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► **To cite this version:**

Mihaela Brut, Florence Sèdes. Ontology-Based Solution for Personalized Recommendations in E-Learning Systems. Methodological Aspects and Evaluation Criterias. 10th IEEE International Conference on Advanced Learning Technologies (ICALT 2010), IEEE, Jul 2010, Sousse, Tunisia. pp.469–471, 10.1109/ICALT.2010.136 . hal-03763192

HAL Id: hal-03763192

<https://hal.science/hal-03763192>

Submitted on 30 Aug 2022

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Ontology-Based Solution for Personalized Recommendations in E-Learning Systems

Methodological Aspects and Evaluation Criterias

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Abstract—The current paper expose a technique for developing a solution of personalized recommendations for e-learning systems adopting an ontology-based modeling of user profiles and document models. Because the solution is situated at the interference of three domains (e-learning, semantic Web and adaptive hypermedia systems), the methodological aspects considered in developing such a solution are discussed with respect to the existing techniques in these domains. As well, some evaluation criteria of such solution are discussed, while considering some existing systems that have similar characteristics to the proposed solution.

Keywords: *adaptive e-learning systems, recommendation techniques, ontology-based modeling*

I. INTRODUCTION

In the context where the number of available resources inside e-learning systems increases steeply, recommending relevant resources is useful since it eliminates or reduces the time for browse and search, and also facilitates users to recognize what resources are interesting for them, since it is often difficult for them to articulate their particular needs [1].

Methods for improving the traditional recommendations techniques are developed, such as combining multiple traditional techniques into a hybrid one, or integrating Semantic Web approaches in these techniques [2]. For being employed into an e-learning system, these techniques should be accommodated with specific standards and structures [3].

The present paper presents the methodological aspects for developing such a solution of personalized recommendations for e-learning systems, with respect to the existing techniques in the three interfered domains: e-learning (EL), semantic Web (SW) and adaptive hypermedia systems (AHS). The user profile (Section II), the document model (Section III), and the recommendation technique (Section IV) are discussed and some previously reported solutions are considered as illustrative examples. Section V presents a comparison of the proposed solution with the existing systems and a discussion regarding an accurate evaluation. The conclusions and research perspectives are presented in the end of the paper.

II. USER PROFILE

AHS adopt a feature-based modeling technique for the user profile, considering some important characteristics of the user as an individual: knowledge, interests, goals,

background, and individual traits [4]. The profile could be represented based on a keywords set, on one or multiple semantic networks (taxonomies, topic maps, or even ontologies) [3], [5].

In the *EL* domain there are two main standards for defining the user profile, where user's competences is the most important characteristic: the *IMS Learner Information Specification* and the *IEEE PAPI (Public And Private Information)*¹.

In the *SW* community, user competences were expressed through models such as *HR-XML* (a standard for exchanging data in the human relations domain), or *ResumeRDF ontology* (defined for expressing curriculum vitae data via RDF constructs)², or through XML/RDF/ OWL versions of the ACM, ODP (*Open Directory Project*), or ECDL (European Computer Driving Licence) taxonomies³. Moreover, some relations between concepts were defined in order to refine the user profile: *prerequisite, is-a, part-of*[4].

The *Recommender systems* develop the user profile based on the user navigation activity, considered in terms of items, pages, (annotated) documents, etc. Data mining technologies are applied to identify the current user activity in an expected sequence of tasks and to provide personalized task-level support [2].

In the discussed context, the user profile should be based on e-learning standards, should express characteristics required by AHS and expressed through an ontology and should integrate the user activity.

In [7] we presented a user profile developed on the top of the IEEE PAPI e-learning standard by extending its Learner Performance category. ACM topic hierarchy was chosen for expressing the user characteristics, grouped on three layers (overlapped on the user's knowledge, interests, and goals individual traits - see Section II):

- *Competences* – expressing the actual, already acquired, competences;
- *Interests* – the desired, foresighted, competencies;
- *Fingerprints* – the currently visited concepts via the annotations associated to the visited documents.

¹ * * *, IEEE P1484.2.25 - Draft Standard for Learning Technology. Public and Private Information (PAPI) for Learners (PAPI Learner) — Learner Performance Information, 2001

² <http://www.hr-xml.org/>, <http://rdfs.org/resume-rdf/>

³ <http://www.acm.org/about/class/>, <http://www.dmoz.org/>, <http://www.ecdl.org/>

The first two layers are developed off-line, through a rule-based technique, while the last layer is developed in real time, through the recommendation technique exposed in Section IV.

III. DOCUMENT MODEL

EL standards such as SCORM, IEEE LOM (Learning Object Metadata) or ADL⁴ are conceived for learning management purposes, and their main objective is to facilitate the reuse of the Learning Objects (LOs).

SW developed vocabularies such as RDF, DCMI, FOAF, DOAP, SIOC, OpenGUID, as well as particular ontologies⁵, used to annotate certain information type, which thus gains a semantic meaning transparent to computers.

In EL systems, ontologies could be used to exclusively annotate materials or in combination with e-learning standards [8]. Various relation types and even roles and/or weights associated to these relations [9] were adopted in order to refine the ontology-based annotations of the LOs. The annotation process is mostly manually or semi-automatically accomplished.

In recommender systems, the documents are treated mostly as items as a whole, or as pages with certain fixed structures, and they are automatically processed in order to develop the document model [10].

Among the current techniques for document annotation according to a domain model, the latent semantic indexing technique [11] could be mentioned, or some knowledge representation models and methods that are typical to artificial intelligence domain (such as neural networks, semantic networks, bayesian networks) [10].

In our context, in order to be conformed to the exigencies of the three domains, a document model should be based on EL and SW standards, expressed through ontological constructs, and automatically developed.

In [12] we presented a document model built on top of the IEEE/LOM e-learning standard by extending its *Classification* category and by defining three relation types between LOs and ontology concepts: *isOnTopic*, *usesTheConcept*, *makesReferenceTo*.

We also developed an automatically annotation technique that split the document in three classes for generating three semantic relations respectively: title and subtitles (headings), hyperlinks and bibliographical references, document body. For each document class, a Latent Semantic Indexing technique is applied and enhanced by a Wordnet-based approach.

IV. RECOMMENDATION TECHNIQUE

Personalized access to the information takes a variety of forms inside adaptive hypermedia systems: personalized search, focused crawling, recommenders. Two main recommendation techniques were developed: content-based recommendations and collaborative filtering. As well, as

already mentioned, the development of hybrid techniques and the integration of semantic Web technologies could enhance the quality of recommendations.

Essentially for any recommendation technique is to analyze the user's *navigational activity* (by using some consecrated data mining algorithms). Some "higher" abstraction level approaches considered the concept-based navigation (where each concept and page is a navigation hub, as in the KBS Hyperbook system), document cluster level navigation [9] or task-oriented navigation [2].

The methodology for integrating ontologies into recommenders involve three steps [13]:

- Data preparation: to analyze documents for generating domain ontology;
- Pattern discovery: to analyze user choices in order to establish semantic usage patterns;
- Recommendations: to match user profile to domain model.

In [14] we proposed a recommendation approach whose novelty consists in supervising the user conceptual navigation through the ontology instead of his/her site navigation: for each visited document, its annotations are considered in order to define user fingerprints through ontology concepts; as well, by adopting a measure of similarity between concepts, the ontology-based domain knowledge is integrated into recommendation algorithm.

The first two steps from the above-mentioned methodology are facilitated: documents are considered as already annotated based on an existing ontology, while the user fingerprints are analyzed in rapport with his existing interests and competences (which play a pattern role).

Concretely, the recommendation technique is a hybrid one that involves two phases [14]:

- Collaborative filtering phase: user conceptual navigation is tracked in order to predict the next concept which will be focused by the user, according to his fingerprints and interests profile;
- Content-based filtering: this concept is used in order to select the documents to be effectively recommended, in concordance with the user competences profile.

For testing purposes, we considered a fragment of the ACM topic hierarchy and we developed a *training set* of fingerprint profiles values considering different user categories (beginner, intermediate, advanced), in different phases of course attendance. As well, we developed a set of documents annotations (according the technique exposed in Section III) and we used it as training set for the second recommender. A collection of 10 documents for each ontology concept was used for testing purposes. The most accurate recommendations were encountered for the advanced users, while the pertinence decreases for the intermediate and beginner users. A possible explanation could be the particularity of advanced users to be more focused on a precise topic in their actions.

V. EVALUATION POSSIBILITIES

Normally, a recommendation technique is evaluated with respect to the similar approaches by comparing the results

⁴ http://www.webbasedtraining.com/primer_standards.aspx

⁵ <http://semanticweb.org/wiki/Ontologies>

obtained over the same data sets. Because a completely similar approach doesn't exist (which to employ a similar modeling and recommendation technique for the case of e-learning systems), nor the corresponding data sets, an evaluation of algorithmic performance is not possible for the proposed recommendation technique.

In our context, the evaluation could consist into a discussion considering some comparable aspects such as:

- Specific type of AHS that adopted a domain ontology for developing the user and document models, regardless it concerns or not the EL domain;
- Considered user traits;
- Ontology adopted for document modeling;
- Algorithmic solution employed for developing adaptive support;
- Data set used for test.

In order to limit this comparison, we selected some AHS systems that employ similar user traits as RecOnto (the recommendation technique described above): competences (C), interests (I) or fingerprints (F). Table 1 presents a synthesis of this comparison.

TABLE I. COMPARING REC-ONTO TO EXISTING SYSTEMS

System	User profile	Docum. model	Adap-tation support	Algo-rithmic solution	Data set
KBS [9]	C+I	concept network	learning path	Bayes networks	Own developed
Bibster [15]	I	ACM taxonomy	query-based retrieval	Similarity between concepts	Community dev.
Course Agent [13]	I	Taxonomy of job profiles	Course recommender	Case-based algorithm	Community dev.
Foxtrot [16]	F	ACM	Hybrid recommender	IBK + Ada-Boost	Own dev.
Persona [17]	F	ODP	query-based retrieval	tree coloring method	Own dev.
RecOnto	C+I+ F	ontology + roles	Hybrid Recommender	kNN + kNN	Own dev.

VI. CONCLUSION AND FURTHER WORK

The paper presented some general methodological aspects to which are constrained the AHS systems that adopt ontology-based modeling in the context of EL domain. A concrete solution was also presented, which respects these aspects. However, these aspects are appropriated into a variety of ways by other AHS systems, and thus it is impossible to establish some precise evaluation criteria. Moreover, the results obtained by each particular system are often dependent of the user types (beginner, normal, expert) employed for testing purposes. Thus, a coherent evaluation for an AHS adopting ontology-based modeling and conceived for a particular domain such as EL should be focused on a particular adaptive functionality (such as recommendations) and should test various algorithmic recommendation solutions, as well as possibilities of

integrating them with ontology-based domain knowledge, while benefitting by a stable set of user activity profiles. That is what we intend to do further with the RecOnto recommendation technique, and we hope to find in meantime some public datasets available, provided by the existing systems.

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