies his goal by a query and after selecting particular resource he is guided through the selected learning resource.

Figure 1 describes examples of activities which support the interaction of a learner with an adaptive eLearning system. The user has the possibility to define a learning goal, or the goal is defined implicitly by a lecture as in the Personal Reader [4] system. In the personal learning assistant (PLA) [5], the user needs to define a learning goal by selecting some concepts from an appropriate ontology. The ontology contains competencies, skills, or concepts to be learned.

Query Rewriting. Inferences take place in the phase of query construction. The initial query restrictions are constructed either from user selected concepts or from metadata about a presented resource. The result variables are taken from user preferences about an environment he has been using. After a formal query is constructed from the concepts chosen by a user, additional restrictions are added based on knowledge about a user. This includes usually user preferences but the query can be restricted further by other information from his user profile.

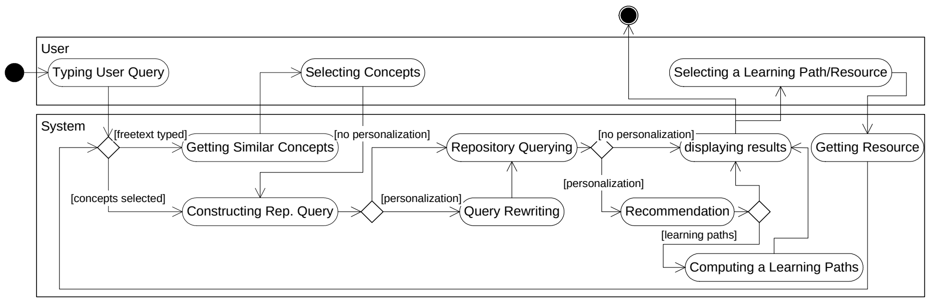

Fig. 1. Activities in adaptive system

Enhancing Query Results. If some knowledge about user was omitted in a query rewriting, it can be considered in inferences on the query results. The inferences are usually based on traversing the ontology graphs and checking whether particular nodes in the graph match to the nodes in the user profile ontology. This for example includes checking prerequisites of resources against learner performance. Language preference partial order can be traversed and used to order returned query results accordingly. Sibling nodes, father nodes, and child nodes of particular nodes in an ontology can be checked against learning performance, portfolios, skills and competencies and generate further levels in learning resources recommended to a user.

The reasoning usually concludes with additional knowledge about learning resources from a personalization point of view. This means for example that a resource is considered as recommended, not recommended or when some prerequisite of a learning resource are missing in user profile they are recommended for particular user as well. The learning resources can be clustered into groups based on their types; e.g. examples, peer experts, additional material, discussion groups, chat messages related to learning goal of a learner or a resource presented.

Annotation and Ranking of Learning Resources. As the ontologies used on a heterogeneous environment can differ from one provider to another and from one user to another, formal reasoning can be employed also for re-annotating resources with ontologies used in a community. This includes different skill ontologies, concept ontologies, and so on. Such annotator was for example used in integration of global context into personal reader [4]. External context was considered for a JAVA tutorial, linking particular resources with related JAVA API page entries. An ontology of JAVA API was learned from JAVA class descriptions, packages, and relations between them[1]. The ontology for JAVA tutorial was used to re-annotate JAVA API pages and JAVA API ontology was used to re-annotate JAVA tutorial pages. This metadata extensions allowed for more precise querying and better fitting the context of the JAVA tutorial pages.

Similarly, an annotator is used in the HCD-Suite online[2] where different competence ontologies are used to index and classify metadata and content (based on term frequency analysis). Such extended annotations are used for ranking purposes. Search results in HCD-Suite are ranked by two different filter types, which are combined to get a weight for each learning resource to rank: *text*, and *categories*. The specified text is searched in all documents and for each document a weight is calculated. The larger the weight, the better the document meets the search criteria. For category filtering, the distances from the specified classifications (e.g. interests) in the ontology to the entries specified in the subject field from each resource are evaluated.

4 Further Challenges

Further challenges have three aspects: pedagogical, technological, and computational. From pedagogical point of view, procedural knowledge in addition to the propositional knowledge about content and user is important especially in learning at workplaces. The procedures which correspond to problem solving and related to a user activity are used to guide users through the problem in according to real workplace settings and workflows. Learners benefit from such an approach because they construct their knowledge in the context of activities they are going to perform. Several information models have been proposed to represent knowledge about learning activities such as IMS Learning Design [11, 14, 13] or IMS Simple Sequencing[3]. However, the connection between learning and work processes has not been studied yet. New EU projects in technology

1 http://www.l3s.de/ dolog/laboratory/ss2004.html

2 HCD-Suite online (http://www.hcm-online.com) is a result of EU/IST ELENA project http://www.elena-project.org

3 http://www.imsglobal.org/simplesequencing/ssv1p0/imsss_bestv1p0.html

enhanced learning, such as Prolix, TenCompetence, and COOPER, are devoted to such issues.

From technological point of view, heterogeneity of information resource is a big challenge. Information integration and approximation approaches are possibly relevant when searching large collections of heterogeneous information sources.

From the computational point of view, performance of the reasoners is a big issue, especially, when considering the large semantically interconnected collections of objects on the web. For practical applications, the performance issues related with reasoning should be researched.

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