Learning Resource Referencing, Search and Aggregation At the eLearning System Level

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Abstract. TELOS is a new eLearning system being built within the Canadian LORNET project. TELOS aims to provide an open operating system in which users can develop and use eLearning and knowledge management resources and environments within a service-oriented and ontology-driven framework. A special emphasis is put on the aggregation of resources through a graphic scenario editor and the referencing of the resources using a knowledge and competency representation. We advocate that this approach is necessary for federated search or harvesting tools to be well integrated and find meaningful learning resources that need to be repurposed and aggregated, taking in account the diversity of technologies, pedagogical intent and referencing schemas.

Key Words. Aggregation Scenarios, Learning Resources, eLearning systems

1. Introduction

The aggregation and repurposing of learning resources is a central question if we want learning resource repositories to be used. By "resource" here, we mean any "content provider" such as multi-media documents or learning objects, learning designs, and knowledgeable persons: expert, trainers or peer helpers. *Learning resource* is thus a concept that subsumes the *learning object* concept.

While many proposals address the search problem through adding sophistication to federation or harvesting search mechanisms, we suggest another approach where functionalities needs to be provided at the eLearning system's level, where resources will be searched, repurposed, aggregated and referenced. To overcome the multiplicity of metadata schemas and the inevitable fuzziness of their use in actual practice, we need to aggregate basic federation and harvesting services with operations providing additional functionalities to enable search through diverse metadata schema and various profiles and control vocabularies that are in use. Another important question is to search for resources according to a knowledge and competency representation of their content and/or structure which is not really well covered by the actual metadata schemas.

In a first section, we present briefly the main principles behind the Technology Enhanced Learning Operating System (TELOS) and its central scenario editor. In the second section we show some examples of TELOS use by different actors involve in different operations with learning resources. In the third section, we address the question of referencing learning resources in a learning scenario to enable knowledge-based search in learning resource repositories. In the concluding section, we discuss some rationale for the proposed approach.

The ideas presented here are the result of a research program that has started at the LICEF-CIRTA Research Center in the mid-nineties on the concept of a Virtual Campus 1 and on the Explor@ system seen as a learning portal generator 2. What follows is based mainly on recent results achieved within the LORNET[1] research network. The architecture of TELOS is described in **Erreur ! Source du renvoi introuvable.**.

2. A Service and Ontology-based Aggregation System

TELOS in designed to work within the semantic Web 4 general framework where semantic reasoning can be performed based on knowledge annotations associated to the resources stored in networks of repositories available through the Internet. TELOS can also be situated in the context of Service Oriented Architecture (SOA) 8. A SOA creates a broad vocabulary, that we can formalize into an ontology, and which is used to model the system's main components, relationships and properties.

The TELOS core is managed, adapted, extended by actors called engineers. With it, technologists produce one or more TELOS platforms (a generalization of the LCMS actually in use in most universities). Using a TELOS platform, designers can create, produce, deliver and maintain a number of applications such as courses, learning events, or knowledge management portals. Within an application, end users, learners and facilitators, will produce resources and outcomes.

An important goal is to embed in the system technology-independent models, to help the system survive the rapid evolution of technologies. For that purpose, the conceptual specifications of TELOS, expressed as ontologies, are not kept separate from the code. In this vision, the conceptual models are not just prerequisite to building the TELOS system; they are part of the system, acting as "conceptual programs", as one of its most fundamental layer: the semantic layer.

TELOS is a distributed system composed of nodes, each containing the TELOS Core which is the central controller of a TELOS system, the resources databases, the semantic layer, and communication services. The resources can be references to users, multimedia files, learning-objects, software components and operations, as well as user-created aggregations of simpler resources. This last type of resources enables users to create new eLearning services by gluing existing software components. It also enables users to model collaborative workflows describing knowledge, processes and practices in work processes or learning scenarios.

The semantic layer is the foundational element of the ODA (Ontology Driven Architecture [5,6]) of TELOS. It is where all TELOS concepts are declared are related together through logical constraints. It defines the global behavior of TELOS. It also contains domain ontologies created by users that later permits the referencing of all kinds of resources by the knowledge they contain. This enables to combine

[1] LORNET (www.lornet.org) is a Canadian research network led by the first author and financed by the Canadian Government and private companies for five years until 2008. It groups 6 research centers and laboratories and over a hundred researchers, research professionals and graduate students.

search using standard metadata with knowledge based referencing using domain ontologies.

3. Executable Graphic Models

TELOS provides a formalism to represent multi-actors human/machine processes or aggregation models. The *TELOS Scenario Editor* aims to generalize both learning workflows (such as defined in the IMS-LD specification) and business workflows (such as defined in the BPMN). It is the main repurposing and aggregation mechanism for learning resources. This editor provides a graphic language designed to be accessible to all TELOS actors including students, workers, teachers, designers, technologists and programmers, through an intuitive visual syntax.

This graphical language provides a high-level visual programming language for TELOS. The models produced by the editor are executable through an execution engine called the *Scenario Evaluator* that uses an inference engine to process the references to the technical ontology associated to each component of the scenario. To illustrate some of the possibilities of this approach, we will now present three working examples that be termed as *TELOS executable use cases*.

3.1 Aggregating components services

In the first model presented in figure 1, an engineer aggregates components to compose a new service embedded in a function called the "Batch LOM Extractor". This function takes a set of keywords, the number of LOMs (Learning Object Metadata records) to find and the name of a folder in a repository of learning resources managed by our PALOMA resource manager. On the frame at the right of figure 1, these three inputs are shown as resources. The result of the aggregated function is to insert the requested number of LOMs responding to the keywords into a new PALOMA folder and to open this folder into the PALOMA software interface.

This new function combines the services of four components embedded in corresponding operations shown on the central part of figure 1. These operations are linked sequentially in the following order:

1. The Google Search Web Services takes the keywords and the number of results as inputs and produces a corresponding number of URLs pointing to Web pages.
2. For each URL, an operation called "Extract DC Metadata" produces Dublin Core metadata automatically through natural language parsing of the Web page.
3. Then this DC XML string is passed to another operation, a "DC to LOM converter" to produce a corresponding standard LOM XML, in the format used by PALOMA.
4. Then, with this LOM XML and the name of a destination folder, the LOM is inserted in the PALOMA folder.

This cycle is repeated until all the LOMs are processed up to the number given initially; when this is finished, the PALOMA software is launched with the folder containing all the LOMs, enabling the display of LOM metadata and of the resource.

What we see here is the aggregation of components built by different groups using different technologies. The Google Search Service is launched using a SOAP Web service connector provided by the TELOS kernel. The Metadata Extractor is a

C# component linked to the TELOS kernel by a C# connector. The DC to LOM conversion is a Scheme component linked through a Scheme connector. PALOMA is a Java application linked through a Java connector.

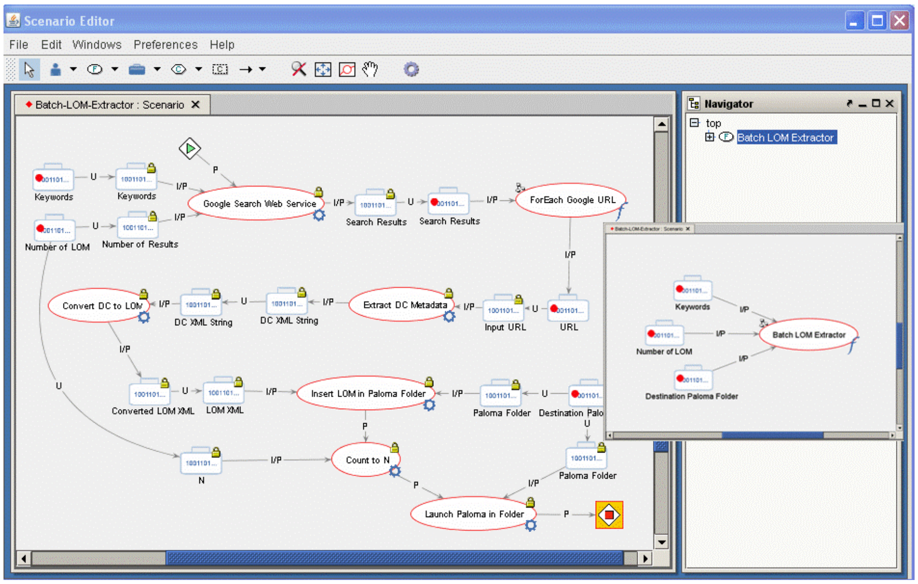

Fig. 1. Engineer constructing an operation aggregating services

All four components have been previously referenced in TELOS libraries of resources with their links to the technical ontology that are instances of some classes of resources. These semantic references describe in particular what kinds of inputs and outputs each service expects. In the scenario graph, values are connected to these ports using U links. Also, the semantic references describe the technology used, so the proper connector is mobilized.

The result is the new aggregated operation shown on the right of figure 1 with its three inputs. This new operation has been integrated in the TELOS library as a new digital resource, which means it is referenced in the TELOS technical ontology and ready to be aggregated with other resources, for example as a tool in an platform or an application. A slightly extended aggregation scenario could involve a combined use of the Google search with a federated search or harvesting engine, together with the use of translation operations between the most largely available metadata schemas and profiles.

3.2 Extending an eLearning platform

The next executable model will show how a technologist can combine functionalities from different platforms and tools to compose a new platform with greater capabilities. The central component of the combined platform is a process graph for the designer to produce courses. This design scenario corresponds to the central tasks of the MISA instructional engineering method [9]. Figure 2 shows part of this scenario that involves using Concept@, our university's actual distance learning platform, augmented with the TELOS scenario editor and other components.

The design scenario starts with two functions performed in parallel by a course designer. One is the design of a course activity structure using the Concept@ platform. The second is the development of a knowledge and competency model for the course using the TELOS ontology editor. Concept@ has no capabilities for knowledge and competency modeling so an external ontology editor needs to be integrated in the designer's environment.

Concept@ produces activity trees representing the course plan and its subdivision into modules and activities. This structure can be exported to a SCORM package. Many roles can be defined in Concept@ but this exceeds SCORM's mono-actor capabilities. After the translation of the SCORM output of Concept@, this information is lost when we open the corresponding graph in the TELOS scenario editor. We can then use the scenario editor to add these actors manually or add an operation to translate the role structure in Concept@, thus extending the SCORM translator. In either cases, a more advanced flow of control than simple sequencing can be added to support more personalized learning.

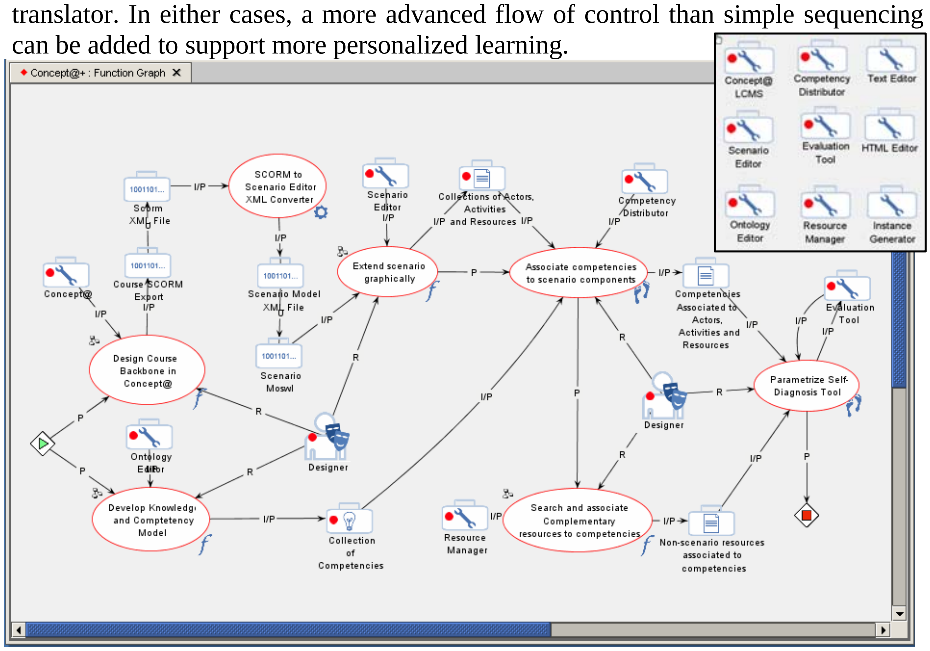

Fig. 2. Technologist constructing an augmented platform for designers

These two main design tasks proceed in parallel up to a point when a relative stability is achieved. Lists of actors, activities and resources are then available from the scenario editor, together with a list of competency produced by the knowledge/competency modeling task. We can then associate competencies and knowledge to resources actors and activities using a competency distribution tool. This will be shown in section 4.

Finally, searching for additional resource using a federation engine in a resource manager like PALOMA must be supplemented with an operation that filters results according to selected terms from the domain knowledge and competency ontology. These associations will serve to parameterize a learner evaluation tool that will be used during the delivery of the course to suggest adequate resources.

In the frame on the right of figure 2, we show a list of tools including all the tools in the design scenario on the left, plus other tools that will be added once the design scenario is completed. All the main functions shown here are further described by sub-graphs down to terminal activities and operations. When this is completed, a designer' Web portal will be produced automatically by TELOS, grouping the tools in menus and providing the design scenario as a guideline for designers.

3.3 Designing an eLearning environment

Using a design scenario such as the one in the previous section, a designer can create course or knowledge management scenarios and environments. Figure 3 shows such a scenario which had first been design according to the IMS-LD specification, using our IMS-LD graphic editor [9]. The upper right window shows the global scenario model where the learning unit on the solar system is subdivided in four acts. The larger window shows the learning scenario for act 2.

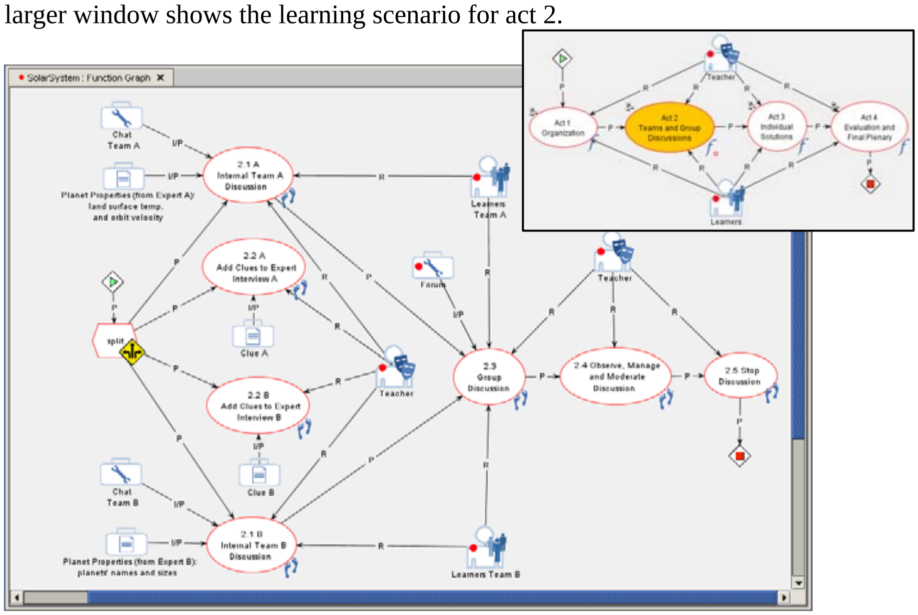

Fig. 3. Designer constructing a multi-actor scenario.

This scenario displays two teams of learners, each using a chat and different input documents to study and discuss planet properties. When the internal team chats are over, both teams and the teachers join in a forum discussion. The teacher observes, manages and moderates the discussion. He stops it at a certain point to start act 3 where individual work will be done by the learners to find a solution to a matching problem between planets names and some of their properties. Again, from this design, different Web environments will be produced automatically by TELOS for the teacher and for each team of learners.

This example shows the power and flexibility of TELOS to repurpose designs. For example, the design shown in figure 3 could be easily adapted to a course in economics or a project workflow in an organization by just replacing the resources with new ones adapted to subject of economics or to the project's content.

4. Semantic Annotation to Resources

A *semantic annotation of a scenario* is simply a mapping from a domain ontology to the objects in the learning design. This corresponds to one the the designer's task in the example shown on figure 2. An illustration of this task is shown on figure 4 in the case of the learning design scenario on figure 3. From the scenario editor interface, we can open a browsing interface to a previously selected ontology for the subject domain. In this graph, we can select knowledge entities to associate with actors, activities and resources in the learning design. These knowledge entities from the ontology can come with competency definition attachment if needed.

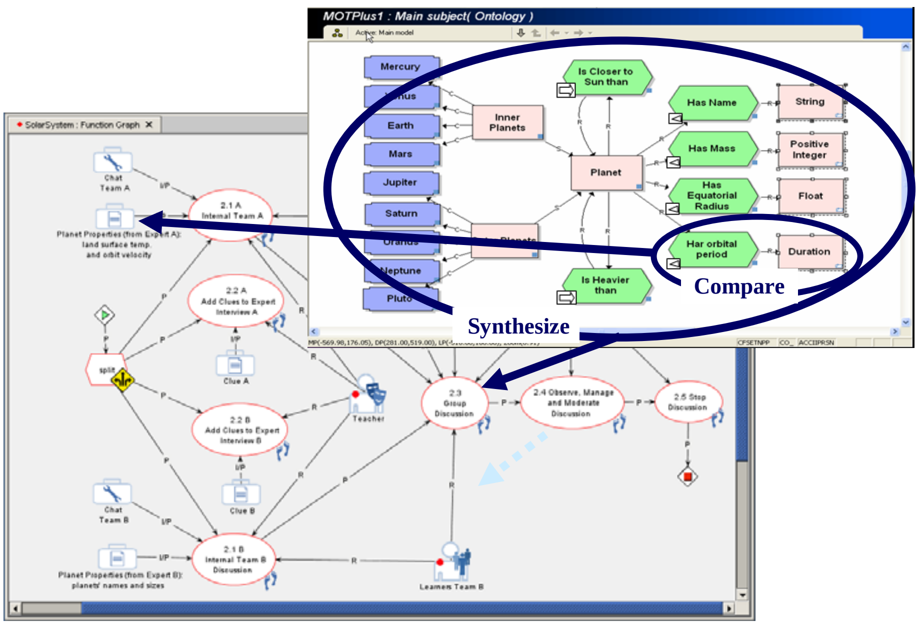

Fig. 4. Referencing Resource using a Domain Ontology

Here, such an association informs the system that the document "Planet Properties (from Expert A) …" is about orbital periods of planets and the target competency is to enable team A learners to compare orbital periods. This resource is not the only input to activity 2.1A; the chat between team members will bring other information to each participant so the knowledge and competencies associated to activity 2.1A would logically correspond to the union of knowledge entities and competencies of these input resources. Finally, figure 4 shows that most of the ontology model will be the subject of the group discussion in activity 2.3 where learners are to develop their synthesis competencies. This is coherent with the fact that the other team B will bring complementary information on other planet properties that will be shared in the forum discussion for the synthesis activity 2.3.

Semantic associations help bring consistency to a design by distributing the knowledge/competency coverage between the theoretical resources that need to be integrated at each level of a design. The knowledge/competency references of these resources can be translated from the domain ontology to keywords or Boolean queries launching a search through a network of learning object repositories. When adequate concrete resources are found they might need to be aggregated or repurposed to cover the needed knowledge; they then replace the theoretical resources defined in the earlier stages of design. Alternatively the knowledge and target competencies can be changed to preserved the consistency of the design if only insufficient resources can be found, adapted or built.

5. Conclusion

We suggest that the extension of functionalities at the eLearning system level can help solve important learning problems. Using the above examples that we have built using TELOS, we can now provide a rationale to support that claim.

- In TELOS, it is rather easy to aggregate a function from other operations. For example, a Google search can be combined with a federated search service designed for learning object repositories without changing the code.
- To enable a federated search service designed for the SCORM profile to tackle a new repository that uses a different control vocabulary, it is possible to code a small operation in any language (for which a TELOS connector has been built) and aggregate it to the initial service.
- To build shareable repositories in a specialized domain might be difficult when different terminologies are used. One repository could use a LOM classification, while another references resources with a local ontology. Federation of the repository can be achieved by an ontology alignment operation to be aggregated to the search process.
- Small text mining component can be aggregated to search engines or resource recommenders to provide automatic metadata extraction and use.

These examples do not exhaust all the possibilities. To try to address all of them improving search services might result in large and rigid tools. We suggest that a simple and efficient service aggregation solution be provided at the eLearning system level to reduce the effort in building solutions in new application contexts.

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