

The LUISA framework for enabling semantic search of learning resources

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Abstract. The paper describes a global framework enabling semantic search of learning resources that makes heavy use of semantic technologies. Firstly, the generic components are presented. Then, the paper exemplifies how the framework can be adapted to a given environment, i.e. which knowledge representations, Web Services descriptions and other building blocks need to be tailored or added to the framework. Following the paper shows, step by step, how queries are processed. Finally, the most relevant lessons learnt and future trends are carefully depicted together with a detailed description of other approaches already published about annotating and retrieving learning objects in Learning Objects Repositories.

Keywords: semantic based search, metadata, learning resource, ontology

1 Introduction

The increasing number of digital learning resources available on the Web has resulted in a growing interest in getting support for annotating, searching, retrieving, adapting and reusing such resources.

A great variety of approaches to solve this problem are currently available, among them the well known Web search (e.g. Google extended search) or the use of specialized “learning object repositories” (LOR).

In the first case there is a universal Web coverage, based on text, therefore *not specific* to instruction/education. This approach uses links instead of educational quality as the main selection criteria, not exploiting the availability of information specific to learning/instruction. In the second case, search-based capabilities rely on local metadata, such as Merlot [1]. The resource pool is limited, some pre-defined classification is provided. In any case, always within the local context of a Web site.

Some ongoing initiatives aim at federating multiple sources (GLOBE [2]), however, currently the query does not entail targeting the selection to the best ones. Both approaches have in common that no domain or common sense knowledge is used. Additionally, little support for queries on instructional properties is provided.

Within the context described, the LUISA project [3] (Learning Content Management System Using Innovative Semantic Web Services Architecture) addresses the development of a reference semantic architecture (also called LUISA) for the major challenges in the search, interchange and delivery of learning objects in a service-oriented context. This entails the technical description of the solution in terms of current Semantic Web Services (SWS) technology, and also the provision of the ontologies, facilities and components required to extend and enhance existing learning technology systems with the advanced capabilities provided by computational semantics.

The content of this paper is structured as follows. Firstly, the generic LUISA components are presented and carefully depicted. Then, the work exemplifies how this framework can be adapted to a given environment, i.e. which knowledge representations, Web Services descriptions and other components have to be tailored or added to the framework. Following the paper shows, step by step, how a query is processed. Finally, the most relevant lessons learnt and future trends are carefully depicted together with a detailed description of other approaches already published about annotating and retrieving learning objects in Learning Objects Repositories.

2 The LUISA general framework

The common framework is designed as a kernel from which applications tailored to fulfill the needs of a given institution are derived. It includes a general architecture based on semantic web services, and two ontologies, one based on LOM [4] for describing learning resources, the other based on Human Resources competencies for describing the existing and targeted competencies of learners and resources. It also provides an annotation tool named eLUISA which shall be filled with data specific to the target application.

2.1 Prototype architecture

This section describes the particular solution of the LUISA architecture (components, data structures and services) adopted for the realization of the current prototype. Figure 1 depicts the layered general architecture. Later, in section 3, we show how to customize this framework for a given application.

The two middle layers represent the SWS-based infrastructure for e-Learning. The Process Language layer, service Abstraction layer and Data layer correspond to the actual interfaces of the SWS-based infrastructure. The Negotiation Layer provides the relationship between the end-users of the LUISA framework and the Semantic Web Service environment. The negotiation layer offers common functionality for the

overall LUISA framework, such that the basic core implementation remains independent from application particularities. This obviously implies that any application specifics remain cleanly separated from the layer's building blocks implementation details. They are rather kept as part of the Web service implementation that grants access to it and with the specific Query Resolver (another component in the Negotiation Layer).

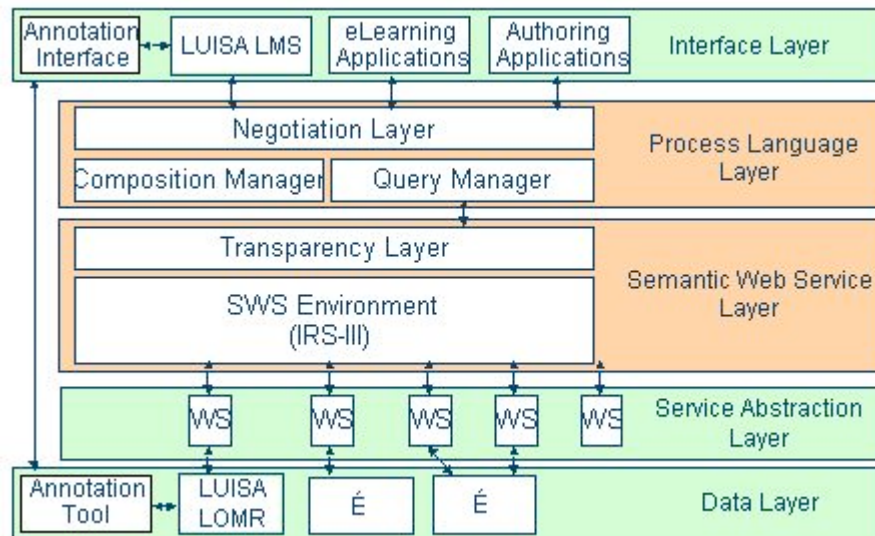


Figure 1: Layered General Architecture proposed by LUISA.

2.2 LOMR and GCO ontologies

In LOM compliant metadata, the semantic interoperability is only performed through the meaning given to categories and through lists of values, the semantic of which is often unclear. This leads to end-users defining application profiles. That is why, in LUISA, we propose a semantic version of LOM, called s-lom.

This ontology is mostly based on the LOM schema to favour standard compliance as far as possible, while providing richer computational semantics. The Learning Object concept is modelled as a class, then the metadata attached to a LO are represented as the property values of a class instance. The value sets are extracted from the developed domain ontologies, which enable further reasoning on them.

There is a growing demand of acquiring new competencies either in higher and professional education or in company training, whereas learning resources are not all indexed in terms of competency acquisition. In LUISA we propose a general competency ontology (GCO), derived from [5]. By these means the means for enriching the description of resources and for performing competency based reasoning, in order to fill competency gaps, are provided. The same ontology would also enable shifting from a competency based search to a subject matter-based search when needed. The reason being that each competency definition is linked to one or several subject matter items. For instance, the competency “being able to use a text

processor” is linked to the subject matter item “text processor”, which in turn is exemplified by Word or OpenWriter.

2.3 eLUIISA, a flexible annotation tool

The flexibility of the knowledge framework would not be possible without flexibility in the annotation. That is why the knowledge framework is completed with a flexible tool derived from the SHAME editor [6], called eLUIISA. eLUIISA is configured for end-users through Annotation Profiles. An Annotation Profile (AP) is a configuration of the metadata editor defining what to edit and how to edit it. Indeed, more and more users participate through different roles in the edition of complex metadata coming from different metadata structure. Thus, APs allow to easily defining in the editor which predefined values (from taxonomies or ontologies) should show up in which style (drop-down list, cursor to move) or how data types have to be checked. An administrator can compose an AP by creating and aggregating some modular bricks of annotation. For example, s/he can create a brick for the “language” metadata by associating a view (display a field entitled “Language”) and a model (linking this field to the category 1.3 of LOM). Then, the administrator can decide to ask the annotators for competencies by adding into the AP a brick displaying a drop-down list dynamically filled with some instances of the competency ontology and associated to another structure than LOM.

3 From the general framework to LUIISA-UHP application

3.1 Problem addressed

The general LUIISA framework is being applied to academic and industrial environments. The first academic prototype explores the application of semantic technologies to discover the best suited Learning Objects for a given learner in a particular domain. The chosen domain is a French diploma (called C2I) for competencies in internet and computer’s field. This will allow the learner:

- To express a query by **exploring a set of competencies** and additional criteria. From a pedagogical point of view, the exploration and interactions with the tree of competencies may improve the user’s perception of the learning domain (meta-cognition).
- To obtain the more appropriate **resources retrieved** from one or several Learning Object Repositories (LOR) specially prepared for the prototype according to the elements of the query.
- To be provided with tentatively **packaged resources**. The system can compose some Learning Objects (LO) to create a new one. The composition rules are very basic in this prototype, so they are introduced as a proof of concept rather than to implement a coherent composition strategy. More advanced and pedagogical compositions will be experimented in the next versions of the prototype.

3.2 The UHP prototype architecture

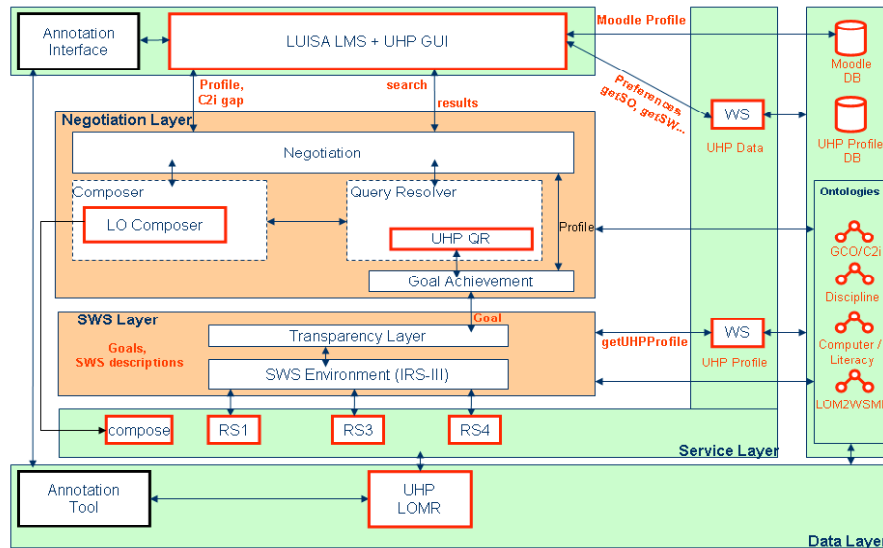


Figure 2: LUISA-UHP architecture

Derived from the general architecture, Fig. 2 shows the architectural components of the university (UHP) prototype. The specific components, data structures and interfaces developed or adapted for the UHP prototype are labeled UHP. They are summarized in Table 1.

The SWS infrastructure and the Annotation tool have to be integrated into a Learning Content Management System to enable users to access to the semantic functionalities supported by the core components of the architecture.

For the first prototype an extension of the Open Source Moodle LMS has been developed.

Table 1: Resources customized or designed for the UHP prototype

Resource	Nature	Description
GCO/C2i	Ontology	Represents the competencies used in the C2i context. These competencies are based on the concepts of the General Competency Ontology. Example: "k_email" is a KnowledgeElementDefinition required by the "B6

Resource	Nature	Description
		competency: communicate remotely” which is a CompetencyDefinition.
Computer Literacy ontology	Ontology	Represents the items (hardware or software) involved in the C2I competencies. Example: “k_email” is a KnowledgeElementDefinition about “EmailApplication” which is a “PrivateCommunicationTool” in the Computer Literacy Ontology.
Discipline ontology	Ontology	Represents the fields of study in the university. Example: “Medicine” is a specialization of “Health” and is “linked to” “Biology”.
LOM/WSML	Ontology	LOM/WSML is a semantic implementation of LOM. It represents all the aspects (from technical requirements to rights management and educational characteristics) of a Learning Object.
UHP Profile	Database	MySQL database including all the other data about a user
C2I LOs Repository	LOMR	Including at LOs about C2I.

It was noticed that some additional user information items were required for the UHP use case to fulfill the requirements for the standard Moodle user profile. Such information comprises: user competencies, user preferences about operating systems, available software, discipline, university preferences about cost and language. These additional information items were stored in local databases.

3.3 Component descriptions

Graphical User Interface (GUI)

During the query phase, the user interacts with the system in order to select the criteria of his/her search. The user must select the competencies s/he desires to acquire and his/her available duration of work. The C2I competencies are presented as a dynamic expandible/ /collapsible tree showing the competencies he/she acquired and the missing ones. The tree is dynamic; when the user selects a competency new

competencies (depending on the selected one) become available. The user can also select the duration he desires to practice.

A screenshot of the query interface is presented in Figure 3.

The screenshot shows a Moodle interface for selecting C2I Competencies. At the top, there is a navigation bar with 'luisa moodle site' and a user login status 'You are logged in as a (Logout)'. Below this is a breadcrumb trail: 'LOSL > Home for semantic search > Competencies selection'. The main content area is titled 'Query phase' and contains a 'C2I Competencies' selection form. The form is organized into a tree structure with expandable nodes (indicated by '+' signs) and checkboxes for selection. The competencies listed are:

- A1: Be aware of the evolution of IT.
- A1.1: Be aware of the evolution of the ICT and of the deontology related to it.
- A1.2: Be aware of the necessary evolution of this system of references.
- A1.3: Work in an open-minded and adaptive way.
- A1.4: Be aware of the exchange, interoperability and standardization problems.
- A2: Comprehend the ethical issues.
- B1: Control his environment of work.
- B2: Research of information.
- B3: Save, secure and back-up his data.
- B4: Realize documents for printing.
- B4.1: Realize short documents (CV, letter, ...)
- B4.2: Elaborate structured documents
- B4.3: Use features for structuration of complex documents
- B4.4: Integrate information (picture, file, graphic, ...)
- B4.5: Process and display of numeric data.
- B4.6: Create schemas. (missing required comp.)

At the bottom of the form are 'Preferences' and 'Search' buttons. To the right of the main form is a 'Constraints' panel with a 'Duration' dropdown menu set to '1 hour'. The footer of the page repeats the breadcrumb trail: 'LOSL > Home for semantic search > Competencies selection'.

Figure 3: Moodle query form.

The competencies ontology is represented as a tree, nodes have a little “+” on the left if they are expandible, a little “-” if they have already been expanded and nothing if they are a leaf. A little checkbox on the right provides the user with the means to select the competencies for which s/he wishes to start the search. A little square reminds whether the user has already acquired a given competency (green) or not (red). If the user is missing the prerequisite competencies for a given one, there’s a label telling that the competency is unreachable (see competency B4.6 of Figure 4). The user can also select the duration from the constraints region on the right.

After the search, the system proposes to the user some LOs. A first pack entitled “*your selection*” is defined by the system, here the user can change the LOs order or deselect them. The second group of results shows some alternative LOs. The corresponding interface is represented in Fig. 4.

The user can change the LOs order using the arrows, or deselected them. The [+]
icon indicates a composed LO, while the [~] means that the LOs competency was
mapped with a competency from another ontology of competencies.

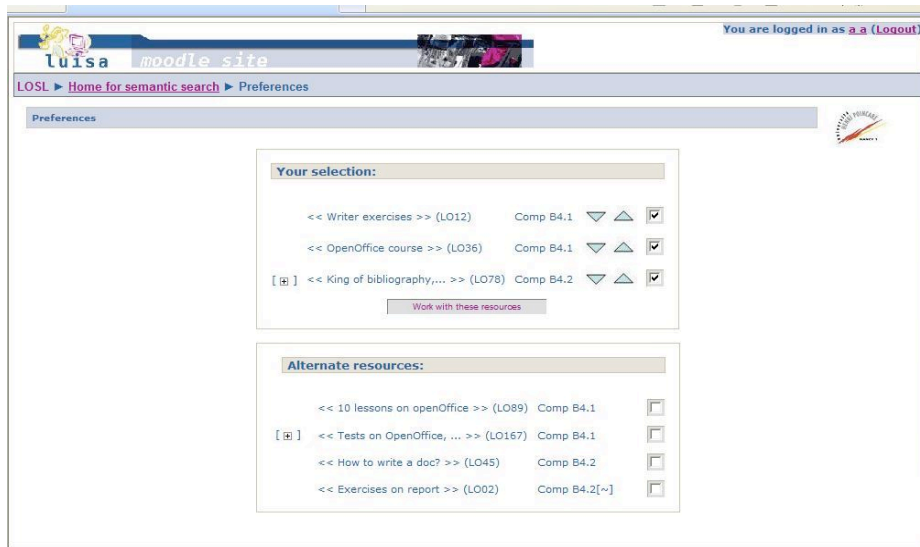


Figure 4: Moodle LOs proposal.

Negotiation Layer

The Negotiation Layer provides the relationship between the end-users of the LUISA framework and the Semantic Web Service environment. The Negotiation Layer consists basically in three main components:

- Negotiation
- Query Resolver
- Composer

The **Negotiation** component enables the management of the communication between end-user layer and the rest of the LUISA framework. The negotiation involves collecting data from the end-user and implies verifying the suitability of the user profile to specific Learning Objects, and assuring the persistence of the session with the End-user GUI.

There is a common functionality offered by the Negotiation component for the LUISA framework and the basic core implementation remains independent from case study particularities. The particularities of the case study are then not in the component itself, but in the Web service implementation that give access to it and in the specific Query Resolver developed for the case study.

The Negotiation component, once received the query, transforms it to a goal invocation and sends it to the Semantic Web Service environment.

A **Query Resolver** implements specific organizational learning rules. After receiving the results of the invocation of the SWS environment by the Negotiation component, these results are gathered and processed by the appropriate Query Resolver implemented for UHP that verifies the rules to which the invocation is bound.

A **Composer** is used if the results of the distributed query can be combined automatically in a new package of learning resources, the Query Resolver will invoke the Composer component to create this package. The Composer component makes use of a Composer Web service designed for the creation of SCORM packages in a LUISA LOMR.

SWS Layer

The Semantic Web Service Layer is responsible for selecting from the available Web Services the most appropriate ones, to achieve a given goal.

Based on the requirements provided by the use case partners, a generic e-Learning scenario was defined. A dedicated sequence of sub-goals has been proposed, the sub-goals are accomplished to achieve a specific learning objective. Fig. 5 represents the sequence of sub-goals which support the overall learning objective.

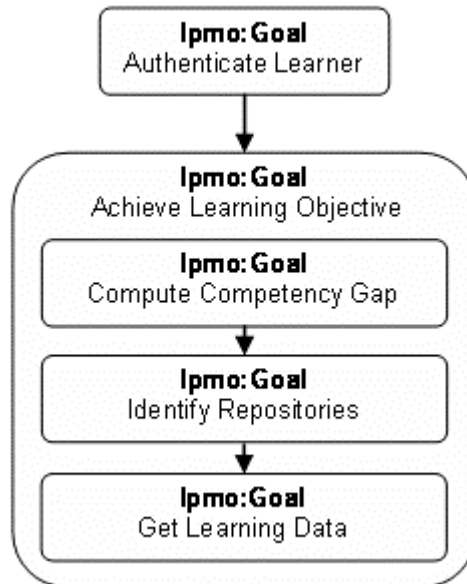


Figure 5: Orchestration of sub-goals to achieve a specific learning objective

As depicted above, in a first step a learner is authenticated to make the system aware of the specific context of the learner – her preferences and requirements. Furthermore, for each specific learning objective, a sequence of goals is to be accomplished. Based on the provided learning objective and the current competency profile of the learner the competency gap is computed. A competency gap is the

difference between user's competencies and targeted ones, for example to reach the level required by a job position.

Given the competency gap, a learner can select and provide the targeted competencies. The actual information context – consisting of parameters such as the user preferences and the competency gap – is used within another goal achievement procedure to identify appropriate repositories which target this context. As for the competency gap, different strategies may be implemented by different service providers to select appropriate repositories. Strategies could differ for instance in the prioritization of the distinct context parameters during the matchmaking procedure to identify appropriate repositories at runtime.

Finally, based on the context – now enriched with a list of matching repositories – appropriate learning objects can be provided which match all or some of the context parameters. Particularly in the process of selecting appropriate content it is important to highlight that, distinct services can follow different strategies to identify appropriate content, since there may be different answers to the question of which objects match a given query the best, dependent on distinct viewpoints, perspectives and philosophies.

LOMR

The LOMR acts as the data layer in the LUISA architecture. It provides a standard, SOAP-based Web service interface to the rest of the LUISA components. The LUISA LOMR is intended as a framework, thus offering in library form several variants, and being devised explicitly for extension with capabilities that are specific to some applications or domains. This section summarizes the design of the interfaces of the LOMR to the rest of the LUISA architecture¹.

Querying LOMR instances is typically done in two phases. Firstly, some calls to search functions for learning resources are issued. Then, for some of the learning object references obtained as search results, additional metadata is retrieved (typically, depending on the information shown in the user interface).

The learning need specification varies with the approach used; it might be based on metadata schemas IEEE LOM, or, as in the example in the Table above, it might be based on some kind of learning need language as competencies. It might also combine both kinds of input elements. In any case, the results is always a collection (ordered or not) of learning object references matching the input criteria.

It is important to clarify that LOMR instances act as black-boxes for the rest of the LUISA architecture, which has two main implications:

1. They are not distinguishable from potential Web-service interfaces provided by non-semantic, existing learning object repositories.
2. LOMR instances might carry out (at its local level) functions of semantic search, composition or inference, but these are transparent to the other components of LUISA. Composition, inference and semantic search are

¹ The code is provided under open source license at <http://www.cc.uah.es/ie/projects/luisa/lomr>.

performed at a distributed level inside the components of the Semantic Web Service Layer of LUISA.

The LUISA prototype aims at demonstrating the distributed semantic capabilities of the LUISA architecture. The LUISA LOMR in the current version includes ontologies of IEEE LOM and IMS LD. The competency-based variant also includes the General Competency Ontology developed in LUISA.

4 A scenario step by step

In this section we provide a scenario description, focusing on the learner interaction with the prototype. The scenario is the following: a learner wants to find a suitable package of Learning Objects that suits his/her needs. The learners will use the prototype on their own, making use of the LUISA-based application in order to create a work plan to increase their competencies.

Step 1 – Login and first set C2I competencies

The learner logs in the LUISA UHP application and, once authenticated in Moodle, the prototype shows the learner his set of competencies according to his profile. The learner may select the competencies he wants to reach and sends the query to the Negotiation Layer.

Step 2 – Rules for negotiation

When the learner posts the request, the Negotiation Layer sends it to the SWS Layer by choosing the appropriate goal. The first invocation of the SWS layer tries always to retrieve LOs for the same competency and discipline that the learner provides.

The Query Resolver component is in charge of analyzing the response for all queries performed to the SWS Layer, trying to check the suitability of the selection. In the current prototype we have provided a specialization of the Query Resolver for the UHP case study that implements the following rules:

R1. If the competency chosen by the learner is a sub-competency:

R1.1 If there are no LOs that fulfill the exact match: The system selects the LOs about the same sub-competency but with a more general discipline. Application of organizational specific e-Learning rules.

R1.2 If there are no LOs with these features: The system selects the LOs about the general competency and the same discipline.

R1.3 If there are no LOs with these features: The system selects the LOs about the general competency and a more general discipline.

R2. If the student chooses a general competency:

If there are no LOs that fulfill the exact match: The system selects a LO about the same competency and a more general discipline + the LOs about

the same discipline but whose target competency are sub-competencies included in the selected general competency.

Step 3 – Rules for composition

The Composer component is in charge of creating learning packages by combination of a set of Learning Objects. The implementation of the composer for the current prototype assumes that the LOs are SCORM compliant and the resulted package is delivered as a new SCORM compliant LO.

If the Query Resolver proceeds to a decomposition of a competency given by the end-user into a set of sub-competencies, then the Composer gathers and packs the results for each sub-competency in a set that, as a whole, matches the super-competency.

Step 4 – Work plan

Once the user selects the appropriate LOs, the work plan is saved in Moodle as the selection made by the user.

5 Conclusions and future plans

The current version of the prototype represents a proof of concept of the LUISA framework, that demonstrates how it could be adapted to specific user needs. It is currently being evaluated by some users from the university Henri Poincaré and is part of the iterative prototyping approach followed in LUISA.

This experimentation will allow observing the behaviour of complex reasoning from two points of view. From a system perspective, we will observe the performance of reasoning across Semantic Web Services. From a designer perspective, we will observe up to which point complex rules applied in the system could stay consistent and useful for the end-user.

Many other on-going projects aim at enhancing the description, the retrieval and reuse of appropriate learning objects. They follow different approaches. Among them, LORNET [7], [8] also proposes an ontology and web service based architecture in its TELOS component. Although it seems possible to customize LORNET components in an application providing the LUISA functions, such an application has not yet been reported. Moreover the LORNET kernel is in some way less specialized than the LUISA one, so a closer comparison is not easy. Another nation wide project in Korea [9] proposes the same kind of common knowledge framework but does not use at all the flexibility provided by SWS and WS.

As far as LUISA is concerned, we would underline that it is a framework for developing specialized systems or brokers for other systems and that it does not replace, but rather extends, existing investment. It also provides key innovations :

- Enabling the expression of queries in terms of terms from ontologies.
- Locating the best sources/providers for given queries (learning needs).
- Suggesting tentative compositions based on learning needs.

- Asking the user back if more relevant info is required.
- Enabling different query resolution/composition strategies, including educational knowledge.

For the final version, we foresee to investigate advanced features as searching over several ontologies or Web 2.0 users' ratings, as proposed by [10]. These features will allow the learner:

- To express a query by **exploring a set of competencies** and additional criteria.
- To obtain the better **resources retrieved** from the available LORs according to the elements of the query. For example, the learner may ask for resources annotated with a competency and be provided among others with resources annotated with a sub-competency of the requested one.
- To be provided with tentatively **packaged resources**. The system can compose some LOs to create a new one, using instructional strategies.
- To be provided with resources **according to the learner profile**. For example, a student in Computer Sciences will obtain some LOs more adapted to her discipline. If no LOs correspond to the user query, the system can propose LOs in a close discipline like Mathematics by using reasoning rules.

Acknowledgments

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