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Ensuring Semantic Annotation and Retrieval within Pervasive E-Learning Systems

Mihaela Brut¹, Dana Kukhun², Florence Sedes²

Abstract—In the age of mobility, many times a certain teacher, a student or a document face difficulties to be integrated in different e-learning systems. Focusing on the Computer Science field, we present a service-oriented solution for annotating and retrieving the documents and persons involved in this domain, enhancing their mobility inside pervasive e-learning systems. The solution is based on the ACM classification system, which is used in order to develop user competence profiles, to annotate materials, and to retrieve them. The ontology-based retrieval mechanism will investigate not only the matches with the concepts involved in a query, but also with their related concepts inside the ACM classification system; the ranking algorithm will consider the documents content as well as the user competence.

Index Terms— ontology based retrieval, semantic annotations, Information retrieval, Information systems, Learning systems, Educational technology

I. INTRODUCTION

IN the age of mobility of devices and people, many times a certain teacher, a student or a document face difficulties to be integrated within various e-learning systems. A good integration could be achieved if they are accompanied – via Web services - by a semantic information which describes their competences, respectively their content. A measure for this integration could be considered the effectiveness of the retrieval demands which intend to locate them.

In order to attain easy and suitable retrieval, e-learning materials should be continuously supervised and indexed because the relevance of a certain query not only depends on their content, but also on many other factors:

- The annotations made by the author, and the authors' competences;
- The annotations made by different users, and their competences;
- The life cycle of each material: when was the latest update; the accessing numbers and intervals, as well as the competence of the users who access it.

As could be seen, a good retrieval mechanism consider three main aspects: documents content, users competences, and the time. Considering these aspects, we will present a service oriented solution for developing the user competences

profile, for annotating the materials, and – finally – for retrieving them according to their annotations and their users competences.

In the next chapter we will present the current approaches in ontology-based competence management techniques and ontology-based retrieval mechanisms, discussing also various solutions for the ranking algorithm.

Our solution consider the particular case of the Computer Science field and the taxonomy provided by the ACM classification system, which is the reference taxonomy for the computer science domain, being frequently used in selecting keywords to be associated with the scientific papers, or with various publications. Our idea is to use it in order to express the competences areas for a certain person in computer science. Each concept in the ACM taxonomy could constitute the name of a possible competence, with a certain competence level (with values from 0 to 5 [6]). For organizing the user profile, we chose the HR-XML standard destined for exchanging data in the human resource domain, as could be saw into the chapter 3.

Also, we will use the ACM classification system for annotate the e-learning materials: a material could be related with many ACM concepts, each relation type having a certain degree of relevance, as we will present into the chapter 4. Inside the retrieval mechanism, the queries will be provided also as ACM concept sets, and the ranking algorithm will evaluate the retrieved documents according to their content and the users competence. The retrieval mechanism will be described into the chapter 5.

The above mentioned functionalities will be integrated – as services - into a pervasive architecture that we will present in the chapter 6: the competence management service and the annotation service will provide information to the retrieval service in order to find and evaluate the results according the ranking mechanism.

Finally, we will present our conclusions and further work directions.

II. RELATED WORK

A. Ontology-Oriented Competence Management Solutions

The idea of managing competencies through one or more ontologies was explored as one type of ontology-driven applications, using ontology for indexing purposes.

The CommOn framework allows one to build shareable

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ontologies and knowledge bases represented with Semantic Web Languages and to develop Competency-Based Web Services dedicated to Human Resource Management [28]. It makes reference to the activity of the HR-XML Consortium, but uses self-defined competence schemes, organized as an ontology. Inside this framework, there was developed the project COMMONCV which provide the above mentioned rich network of competencies to be used for CV development and search.

[1] proposes the knowledge space theory as a way of structuring an ontology that allows making inferences in skills identification.

[27] presents a system that matches the present skill profiles to requested skill profile for projects or available job, using a domain ontology for the IT related competences. We choose the ACM taxonomy because this is imposed as the reference classification system for computer science domain.

In [30], there is presented “GMS” – an ontology based competency management system for managing group competencies.

[14] present “MaSel” - an XML-based competency management system. In [12] there is described a prototype ontology based system for competences management which is intended to be integrated with e-learning and other human resource functions, such as succession and career planning, training needs analysis and organizational planning;

Due to their description logics formalism [5], [26] considers that the ontologies provide a rich set of modeling capabilities for expressing competency schemas.

[22] proposes an ontology for evaluating skill-based human performance. [25] enumerate the requirements that an ontology used for competence management should fulfill.

In [11] there is presented an information system for storing, evaluating and reasoning about competencies of students at universities, based on a fine-grained representation of skills and a competence ontology. The representation of profiles is based also on HR-XML in order to enable an exchange of data, but the ontology is much more vast then the computer-science centered ACM.

An approach which make use of the ACM classification system in order to manage the scientific talks and to notify the interested users according their personal profile is provided by [17]. Here it is defined an agent system in charge with the classification and user notifications.

We did not find any approach that uses ACM classification system as an ontology for managing the competences in the computer science domain, with the support of HR-XML existing framework, which is accepted as a standard for competences modeling.

B. Ontology-Oriented Retrieval Mechanisms

The ontology capability of enhancing the data semantics for computer applications lead them also to a frequent use in annotations and a more precise information retrieval.

In [23] is proposed a method of searching a document collection via queries which are constituted by ontology concepts, but the ranking algorithm does not consider in fact

the relations between ontology concepts.

[29] describe a system with ontology-based annotation and retrieval capabilities for managing the audiovisual information. After the multimedia segmentation process, the annotations are made by specialists, by making reference to some previously selected ontologies, and stored in the semantic base. The search mechanism, implemented as a API, provide support for semantic queries, based on the some provided search templates.

[15] describes Bibster, a Semantics-Based Bibliographic Peer-to-Peer System, which uses ACM ontology together with SWRC ontology in order to describe properties of the scientific publications. The retrieval mechanism make also use of a learning ontology, developed on the fly, in order to reflect the actual content of the individual users.

ACM ontology was also used, together with SWEBOK (Guide to the Software Engineering Body of Knowledge) ontology in order to refine the the e-learning materials annotation [9].

[19] develop an ontology for reformulating and storing the user queries in a semantic enriched form; in order to approximate the meaning of users’ queries each query term is mapped to a Word-Net sense. The retrieval mechanism compute the similarity of documents and the already constructed query ontology, by using the AUTOMS5 proposed method, which combine lexical, semantic, and structural matching methods.

In the system proposed by [16] for annotating the images in order to be easily retrieved, the WordNet ontology is used, for being avoided the ambiguous annotations, as well as for automated extension of image annotations e.g. by synonyms.

[18] presents METIS is a highly expressive and flexible model for media description and classification, that enable user to define customizable media types, metadata attributes, and associations. Media types may be arranged in specialization relationships in order to be able to model taxonomies.

The authors provide as case study the implementation of an archive system for research papers and talks in the Computer Science domain, classified according the ACM classification system. The semantic annotations are made by the users through a Web annotation interface. Scientific materials are thus available for browsing, classification, and annotation through the standard METIS Web administration interface. The retrieval mechanism is in the proposal phase, taking into discussion a possible implementation of the R-Tree algorithm. METIS could be an implementation framework for our proposal.

The existing retrieval mechanisms try to implement an efficient ranking algorithm for the results provided for a certain query. Many ranking methods were introduced, based on clever term-based scoring, link analysis, evaluation of user traces etc. [21].

The term-based scoring is the most common ranking method adopted by the information retrieval systems, based on comparing the words (terms) contained in the document and in the query. The ontology-based retrieval systems adapt this

method to a concept-based scoring, but there isn't yet an imposed method to this respect.

In the traditional term-base scoring, there is computed the weight of each term that appears in the query, through a statistical analysis. In the case of ontology-based annotation and retrieval mechanism, instead the documents there will be considered their semantic annotations, and the queries will be composed of ontology concepts. To evaluate the relevance of a document for a certain query, there is computed a retrieval status value (rsv). This is equal usually with the weights average, when the query terms are composed through the AND operator, as we consider in our system.

Alongside with average, other possible operators for weights aggregation that are found in the literature are similarity-based evaluation, p-norms, fuzzy logic conjunctive or disjunctive operations [7]. After each document rsv is computed, then documents are ranked on the basis of their rsv.

III. COMPETENCE PROFILE DEVELOPMENT

We will use the ACM ontology in order to express the computer science competences areas for a certain teacher of student. Each concept in the ACM taxonomy could constitute the name of a possible competence, with a certain competence level (whith values from 0 to 5 [6]). This approach is in fact an overlay model for structurally representing the user knowledge in the specified domain: it represents the individual user's knowledge as a subset of the *domain model*, together with an estimation of the user's knowledge level of this fragment [10].

The HR-XML Consortium (<http://www.hr-xml.org>) is a non-profit group developing standard vocabularies and XML schemas for the human resource domain. HR-XML became an international standard for exchanging data in the HR domain, being used as a template for storing profiles, job roles and skills. The description of skills support the reference to the taxonomies, because one competency might be decomposed into several component competencies. We consider this model suitable for e-learning environment because its user are already or are preparing to be part also into the job market and into the social Web communities.

The competency model of the HR-XML consortium [4] assumes that a competency has a name, a description, and a number of explanatory sub-elements: *CompetencyId*, *TaxonomyId* (identifier for the referenced taxonomy), *CompetencyEvidence* (the information which substantiate the existence, sufficiency, or level of the Competency), *CompetencyWeight* (information on the relative importance of the Competency or the sufficiency required), *Competency* (the eventual sub-competencies), *UserArea* (allows the references to the trading-partner extensions).

The mention of the *competency level* is made inside the *CompetencyEvidence* element, through the *<NumericValue>* or *<StringValue>* sub-element. It is remarkably that this model enable to keep track of the level of a certain competence, because each associated *CompetencyEvidence* sub-element mention this level, gained as a result of a specific event (mentioned through the *name* attribute, which could

refer to test results, reports, performance appraisals, evaluations, certificates, licenses etc.), at a certain date (specified through *dateOfIncident* attribute). We adopt the following convension: the default range for *<NumericValue>* element is 0..5 (in order to follow the convention from [6]); for using another range, there must be specified the *minValue* and *maxValue* attributes (for could being automatically obtained the conversion to the previous range).

For example, "Synchronous interaction" is a concept inside the H.5.3 ACM taxonomy branch ("Group and Organization Interfaces"). The HR-XML description for the "Synchronous interaction" will be integrated (as a child) inside the "Group and Organization Interfaces" competence description. For each competence, many evidences will be presented, as they are gradually included into the CV:

```
<?xml version="1.0" encoding="UTF-8"?>
<Competency xmlns="http://ns.hr-xml.org" xmlns:xsi=
http://www.w3.org/2001/XMLSchema-instance
xsi:schemaLocation="http://ns.hr-xml.org Competencies.xsd"
name="Group and Organization Interfaces"
description="Models the experience in Group and
Organization Interfaces">
  <CompetencyId id="ACM.H.5.3"/>
  <TaxonomyId id="ACM98" idOwner="ACM"
description="Association for Computing Machinery"/>
  <CompetencyEvidence dateOfIncident="2007-09-28"
name="YearsExperience" typeDescription="Years
of Experience" typeId="Experience">
    <EvidenceId id="7" idOwner="userID"/>
    <NumericValue description="Score for the number of
the years experience in developing Web
interfaces">2</NumericValue>
  </CompetencyEvidence>
  <CompetencyEvidence dateOfIncident = "2007-09-28"
name = "HCI Exam" typeDescription =
"Score obtained at the HCI exam">
    <EvidenceId id="8" idOwner="userID"/>
    <NumericValue description="Score obtained at the
HCI exam">4</NumericValue>
  </CompetencyEvidence>
  <Competency name = "Synchronous Interaction"
description = "Models the experience in
Synchronous Interaction">
    <CompetencyEvidence dateOfIncident="2007-05-22"
name="Project release" Description="Semester
Project in Web Technologies" typeId="Project">
      <EvidenceId description="Project
presentation" id="9" idOwner="TW"/>
      <NumericValue description="the score
obtained for the project" max="100"
min="0">75</NumericValue>
    </CompetencyEvidence>
  </Competency>
</Competency>
```

The Web service in charge with the Computer Science competence profile management will be activated – as we already suggested – when the user edit his CV, because

usually a user keeps track of his own competences through his CV. For ontology alignment and compatibility purposes, we will structure the user CV according to ResumeRDF ontology, specially developed to express information contained in a personal Resume or Curriculum Vitae (CV) to be available for the Semantic Web applications. This includes information about work and academic experience. Regarding the user competences, the ontology includes two classes: LanguageSkill and Skill. The last one could be extended in order to make reference to the above described HR-XML constructs.

IV. ANNOTATION SERVICE

The second proposed service will facilitate the ontology-based annotation of course materials, by their authors or by other users. The service could be used especially inside the e-learning platform supporting the IEEE/LOM standard, because this provide support for semantic extension [2], as could be considered the developed annotations. The integration of a new material into an e-learning platform involves the specification of the material relations with the existing ones. Usually, there is used the Dublin Core / LOM relations set between LOs: isPartOf/hasPart, isVersionOf/hasVersion, isFormatOf /hasFormat, isReferencedBy/References, isBasedOn/isBasisFor, isRequiredBy/Requires. The semantics of these relations is refined or modified in [13], and also some new relations are introduced for the purpose of relating various LOs in a more semantic manner: isNarrowerThan/isBroaderThan, isAlternativeTo, Illustrates/isIllustratedBy, isLessSpecificThan/isMoreSpecificThan.

Our purpose is to relate the LOs with the ACM ontology, and subsequently to find relations between LOs through this ontology. Thus, in order express the rapport between the educational materials and different ontology concepts during the annotation activity we will consider the following relations, in the decreasing importance order:

- isOnTopic – for a material which is especially destined to a certain topic
- hasAsEssentialConcept – for expressing the general keywords associated with a material
- usesTheConcept – for expressing the ordinary concepts encountered into material
- makesReferenceTo – for marking the referenced concepts from other ACM structure branch.

At the beginning of the material editing process, the annotation service captures the following metadata: the author name, the material title, abstract, the creation date, using for these the most suitable format [8]:

```
<?xml version="1.0" encoding="UTF-8"?>
<rdf:RDF
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:dc="http://purl.org/dc/elements/1.1/"
xml:base="http://www.our-platform.edu/materials">
<rdf:Description rdf:about="mdb01.html">
<dc:Creator>#JSmith</dc:Creator>
```

```
<dc:Title>Multimedia Databases</dc:Title>
<dc>Date>21/09/2007</dc>Date>
<dc:format>text/html</dc:format>
<dc:Type>Course material</dc:Type>
</rdf:Description>
</rdf:RDF>
```

The author is then asked to select a major topic and some key-concepts from the ACM ontology, in order to be assigned to isOnTopic and hasAsEssentialConcept relations of the material with the ontology.

Afterthat, during the on-line editing process, the annotation agent notify the user about the possible matches between the different material words and certain ontology concepts, asking him if there really exist one of the other two mentioned relations between them: useTheConcept or makesReferenceTo. Thus, a certain material is related to many ontology concepts, with four relation types of different importance degree.

In case an existing material is accessed by a certain user, the service capture and include in the material metadata the user identifier, the beginning and the end of the accessing period:

```
<accessed>
<user>#MFord</user>
<dc>Date>23/0/2007</dc>Date>
<startTime>14:00</startTime>
<endTime>15:12</endTime>
</accessed>
```

Of course, the user could make some new annotations, and all these will be included into the created <accessed> element. For example, he could add some new “hasAsEssentialConcept”, “useTheConcept” or “makesReferenceTo” relations. If the user is even the material author, then an <updated> element is created instead the <accessed> element.

V. RETRIEVAL MECHANISM

The retrieval information Web service will receive queries in the form of ACM ontology concepts (possible selected through a graphical Web interface), and will provide the results according to the relevance of the annotations associated with the materials, and according to the competence of the annotations authors into the query topics.

More precisely, the Web service will run the user query over the existing meta information database (developed with the support of the Annotation Web service). For each retrieved document, the score will be calculated, as we mentioned in section 2, as average of the scores obtained by each query’s concept, according to its occurrence among document associated metadata and to the annotation author competence into the topic expressed by the concept.

Because the ACM ontology has 4 levels, we will consider a *level coefficient LC*, with the following values (which have the sum equal 1):

- 0.4 the coefficient for a concept associated with the document which is also one of the query concepts;

- 0.3 the coefficient for a concept situated at one level distance (the concept associated with the retrieved document is parent or child of a query concept);
- 0.2 – the coefficient for 2 levels distance, and
- 0.1 – the coefficient for 3 levels distance;

Also, because the relevance of a concept is provided by its relation with the document, we will consider a Relation Coefficient RC, with the following start values:

- 1 if the concept is referred by *isOnTopic* relation;
- 0.5 if the concept is referred by *hasAsEssentialConcept* relation;
- 0.25 – for *usesTheConcept*;
- 0.12 – for *makesReferenceTo*.

The above listed values are multiplied with the CC - competence coefficient assigned to the author of the metadata which specify this relations, and with the TS - time stamp coefficient (the recent metadata are more valuable then the older ones). The time stamp coefficient is 1 for the last 3 months annotations, and decreases with 0.1 at each 3 months, until it reaches the 0.1 value. The author coefficient reflects the author competence into a certain topic, and could be extracted from the competence profile which development is exposed into the chapter 3. Because the values range is from 0 to 5, we will divide it by 5 in order to obtain a sub unitary value. We consider these operations as constituting the body of the evaluate_RC (C, D) procedure, having as parameters a concept C and a document D whose metadata is processed.

We provide below the proposed ranking algorithm, which assign to each retrieved document receives a score in order to sort them:

```

for each particular retrieved document D
  DS=0; //The initial document score is 0;
  TN = number of the query concepts; //For average
  for each query concept C
    CS=0; //the concept score is initially 0;
    if (query concept  $\subset$  document associated metadata)
      then evaluate_RC(C, D);
      LC = 0.4; CS = CS + LC*RC;
    else for each CR = concept related to C
      //(situated on a same tree branch as C)
      evaluate (CR, Q, C); endfor;
    endif;
  DS = DS + CS; endfor;
DS = DS / TN;
endfor;
sort documents according their DS;
display the sorted document list;
procedure evaluate (CR, Q, C)
// contribution of CR to concept C score for query Q
LC = 0.1 * (4 - the number of levels between C and CR);
if CR among the (query concepts)
  then exit; // CR examined in the main algorithm
else if CR among the document metadata
  then evaluate_RC(CR, D);
      CS = CS + LC*RC; TN = TN + 1;
  //one concept more in the final score

```

```

endif;
endif;

```

VI. THE PERVASIVE SERVICES SYSTEM ARCHITECTURE

The classical Web services conceptual model [20] is based on the interactions between three entity types: Service provider, service requestor and service registry. In order to access a certain Web service, the applications should make a special demand (push a request to the system). In addition to this sort of facilities, a pervasive system might also study the user's profile to anticipate the user needs and desires and would propose to him available services (pull services and present them to the user). This is the reason for which we chose a pervasive system architecture in order to integrate the previous exposed services.

In the pervasive or ubiquitous computing paradigm, computing elements will disappear from the user's consciousness while functioning homogeneously in the background of his environment [31]. In such systems, users will communicate and compute with each others whenever, wherever and however [24]. Pervasive systems are user-centered systems that contain heterogeneous and dynamic components: data, software, hardware and users [3]. Following a service-oriented model, pervasive systems aim to provide proactive, procedural and implicit services [32].

Moving around different e-learning pervasive systems, the teachers and students could use the above mentioned services into an explicit manner (through different user interfaces for CV development, materials annotation or information retrieval), having the advantage of a ubiquitous access the corresponding information. Moreover, a certain system itself could propose to the user to access certain services in the appropriate moments:

- When a student pass an exam, or a teacher publish an article or finish a certain project, the system could propose him the usage of the Competence profile development service;
- When a user access a certain material, could be invited to develop its annotations;
- When a user reach a new e-learning pervasive system, could be notified about the persons and the documents matching his profile.

VII. CONCLUSIONS AND FURTHER WORK

In this article, we provide a service-oriented solution for annotating and retrieving the documents and persons involved in the Computer Science domain, enhancing their mobility inside the pervasive e-learning systems. The solution is based on the ACM classification system, which is used in order to develop user competence profiles, to annotate materials, and to retrieve them. The retrieval mechanism uses a ranking algorithm which evaluates the relevance of a concept for a certain document considering also the related concepts, as well

as the time when the annotations were made, and the annotator competence in the concept topic.

In our future works, we aim to extend our system by enabling different mechanisms of developing the competences profile in an automatic way directly after the occurrence of an event (test, report, performance appraisal, evaluation, certificate, license, etc.).

We also intend to associate some access policies to a competence profile and to the documents annotations in order to guarantee the privacy, coherence and security for our system users.

An improvement could be brought to our algorithm by using an incrementally approach: the results for a certain query could be stored, and reused for all the next similar queries, together only with the last created metadata.

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