Learning Object Network: Towards a Semantic Navigation Support

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Abstract: In this article, we try to provide a solution facilitating navigation between resources in a Learning Object Repository (LOR). Our aim is to open up this kind of knowledge systems and transform them into *open repositories*. We define as *open repository* a LOR that can export and import resources between LORs and other knowledge sources such as the domain model and the Web. Building upon the state of the art, we propose a way of expressing learning objects inter-relations that can take advantage of such as Semantic Web, adaptive hypermedia, e-learning, etc. We identified problems of variety of terminology, and difference of formalism to represent knowledge sources. After choosing the graph representation, we propose an architecture which is based on an extended LOR that defines an overlay navigation layer called Learning Object Network (LON).

Introduction

The great diversity and volume of on-line data and the increasing use of non-textual resources decreases the effectiveness of existing search tools. It can be provided by and extracted from a wide range of different sources: the Web, a Learning Object Repository (LOR)[1] [Koper 01] or a specific domain model[2] related to an adaptive hypermedia system[3] [Brusilovsky 96]. There are as many data sources as research communities interested on the issues related to organizing, searching, navigating and delivering data according to the user's needs. Unfortunately, despite their common interests, these communities do not collaborate and nor share results. We believe it is necessary to break this segregation and hope to propose a framework to enable cross-communication by way of our so-called *open repositories*.

In the context of Ariadne[7][Ariadne 02] we have developped, based on SEPHYR **[**SEPHYR 02], an authoring tool called Phoenix [Yoo&al 04] which generates indexed learning self dependent objects[8] that can be inserted into the Ariadne's LOR called Knowledge Pool System [Duval&al 01]. Despite the emergence of GLOBE [Globe 05], which guarantees a federated search of learning objects amongst LORs, a LOR is considered to be a closed environment. We define an *open repository* as a LOR that can export and import resources from either LORs or other knowledge sources such as the domain model and the Web.

Our purpose is to provide a semantic navigational support for open-repositories. To achieve our purpose, we need an additional layer which describes explicitly the relationships between learning objects no matter where they come from. To define those relationships, we propose to use the same formalism used by the other knowledge sources to guarantee interoperability. Relationships' ontology seems to be a solution (Fig. 1).

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[1] Learning object repositories (LORs) are essentially storage and retrieval systems for learning objects
[2] The domain model is composed of a set of small domain knowledge elements (DKE). Each DKE represents an elementary fragment of the given domain.
[3] By adaptive hypermedia systems we mean all hypertext and hypermedia systems which reflect some features of the user in the user model and apply this model to adapt various visible aspects of the system to the user
[4] ARIADNE, Alliance of Remote Instructional Authoring and Distribution Networks for Europe, is an interoperable and open e-learning platform. See http://www.ariadne-eu.org/en/about/general/
[5] Any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning.

In this article, we will first deal with existing formalisms for knowledge representation. After choosing the graph representation, we will present our architecture which is based on an extended LOR that defines a navigation layer called the Learning Object Network (LON). Then, we will describe in detail the two knowledge processors: the authoring tool (Phoenix in our case) and the relation miner.

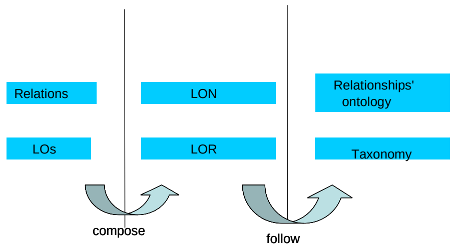

Figure1: Organization of learning objects and their relationships

Panorama of the formalisms used by the different communities

The first problem that we encounter is the vocabulary.
Units of information are called :

- Resources (RDF [RDF 05]), topics (topic map [ISO 13250]), collections [Marshall 95] or hypergraphs [Harel 88] by the Web community,
- Concepts by the Adaptive hypermedia community,
- Learning objects by the E-learning community.

Three different formalisms are used to represent knowledge [Escrire 99]:

- *The graph family* comprises *:* (i) the *Conceptual graph* model is described by [Sowa 84] and formalized by [Chein 92]. The domain is described by a graph which nodes are either concepts or relations between concepts; (ii) the *Concept Map* [Cmap 05 represents relationships between concepts. Recently, some tools like CmapTools [Cmap 05] are developed to facilitate the online manipulation of concept map such as share, search and retrieve maps; (iii) the *Topic Map* [ISO 13250] is an ISO standard for describing knowledge structures and associating them with information resources. Called “the GPS of the information universe”, topic maps are also conceived to facilitate navigating into large and interconnected environments; (iv) the *Collection* [Marshall 95] clusters the hypermedia content into semantically connected groups with implicit and explicit links; (v) the *Hypergraph* [Harel 88] is a visual notation formalism; it can be expressed in Hypermap through collections and arrows to add in the visual clarity of hypermedia documents.
- *The Object Family*: Knowledge can be represented by an object [Euzenat 98]. Objects are instances of classes organized into taxonomies. As an example of a language using this representation, we propose RDF [RDF 05].
- *The Description Logics* Family [Nardi&al 02]: Knowledge is represented by descriptions corresponding to concepts, roles and individuals.

Our aim is to describe an open environment in which navigation is easily performed. We thus chose to represent our environment as a graph to facilitate navigation through learning objects.

A general architecture for a self-controlled LOR

A LOR contains unrelated learning objects that, for a navigation purpose, need to connected formally resulting in a graph that we denote Learning Object Network (LON) (Fig. 2). Relationships (denoted by R) between learning objects can be sequential, alternative or other relations that can be either defined by authors (called *predefined relationships* [Xing 05]) or mined by the system (called *discovered relationships* [Xing 05]) as we will mention in the next section.

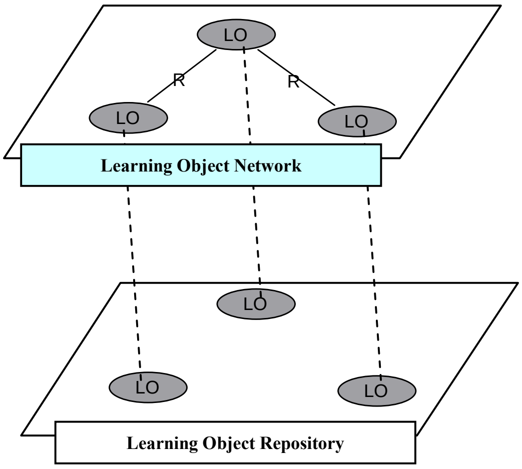

Figure 2: Extended LOR

We propose an architecture based on three components : our extended LOR, comprising a LOR and a LON, which we consider as our knowledge source; a knowledge processor and a delivery processor (Fig. 3):

The Knowledge Processor

We distinguish two kinds of knowledge processors: the authoring tool and the relation miner.
Our authoring tool produces learning objects and inserts them into the LOR. Besides, it can:

- send requests to the LOR and retrieve adequate elements for reuse,
- update a version of a learning object.

The relation miner defines the relationships between learning objects either manually (author's or authorized user's intervention) or automatically. It extends the LON every time that a new learning object is inserted by defining its relationship with older LOs. It is composed of three processors: the sequential linker, the network matcher and the relationships definer.

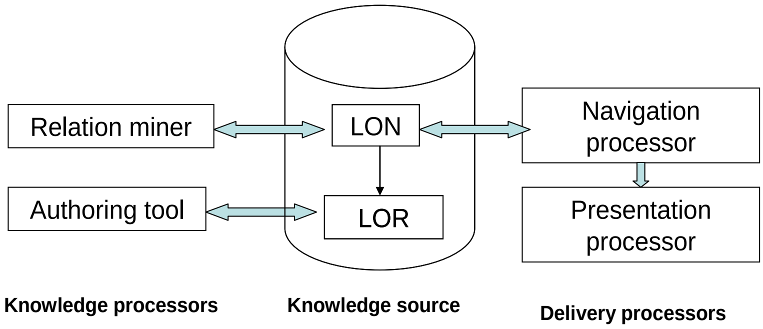

Figure 3: Self-controlled LOR general architecture

The Delivery Processor

The delivery processor is composed of:

- the navigation processor that uses the resulting learning object network to navigate through learning objects in order to deliver an appropriate pedagogical sequence (with explicit relations other than sequential ones) according to user's needs.
- the presentation processor that delivers the result of the navigation processor in an adequate format according to user's interface (used API).

Knowledge processors: Phoenix and the relation miner

The aim of the knowledge processors is to provide a self-controlled LOR benefitting from LO reuse. In fact, a learning object change context everytime it is reused. Finding the reused object in its former context helps insert and connect new Los belonging to its new context in the eXtended LOR. For that, the authoring tool helps create learning objects to be inserted into the LOR. In our research team, we are developing an authoring tool called Phoenix allowing the edition and pedagogical segmentation process. The relation miner is relating new inserted objects with older ones.

Authoring Tool: Phoenix

In the framework of the segmentation of a single document, we made the assumption that a domain could be represented by a finite number of presentation chains, each containing at least the contextual definition of a concept [Wentland 94]. Each concept could be further explicited through a series of pedagogical arguments that were graphically regrouped to constitute the above mentioned presentation chain. Segmenting a document consists precisely in identifying and marking the concepts and their related presentation chains in order to construct meaningful and contextually pertinent pedagogical chains. We could say that the biggest granularity of a document is the document itself while the smallest is any of the identified elements.
The entities it can be composed of are the following:

- A Concept is a semantic element explicitly defined in the text. Its definition refers to either already identified concepts or of prerequisites defined elsewhere. It is characterized by a presentation order, a label, a gender, a type, a complexity degree and a content.
- An Argument is a semantic element that refers to a concept and is used to help familiarize with, clarify or reinforce the concept. An argument is characterized by its pedagogical function and role, according to an existing typology [Wentland 94].
- A Solved problem is a special type of argument that refers to several concepts.
- A Simple Text is a simple element used to handle unmarked text.

The resulting semantic network highlights the definitional relationships between the concepts and the links between a concept and the pedagogical entities that are related to it in order to reach a pedagogical goal [Wentland&al 95a] [Wentland&al 95b]. For example, in $C_5 = C_1 \Re C_2 \Re P_3$, the "=" relation is a tertiary one. $\Re$ represents the definitional relationship that C_5 has with the other predefined concepts C_1 and C_2 and with a pre-requisite P_3. To understand Concept C_5 one must have previously understood concepts C_1 and C_2, that are to be found in the same hyper document, as well as pre-requisite P_3 to be found elsewhere.
Figure 4 represents the semantic network generated by Phoenix tool that allows segmenting any document regardless of its format (HTML, Text, Sephyr, and Phoenix). This tool generates a phoenix document (.phx) which is a compressed file that includes an XML document including images or video clips.

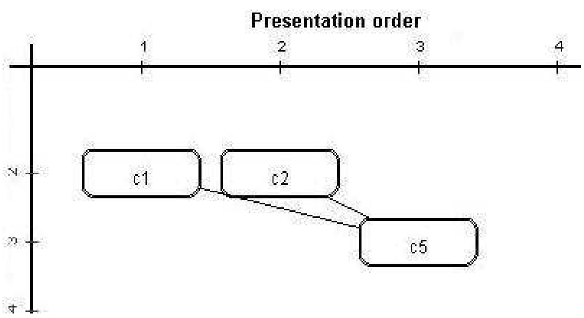

Figure 4: The semantic network by Phoenix tool

Communication Phoenix/KPS

To facilitate submitting queries and getting results, learning objects are often associated to its Meta data which consists of information about their content, audience and format. In the context of ARIADNE [2], we use the Knowledge Pool System (KPS) [Duval&al 01] as a LOR. Via web services [Ternier 03], on one hand, the user can retrieve the information he chooses by defining his criteria: key words, file format, and so on. The file downloaded from KPS has a Learning Object Metadata (LOM) [LOM 00] header. A Phoenix user is not required to define a new header, the LOM one is reusable as such. Besides, the original information (such as author, publication date, and so on) is preserved. On the other hand, he can insert his phoenix document (already indexed) into the KPS. This document is then decomposed [Madhour&al 05] following our already defined taxonomy called Semantic Learning Model [Fernandes&al 05b].
Assumption 1[SEPHYR 02]

> As a learning object is *any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning,* we can assume that a presentation chain is a learning object.

In this article, we assume that phoenix tool produces a presentation chain as a learning object to be inserted into our LOR. It associates to it its semantic network as the context of this learning object. We will describe after how this semantic network will serve to relate the new learning object to older ones.

Relation miner

We distinguish three categories of relation miner: sequential linker, network matcher and relationship definer.

Sequential linker

SLM [Fernandes&al 05b] was conceived to support reusability based on the principle that having different levels of granularity enhances reusability. In this article, we will focus on the context level.
The context is represented by a semantic network which is a rigid structure (one to many). A semantic network is a set of presentation chains. A presentation chain is a concept related to 0 or many argument(s).
In a presentation chain, eventual argument(s) can have three types of relationships with its corresponding concept [Wentland 94]:

- Familiarize: this function aims to familiarize the learner to the correspondent concept. It introduces, define, simplify, compare, remind or digress the concept.
- Clarify: this function aims to clarify a concept by giving observations, demonstrations, descriptions or reformulations.
- Reinforce: Reinforce a concept means illustrate, discuss, corroborate, justify or recapitulate it.

Assumption 2:

> A presentation chain is described by its concept because it is the only mandatory element. For that reason and for a simplification aim, we assume that a presentation chain is a *black box* that can be eventually considered as a *concept*.

For navigation purpose, we have to transform this context into a graph.
Considering contexts which have common pedagogical information (concept or argument), we can transform them to obtain a graph G: $< Pc_i, R_i >$ Where Pc_i represents presentation chains and R_i represents relationships between Pc_i .
Either definional relations (DEF), we distinguish two other types of relationships:

- Presentation Order: In this category, we can have two cases:
  SEQ: A concept C1 (eventually a presentation chain) whose presentation order attribute is equal to i have a sequence relationship (SEQ) with C2 if the presentation order attribute of C2 is equal to i+1 and no other concept (eventually a presentation chain) has presentation order attribute equal to i+1.
  ALT: A concept C3 (eventually a presentation chain) whose presentation order attribute is equal to i have an alternative relationship (ALT) with C4 if the presentation order attribute of C4 is equal to i+1 and it exists at least another concept (eventually a presentation chain) (ex. C5) whose presentation order attribute is equal to i+1.

(Fig. 5) represents the result of the sequential linking process applied to the semantic network of figure 4.

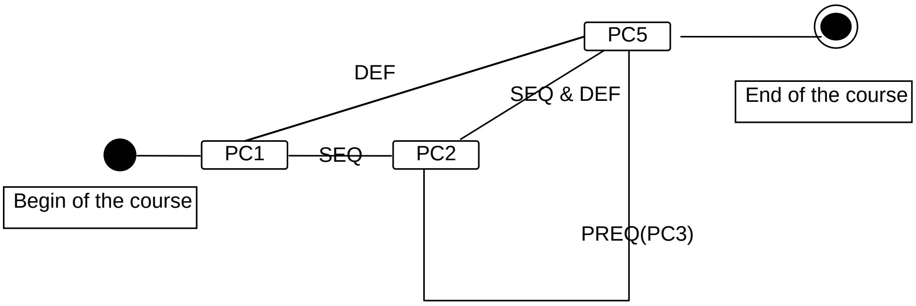

Figure 5: Sequential linking result

- Navigation requirement: this relationship is essentially the prerequisite relationship (PREQ) between two concepts (eventually two presentation chains).
  There are two kinds of relationship: internal and external
  Internal: A concept C1 have a PREQ relationship with C3 based on the acquisition of the concept C2 if C2 must be learned before learning C3 and C2 is belonging to Pi. It is important to notice that it is not essential to learn C2 after C1. C2 may be learned at any time (before or after C1) but before reaching C3.
  External: : A concept C2 have a PREQ relationship with C6 based on the acquisition of the concept C'1 if C'1 must be learned before learning C6 and C'1 does not belong to Pi.

We obtain then a set of graphs; we must notice that those graphs are digraphs because we can have different relationship between two presentation chains depending on the user properties.

Network matcher

We note:

Lo_{new}: The new inserted learning object.

Lo_{old}: Any existing learning object

LON: the existing learning object network.

A Lo_{new} has a related conceptual network that we note: Net (Lo_{new}). For example, to insert PC1, Net(PC1) is the graph represented by figure5.

Two scenarios are possible (Fig. 6):

- Similarity matching function finds some similarities between Net (Lo_{new}) and LON. In this case, we can perform a sequential linking process as it is described in the previous section and then we can change sequential relationship into more explicit one.
- Similarity matching function doesn't find similarities between Net (Lo_{new}) and LON. In this case, we have to define directly relationships.

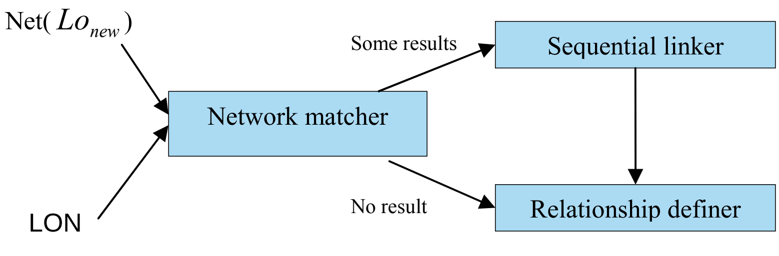

Figure 6: Network matcher

Relationship definer

We can define relationship either manually or automatically:

- Manual definition: Both author and user can define relationships between learning objects.
  Author: the semantic network designer can in the same time define manually relationship between presentations chains composing his network. The segmentation process is not automatic because we estimate that the author is the most reliable actor to do this task. For the same reason, the linking process is done manually. The author can also validate modified relationships.
  User: We denote a user, the learner and the *reuser* (the person who want to reuse a resource). In this case, we can propose to the user to modify a sequential link into a more explicit link:
  This modification is not considered by the same way for the two kinds of user: in fact, for the learner case, it must be a majority of learners who propose the same relationship to modify definitively this relationship. For the reuser who is a special author, the confidence degree is higher. So, his modification is more reliable and it can be earlier considered.
- Automatic definition: Ontology based linker uses ontology (Fig.7) to define or modify (if sequential relationship) relationship between Lo_{new} and Lo_{old} .

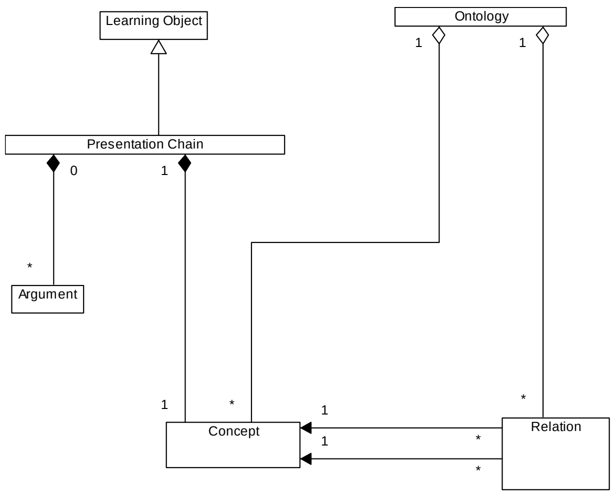

Figure 7: Relationship ontology

Conclusion

The article features a level of navigation upon learning objects repositories, and learning objects in order to facilitate their reusability, by facilitating the identification of their relations with other learning objects. Those relations have to be drawn manually or automatically according to the orientation of the scientific research on Ontology, Semantic web or/and all languages allowing the expression of relations between concepts. By defining such a level of navigation, we can address either authors and learners with the same system, even if their objectives of accessing those learning objects are not the similar. Unlike other knowledge sources, the proposed one is self-controlled. Moreover, learning object reuse will help to proliferate implicitely the knowledge domain. Our future work will probably rely on the definition of a common formalism [Miniaoui&al, to be published], to express relations understandable by each concerned domain, and find the algorithm allowing the network matching. By the way some new problems will emerge like the way of identifying how a learning object has been modified, and some copyrights problems linked with the intellectual property.

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