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# OrPAF: an Environment of Adaptive Hypermedia Courses in the Semantic Web Context

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## **ABSTRACT**

Adaptive learning support for learners becomes very important in the context of increasing re-use of resources from heterogeneous and distributed learning repositories. This chapter presents OrPAF, an Adaptive Educational Hypermedia (AEHS) and web-based System which integrates semantic web models and technologies in order to achieve interoperability with e-learning systems. The key feature of OrPAF is the construction of adaptive hypermedia courses: both the course structure and the course content are dynamically generated and adapted to learners. On the one hand, a learning ontology is proposed to describe, at a meta-level, abstract characteristics of an e-learning system. This learning ontology is instantiated to construct learning models: domain model, learner model and pedagogical model. On the other hand, semantic annotations and a semantic relevance measure are proposed to improve the LOM metadata associated to learning resources in order to reuse and share them. We experimented the realized prototype on learners in order to evaluate the usability of OrPAF and conceptual capabilities developed by learners who used it.

Keywords: hypermedia technologies, web-based education, ontology, metadata.

## **INTRODUCTION**

Many researches propose personalized learning supports in order to reuse and share learning resources from distributed repositories (Nejdl, Wolf, Qu, Decker, Sintek, Naeve, Nilsson, Palmer, & Risch, 2002; Miklos, Neumann, Zdun, & Sintek, 2003; Dolog, Henze, Nejdl, & Sintek, 2004). The personalization of existing learning resources can be a solution to the problem of developing online courses. However, the personalized learning that used distributed metadata of learning resources is still an unsolved problem in the e-Learning research area.

Considering the increasing re-use of learning resources from the Web it becomes almost impossible for the learners, experts and formation responsible to get an overview of all the

available information relevant to their current needs, tasks, roles and goals. And even if they find some materials, which seem suitable, they are not able to assess completely whether the found content is entirely appropriate for their goals or current knowledge and cognitive state. For that reason, learning resources searched from web repositories must be first subject to a pedagogy engineering work in order to give them reusable in the context of a specific training for specific learners. This engineering work is time and effort consuming in the design step of an e-learning system. To solve this problem, we propose an approach that moves part of this engineering effort from the training responsible/ expert to the software system and delivers an adaptive hypermedia course directly to learners.

In this context we aim to offer personalized course support which generates dynamically, for each learner, an individualized course structure and an individualized course content by selecting the most optimal learning topics (e.g. the topic Function in the Algorithmic and Programming Languages domain) and the most relevant learning web resources (e.g. the Definition of the topic Function) at any moment. Optimal learning topics and associated relevant learning resources are selected to bring the learner closest to his/her ultimate learning goal. This approach is well suited for individual and autonomous learners taking a self-study distance-learning course. They can be employees in an organization who have various experiences and background knowledge and where employees evolve in competitive economic environment and require long life learning.

We propose a learning environment which generates adaptive hypermedia courses and reuses learning resources from distant web repositories, called « Organisateur de Parcours Adaptatifs de Formation » (OrPAF) (Yessad, Faron, Dieng, & Laskri, 2008). Queried learning resources are already annotated with LOM metadata but stay very difficult to reuse automatically because of the semantic lack of LOM metadata. Our work is based on semantic web models, particularly ontologies and semantic annotations, in order to improve the quality of LOM metadata and describe in a standardized way several characteristics of e-learning system (e.g. learning resource, pedagogical strategy, learner model). The semantic Web for E-Learning (SW-EL) field has shown the greatest activity in this trend with several interesting and recurring practices (Dolog & Nejdil, 2003; Aroyo & Dicheva, 2004; Yessad & Laskri, 2006). Our aim is to improve the learning process efficiency (1) by providing the learner with adaptive learning paths according to his/her level of knowledge, learning goal and time constraints; and (2) by reusing learning resources of different web repositories. On the one hand, an adaptive learning path is constructed on the base of the conceptual structure of the domain model (e.g. the Algorithmic and Programming Languages domain) and the learner model (e.g. beginner). In the learning environment, the learner is assisted to construct a «correct» representation of a particular domain of knowledge and the learning is self regulated (Pintrich & Schunk, 2002; Perry, Phillips, & Hutchinson, 2004). For this purpose, we apply filters on the domain model to generate a map of relevant learning topics. We call this map Adaptive Conceptual Map (ACM). An ACM is automatically generated and displayed to a learner, which takes into account a specific goal, the knowledge and temporal constraints of the learner. An ACM represents an adapted view of the structure of the hypermedia course. On the other hand, learning resources that are queried from distant web

repositories like ARIADNE or created locally by domain experts are annotated by adding a conceptual layer on LOM metadata description layer. We propose a measure to evaluate the semantic relevance of annotated learning resources in order to associate them to the generated ACM and recommend them to the learner.

This chapter is organized as follows: the next section presents an overview and the positioning of our learning environment approach. Then, we show how we represent e-learning knowledge in a meta-model and how we use it to construct different e-learning models. After that, we explain the generation of an adaptive structure and an adaptive content of the hypermedia course. The last section is dedicated the implementation of OrPAF and our evaluation protocol.

## **POSITIONNING**

Representative examples of personalized support for learners are adaptive textbooks constructed with AHA! (De Bra, Aerts, Berden, de Lange, Rousseau, Santic, Smits, & Stash, 2003), InterBook (Brusilovsky, Eklund, & Schwarz, 1998) and Net-Coach (Weber, Kuhl, & Weibelzahl, 2001), or adaptive courses within ELM-ART (Brusilovsky, Schwartz, & Weber, 1996), PAT (Ritter, 1997) and AIMS (Aroyo & Dicheva, 2001). There are also more global but still highly specialized efforts, such as ARIADNE and EdNa courseware-reusability frameworks that provide repositories of reusable learning resources. In this context, our research aims to propose a learning environment which is an adaptive educational hypermedia and web-based system (AEHS). Our learning environment integrates semantic web models and technologies like ontologies, semantic annotation and learning standards in order to achieve interoperability with e-learning systems and then to improve the reusing of its components.

Similarly to the Dynamic Course Generation system (Brusilovsky & Vassileva, 2003) and researches of (Ullrich, 2004) and (Dehors, Faron-Zucker, & Dieng-Kuntz, 2006), the core of our learning environment is the explicit representation of the domain model, separated from learning resources and pedagogical strategies. We define a learning ontology that describes characteristics of e-learning systems (e.g. learner, pedagogical activity). This learning ontology is a meta-model which describes abstract learning characteristic independent of a specific learner, a specific domain (e.g. the Algorithmic and Programming Languages domain), a specific pedagogical strategy (e.g. the deductive strategy) or a specific learning resource (e.g. Slides created by JamesRumbaugh introduce the Object Modelling notion). The meta-model is instantiated to construct specific learning models: the domain model, the learner model and the pedagogical model. Contrary to the learning ontology, these models describe respectively learning topics of a specific domain (e.g. Arithmetic Operators in the Algorithmic and Programming Languages domain), a specific learner and a specific pedagogical strategy (e.g. inductive strategy). In contrast with other approaches mentioned above, by the addition of learning characteristics at the meta-model makes easier the extensibility of our learning system.

In authoring tools like InterBook (Brusilovsky et al., 1998), MetaLinks (Murray, 2001), and NetCoach (Weber et al., 2001), the expert explicitly provides the course structure as a

textbook hierarchy (like page1 has subsection page1-1) whereas, in our approach, the structure of the course is an Adaptive Conceptual Map (ACM), a graph of domain topics. In fact, we use the structure of the domain model as a roadmap to generate course paths. Given a certain goal topic (e.g. Arithmetic Operator in the Algebra Domain) that the learner wants to acquire and given his/her learner model, our learning environment generates a map of learning topics to the learner in order to achieve his/her goal.

Moreover, our learning environment implements a query component. This component uses a semantic measure to detect the relevance of learning resources by computing the similarity between the ACM and the resource annotations and so, the semantic measure depends on the learning context of the learner. Much research proposes to query resources from the web by relaxing the topics of the query to other topics close to them in the domain model. The close topics are chosen by using similarity measures.

We can consider that there are two big families of approaches to compute the semantic similarity. On the one hand, approaches that use only the subsumption relationship to compute the semantic similarity (Corby, Dieng-Kuntz, & Faron-Zucker, 2004; Rada, Mili, Bicknell, & Blettner, 1989; Wu & Palmer, 1994). On the other hand, approaches which include besides the subsumption relationship other information. This information can be statistics about the use of concepts in corpus (Resnik, 1995; Jiang & Conrath, 1997). Particularly, the research of (Jiang et al., 1997; Lin, 1998) introduces the notion of conditional probability of encountering an instance of a child-concept given an instance of a parent-concept.

Among the measures that are based on the context there is the approach of (Torniai, Jovanovic, Gasevic, Batemen & Hatala, 2008) which propose a weight-based measure to contextualize semantic relatedness measures in order to leveraging folksonomies for domain ontology evolution. Similarly to previous researches, this measure is based only on the concept hierarchy.

Similarly to our approach, the research of (Zhong, Zhu, Li, & Yu, 2002) defines a similarity measure between conceptual graphs: a query graph and a resource graph. However, the originality of our approach stands in the use of a relative weight-based relevance measure where the weights of the topics depend on the learning context and are not fixed in advance.

## **LEARNING ENVIRONMENT KNOWLEDGE**

Because of the increasing complexity and heterogeneity of knowledge in e-learning systems (e.g. domain knowledge, learner knowledge, pedagogical knowledge), we require an efficient and modular knowledge organization. We represent our learning environment knowledge in two levels: meta-model level and model level. The meta-model knowledge is used to construct learning models which are used by functional components of the learning environment: Querying resource components, annotation component, testing component, and course generation component (cf. figure 1).

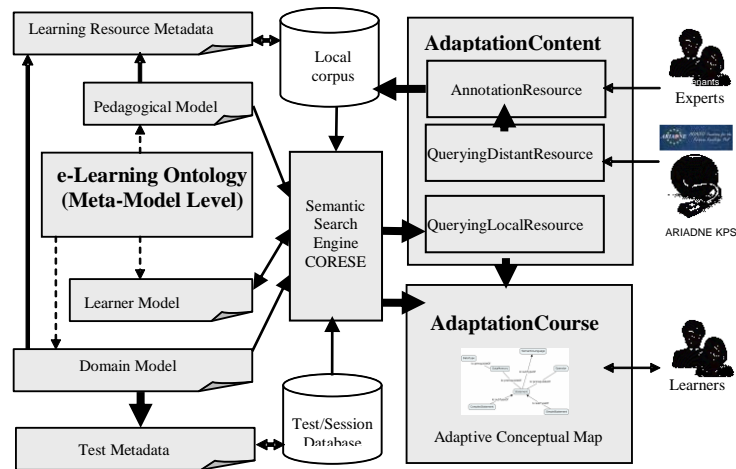


Figure 1. Architecture of the OrPAF system

### Learning Ontology

The learning ontology we developed is the meta-model and the backbone of the learning process. It describes concepts and properties that are instantiated in order to specify the domain of interest (e.g. Algorithmic and programming languages), profiles of the learners (e.g. beginner), pedagogical strategies (e.g. deductive strategy) and annotations of learning resources (e.g. learning resource role). Formally, we define a learning ontology LO as follows:

$LO = (C, P, H^c, H^p, \text{Signature}, \text{Rules})$ , where:

- C and P are two disjoint sets, whose elements are called respectively concepts and properties. Each of these elements is identified with a URI (Unique Resource Identifier).
- $H^c$  is a concept hierarchy, which is an acyclic directed graph  $H^c \subseteq C \times C$ .  $H^c(c_1, c_2)$  means that  $c_1$  is a sub-concept of  $c_2$ .
- $H^p$  is the property hierarchy, which is an acyclic directed graph  $H^p \subseteq P \times P$ .  $H^p(p_1, p_2)$  means that  $p_1$  is a sub-property of  $p_2$ .
- Signature:  $P \rightarrow C \times C$  is a function which relates concepts and defines the signature of any property p. The function domain:  $P \rightarrow C$  with  $\text{domain}(p) = \prod 1(\text{Signature}(p))$  gives the domain of p and the function range:  $P \rightarrow C$  with  $\text{range}(p) = \prod 2(\text{Signature}(p))$  gives its range.
- Rules is a set of rules on C and P.

Concepts and properties are seen as general objects. So, the learning ontology (meta-model) is instantiated to construct three learning models: a domain model, a learner model and a pedagogical model. Contrary to the learning ontology, these models describe specific objects. For instance, in the learning ontology, we describe types of learning topics of a domain (e.g. a medium topic) and relationships between these types (e.g. prerequisite relationship) whereas in the domain model we describe concrete learning topics and their relationships. For instance, the topic *Operator* and the topic *Statement* are instances of the concept

*LearningTopic* defined in the meta-model (cf. figure 2); and in the domain model, the topic *Operator* is related to the topic *Statement* by the relationship *prerequisiteOf* (cf. figure 3). The concepts of the learning ontology are hierarchically organized with one general and abstract concept called *ELearningConcept*. The concept *ELearningConcept* has three direct sub-concepts: *LearningTopic*, *LearningPerson* and *LearningPedagogy* which are used to construct respectively the domain model, the learner model and the pedagogical model. For example, all learning topics of the domain model are instances of sub-concepts of the concept *LearningTopic*. Similarly, properties of the learning ontology are hierarchically organized with one general and abstract property called *eLearningProperty*. The property *eLearningProperty* is specialized in three sub-properties: *learningTopicProperty*, *learnerProperty* and *pedagogicalProperty*. The set Rules is a set of rules and concerns the concepts and the properties of the learning ontology. For instance, we can have a rule which describes that the property *prerequisiteOf* is not a symmetric relation or that the property *subTypeOf* is a transitive relation.

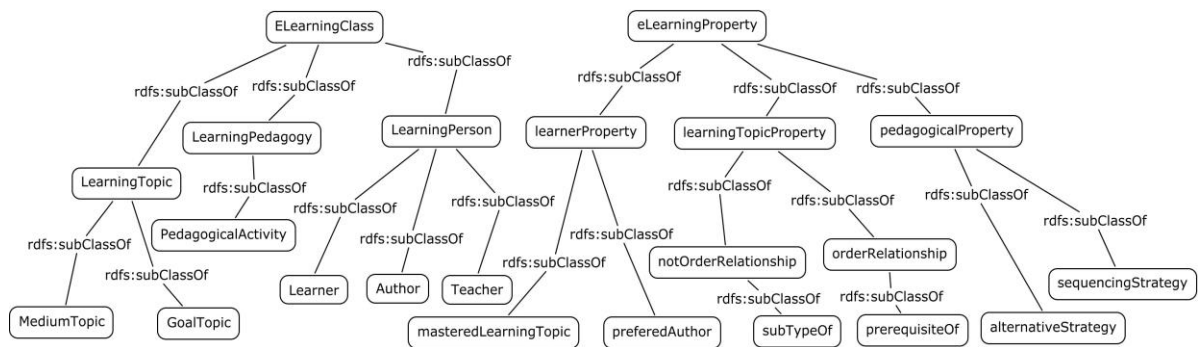


Figure 2. An excerpt of learning ontology

The concepts and the properties of the learning ontology are described in the OWL language (<http://www.w3.org/TR/owl-features/>). For example the concepts *Learner* and *Author* are described in the learning ontology as sub-concepts of the concept *LearningPerson* and are used in the system OrPAF to define the learners and the learning resource authors:

```
<owl:Class rdf:ID="LearningPerson">
  <rdfs:subClassOf rdf:resource="#ELearningClass"/>
</owl:Class>
<owl:Class rdf:ID="Learner">
  <rdfs:subClassOf rdf:resource="#LearningPerson"/>
</owl:Class>
<owl:Class rdf:ID="Author">
  <rdfs:subClassOf rdf:resource="#LearningPerson"/>
</owl:Class>
```

For example the property *preferredAuthor* connects the concept *Learner* to the concept *Author* and signifies that a learner prefers an author.

```
<owl:ObjectProperty rdf:ID="preferredAuthor">
  <rdfs:subPropertyOf rdf:resource="#learnerProperty"/>
  <rdfs:domain rdf:resource="#Learner"/>
  <rdfs:range rdf:resource="#Author"/>
</owl:ObjectProperty>
```

### **Learning Models**

The learning ontology is instantiated into three learning models: the domain model, the learner model and the pedagogical model. Formally, we define a learning model LM as follows:

LM = (LO, I, InstC, InstP), where:

- LO=(C, P, H<sup>c</sup>, H<sup>p</sup>, Signature) is the learning ontology.
- I is a set of instances (C, P and I are disjoint sets).
- InstC:  $C \rightarrow 2^I$  is a function which defines the instances of concepts in C.
- InstP:  $P \rightarrow 2^{I \times I}$  is a function which defines the instances of properties in P.

### **Domain Model**

The domain model represents the domain of interest where the learner evolves. A specific domain of interest (e.g. Algorithmic and programming languages) is described by learning topics and their mutual relationships in a specific discipline. In figure 3, we show a fragment of the domain knowledge covering learning topics of « Algorithmic and programming languages » domain, including the *subTypeOf* and the *prerequisiteOf* relationships between learning topics.

We build Adaptive Conceptual Map (ACM) by filtering the domain model. An ACM is a sub-graph of the whole graph of related learning topics. It is used by a learner to construct his/her cognitive representation of the domain of interest in order to achieve his/her learning goal.

Learning topics related with an order relationship (e.g. *prerequisiteOf*) must be taught following a certain order.



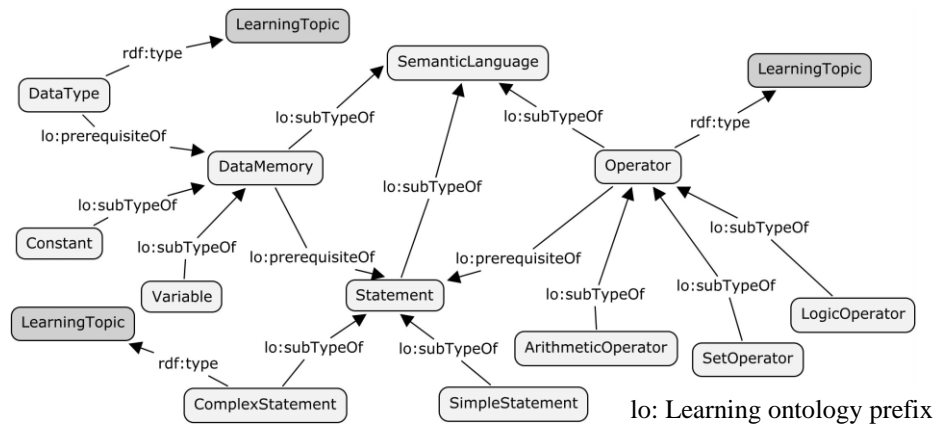


Figure 3. An excerpt of the domain model « Algorithmic and programming languages »

The learning topics of the domain « Algorithmic and programming languages » are described by RDF triplets (<http://www.w3.org/TR/REC-rdf-syntax/>). For example the topic *Statement* is an instance of the concept *MediumTopic* and a generalization of the topic *ArithmeticStatement*. The topic *Operator* is a prerequisite of the topic *ArithmeticStatement*.

```
<MediumTopic rdf:ID="ArithmeticStatement">
  <lo:subTypeOf>
    <GoalTopic rdf:ID="Statement">
      </GoalTopic>
    </lo:subTypeOf>
  <lo:hasprerequisite>
    <MediumTopic rdf:ID="Operator"/>
  </lo:hasprerequisite>
</MediumTopic>
```

### ***Learner Model***

The learner model captures knowledge and preferences of the learner. It represents what the system knows about the learner. In our learning environment, we represent the knowledge of the learner by the overlay model (Galeev, Tararina, & Kolosov, 2004). For instance, as shown in figure 4, if the learning topic *Operator* is mastered by the learner *Rose*, the knowledge  $\langle \textit{Rose}, \textit{masteredLearningTopic}, \textit{Operator} \rangle$  occurs in the learner model, else the topic *Operator* is unknown by the learner *Rose*. The learner model changes during the learning process when the learner passes tests. In this way, our learning environment provides mechanism for self regulated learning (Pintrich & Schunk, 2002; Perry et al., 2004).

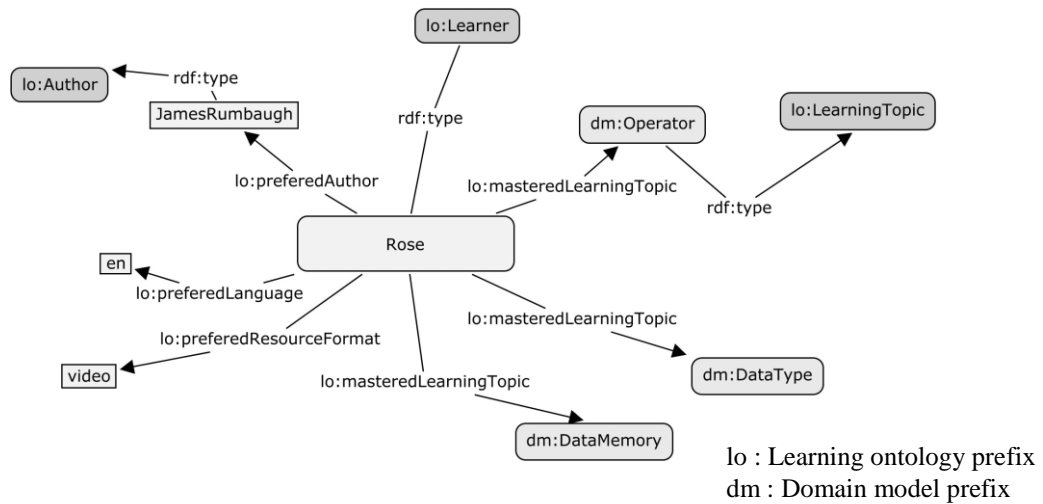


Figure 4. An excerpt of a learner model

### ***Pedagogical Model***

The structure of the domain model alone is not sufficient to decide how to present the selected learning topic to the learner, i.e. what pedagogical type of learning resources to select, or how to sequence several learning resources to teach a given learning topic. For this purpose, we define a pedagogical model which describes pedagogical strategies to teach learning topics. It describes different pedagogical activities (e.g. *Exercise*, *Lecture*) and their relationships. For instance, as shown in figure 5, the *Definition* activity (instance of the concept *PedagogicalActivity* in the meta-model) must precede the *Exercise* activity; both activities are related by the *sequencingStrategy* property which is defined in the meta-model. The *alternativeStrategy* relationship between pedagogical activities means that learning resources related to these pedagogical activities can be accessed by a learner in any order whereas the *sequencingStrategy* relationship requires an order in the presentation of learning resources to the learner.

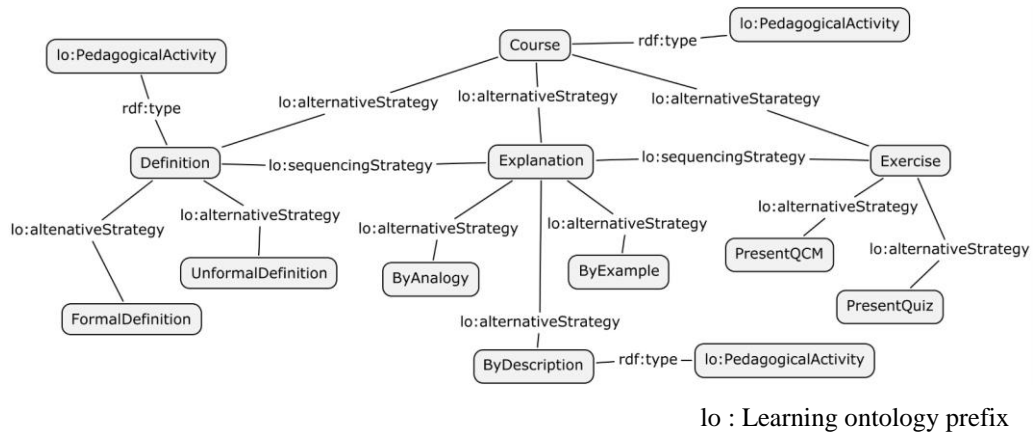


Figure 5. An excerpt of the pedagogical model

## ADAPTIVE COURSE GENERATION

The learning environment aims to construct a hypermedia course as combination of an adaptive course structure and adaptive course content. The course structure is represented by an Adaptive Conceptual Map and the course content is a set of reused relevant learning resources searched from external learning repositories.

### Adaptive Conceptual Map (ACM)

An ACM is a course structure generated and displayed by the learning environment in order to help the learner to construct a «correct» mental representation of the learning domain. It is a sub-graph of the domain model and contains learning topics that the learner must learn to achieve his goal in required time. An ACM enables the learner to navigate between the learning topics of the course. We distinguish between three conceptual maps constructed on the goal topic  $G$  of the domain model (DM): simple  $M_s(G)$ , hierarchical  $M_h(G)$  and relational  $M_{r,m}(G)$ . Each one of these maps results from the application of a specific filter on the domain model and only the topics which pass the filter are displayed to the learner.

- Simple  $M_s(G)$  is the smallest map. It is composed of the goal topic and all topics related to it directly or by transitive closure of order relationships.

$$M_s(G) = \{G\} \cup \{t \in \text{InstC}(\text{DM}) / \exists p \in \text{orderRelationship } p^t(t, G)\}$$

- Hierarchical  $M_h(G)$  is the conceptual map that extends the simple conceptual map to descendants and ascendants of the goal topic.

$$M_h(G) = M_s(F), \text{ where } F = \{G\} \cup \{c \in \text{InstC}(\text{DM}) / \text{subTypeOf}(G, c) \vee \text{subTypeOf}(c, G)\}$$

- Relational  $M_{r,m}(G)$  is the conceptual map that extends the simple conceptual map to all topics related to the goal topic by a path of relationships, the length of this path being less than  $m$ .

$M_{r,m}(G) = M_s(F)$ , where  $F = \{G\} \cup \{t \in \text{InstC}(\text{DM}) \mid \forall p \in \text{learningTopicProperty} (p^l(G, t) \vee p^l(t, G)) \wedge \text{length}(G, t) \leq m\}$

OrPAF implements each of these three filters. For the same topic goal, the filter depends on learner temporal constraints: the simple filter for learners with hard temporal constraints, the hierarchical filter for learners with medium temporal constraints and the extended filter for learners with flexible or no temporal constraints. This approach can be compared to the micro, the meso and the macro learning approaches (Hug, 2005).

Before displaying the ACM to a learner, an additional adaptation layer is applied on it. It consists of applying rules in order to annotate each learning topic similarly to link annotation technique in adaptive Hypermedia (De Bra, Brusilovsky, & Houben, 1999). Different icons represent different states of a learning topic (cf. figure 6). A learning topic is accessible to learn if all its prerequisites are mastered by the learner. Elsewhere, the learning topic is not accessible to learn and no learning resources are attached to it. A topic without prerequisites is always accessible. In our environment, we distinguish also between a mastered topic and not yet mastered topic. Graphical icons are used to represent the difference between these three learning topic states. For instance, figure 6 presents an ACM where the learning topic *Operator* is mastered, the learning topic *Procedure* is not mastered and the learning topic *SemanticLanguage* is not accessible. The state of a learning topic can change from inaccessible state to accessible state if its prerequisites become mastered. Also, it can change from non mastered state to mastered state. These alterations in the ACM result from updating the learner model.

### **Adaptive Course Content**

In our work, learning resources are files with different formats (.pdf, .doc, .html, etc.) queried from web repositories. In our prototype, we use the ARIADNE Knowledge Pool System (ARIADNE KPS), a distributed database of learning resources annotated with LOM metadata elements. In the learning environment, we propose: (1) A conceptual annotation process for annotating learning resources and (2) a query component for querying learning resources from the local repository.

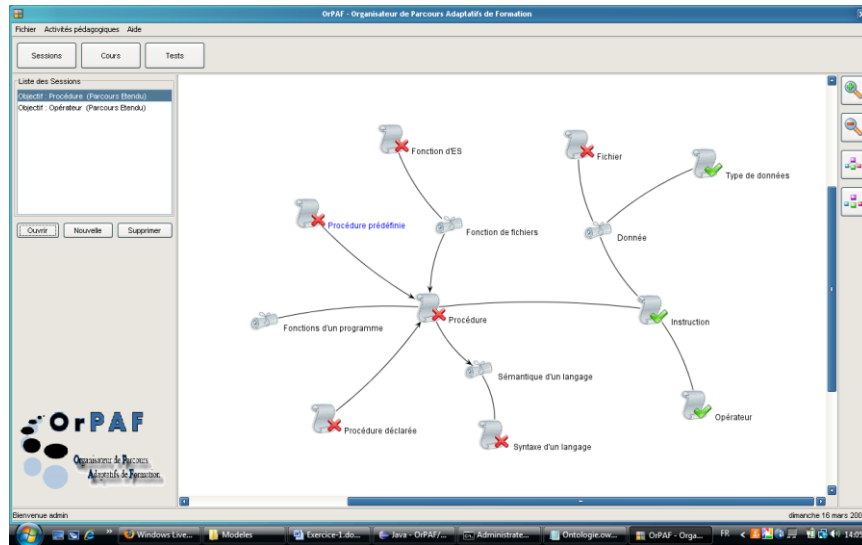


Figure 6. A screenshot of course structure

### ***Annotating Learning Resources***

Once a distant learning resource is downloaded, it is submitted to a semi-automatic annotation process assisted by a teacher/expert; and finally the learning resource is stored in a local repository. Conceptual annotations of the learning resource are constructed by instantiating some concepts and properties from both the domain model and the pedagogical model. For instance, in figure 7, the learning resource *RI* is an *Exercise* (defined as *PedagogicalActivity* in the pedagogical model) and teaches the learning topic *ComposedStatement* (defined as a *LearningTopic* in the domain model). Characteristics (e.g. *learningResourceTopic*, *learningResourceRole*, *learningResourceAuthor*) of the resource are manually identified by experts and annotations are automatically generated by the system according to learning models. The so-built conceptual annotations are then added to learning resource metadata (in our case, the RDF-LOM binding metadata).

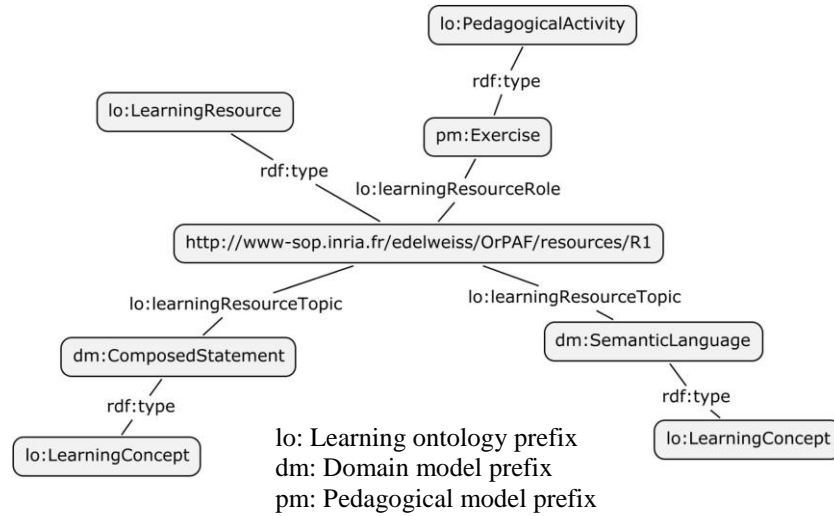


Figure 7. An excerpt of the conceptual annotation of a learning resource R1

### ***Querying a Local Learning Resource***

The learner can consult resources about accessible learning topics in his/her ACM by a simple click on it. The querying component searches for relevant learning resources from the local repository. It computes the relevance of a learning resource by matching its conceptual annotations with the ACM.

We propose an approach for computing the semantic relevance of a learning resource in a particular learning context. In our case, the learning context is composed of the current learning topic (the topic clicked by the learner) and the state of the ACM. Only learning topics of conceptual annotations are used in the calculus of the semantic relevance. Our calculus relies on the assignment of a relative weight to each learning topic related to the learning resource. These relative weights depend on the current topic in the ACM and the type of relationships that connect the current topic to topics related to the learning resource. Let  $P \langle t_1, t_2, t_3, \dots, t_n \rangle$  be a learning path of length  $n$  and composed of topics  $t_i$ . Let  $w_{t_i/t_1}$  ( $i > 1$ ) be the weight of topic  $t_i$  relative to the current  $t_1$  topic in the ACM. Let  $w_{t_1}$  be the weight of the current topic  $t_1$ . We define the relative weight as follows:

$$\begin{aligned}
 W_{t_1/t_1} &= N \\
 W_{t_2/t_1} &= 1/a \\
 W_{t_i/t_1} &= (1/a) W_{t_{i-1}/t_1}, \quad i > 2
 \end{aligned}$$

Where “a” is a variable whose value is as follows:

- a=2 if the relationship between  $t_{i-1}$  and  $t_i$  is *subTypeOf* or its inverse relationship
- a=3 if the relationship between  $t_{i-1}$  and  $t_i$  is *hasPrerequisite* or its inverse relationship
- a=5 if the relationship between  $t_{i-1}$  and  $t_i$  is *aggregationOf* or its inverse relationship

N is the weight of the current concept and chosen as a big number.

Each time that we have a new relationship in the domain model we add a new value to the variable “a”. The inverse value of “a” represents the weight of the relationship connecting two concepts in the domain model. This weight represents the relation strength between nearby concepts.

When there are several relative weights for one learning topic (due to graph cycles) we take the smallest value. Once defined the relative weight of each learning topic related to the learning resource, the semantic relevance SR of the learning resource can be measured as follows:

Let E be the set of topics both present in the learning resource annotation and the accessible topics of the ACM, let F be the set of topics present in the learning resource annotation and not present in the accessible topics of the ACM, and let t be the current concept of the ACM.

$$SR = \frac{\sum_{x \in E} w_{x/t}}{1 + \sum_{y \in F} w_{y/t}}$$

The definition of SR reflects the fact that the weight of a topic depends on the current topic and the state of the ACM and therefore of the learning context. A resource is relevant if its learning topics have important relative weights and are largely similar to the accessible learning topics of the ACM. Otherwise, the resource is less or not relevant.

## **IMPLEMENTATION AND EVALUATION**

### **Implementation**

The implemented prototype of the learning environment integrates several functions to fulfill requirements for the generation of adaptive courses. We used JAVA language for implementing all user interfaces and functional components of OrPAF. The interoperability between the implemented prototype and ARIADNE KPS is implemented by a java API named KPS client package. The learning ontology was described in OWL Lite language and learning models were described in RDF language. OrPAF uses Corese, an ontology-based search engine for the semantic web, dedicated to the query of RDF annotations by using the SPARQL query language (Corby, Dieng-Kuntz, Faron-Zucker, & Gandon, 2006). Corese is used to extract concepts and properties of learning models and conceptual annotations. OrPAF prototype is experimented to teach learning topics of the domain «Algorithmic and programming languages» on a group of thirty learners in graduation of mathematics and computer sciences.

Each learner has to give identification information (username and password) in order to access to OrPAF. Once logged in, he/she can:

- Open a new learning session by submitting his/her learning goal topic and his/her time constraints that define the filter type and therefore the size of the ACM.

- Save a current learning session (the ACM, the learner comments, the relevant learning resources, etc.). The learner sessions are stored in his/her learner model.
- Reload an interrupted session.

### **Evaluation**

We experimented the OrPAF prototype on a group of thirty learners who belong to three different graduation levels. We applied an accurate evaluation protocol: we divided the group of learners into two subgroups A and B. In the first step of the protocol, the learners of the group A used OrPAF whereas the learners of the group B used paper-support resources. In the second step of the protocol, the learners of the group B were invited to use OrPAF. After each step, an exercise was performed by the learners. It aimed to detect the conceptualization capabilities of the learners before and after the use of OrPAF.

The purpose of this evaluation protocol was to analyze behaviour /ratings of the learners according to three orthogonal directions: the usability of OrPAF, the conceptualization capabilities acquired by the learner and the learner ratings of the relevance of learning resources proposed by OrPAF. For each direction, interviews were presented to the learners in order to capture their feedback.

We present in the figure 8 a histogram which synthetizes the results of the evaluation. Each bar of this histogram represents the repartition of the thirty learners according to the OrPAF usability (the first bar), the results of the conceptualization exercises (the second and the third bars) and the learner ratings of the learning resource relevance (the fourth bar). In the first bar, the learners of the group B appreciated OrPAF more than those of group A - certainly because they found that the learning process with OrPAF is easier than the learning process with the paper-support resources. They found more assistance with OrPAF. After the step1, the learners of the group A obtained good results in the exercise of conceptualization whereas, the learners of the group B had difficulties to perform the exercise and obtained bad results (see the second bar). After the step 2, the learners of the group B obtained best results in the exercise of the conceptualization (see the third bar).

The most learners agreed to say that the learning resources which are presented to them are relevant (see the fourth bar).

Therefore, we can conclude that the evaluation of the system OrPAF gives positive results according to the user interface usability, the development of conceptual capabilities of the learner and the relevance of the generated content.



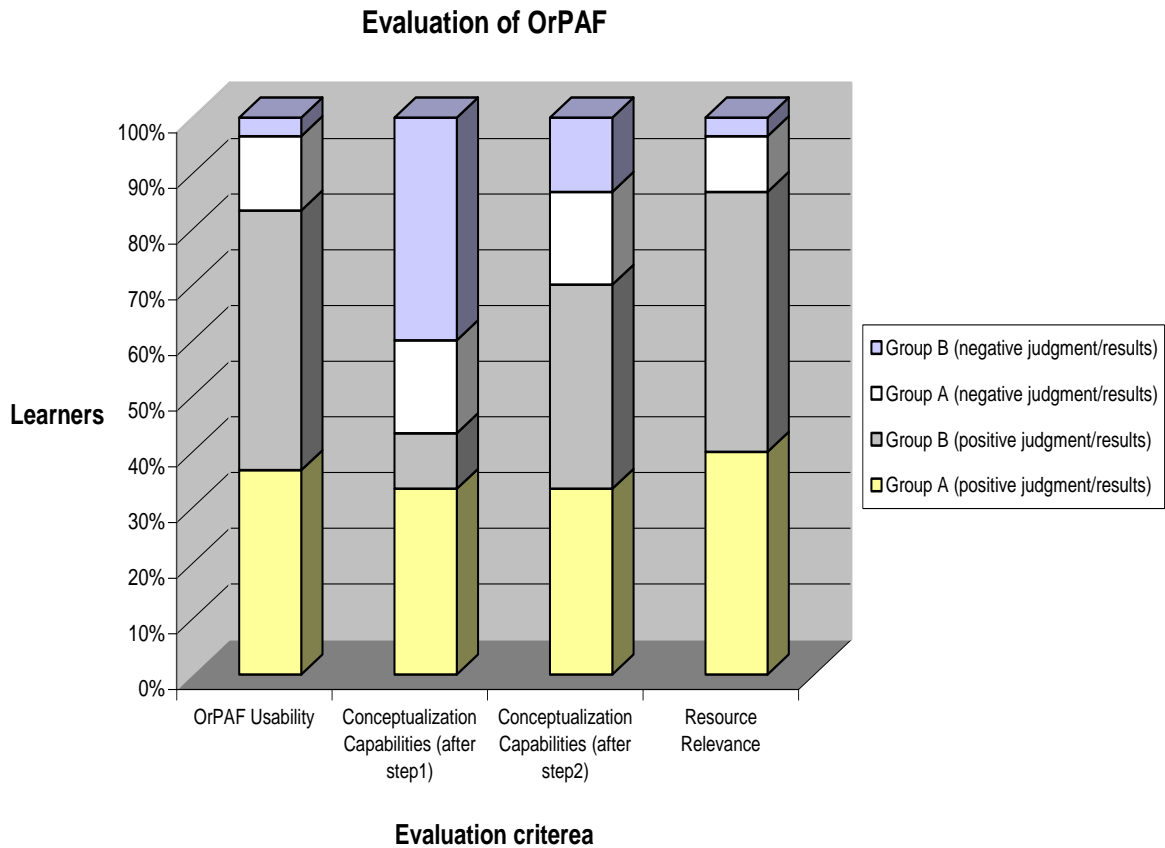


Figure 8. Results of the experimentation of OrPAF on learners

## CONCLUSION

This chapter presents OrPAF, a learning environment for the generation of adaptive hypermedia courses which enables a self-regulated learning for learners with different profiles. OrPAF reuses learning resources from distant web repositories. A learning ontology is proposed to describe, in the meta-level, abstract characteristics of an e-learning system. This learning ontology is instantiated to construct a domain model, a learner model and a pedagogical model which describe concrete characteristics of e-learning systems. As a result, the learning environment is multi-domain and multi-learner profile with minimum changes in the learning models in order to adapt them to new learner profiles and domains. In addition, the common description of all learning characteristics in the learning ontology improves the reusability of the external resources. Contrary to the learning systems, cited in section 2, the learning environment OrPAF provides a personalization support for both course structure and course content; and due to the use of the semantic web technologies is an efficient support with few means.

OrPAF generates a hypermedia course as the combination of an adaptive structure and an adaptive content. On the one hand, the course structure is a map of relevant learning topics. This map is generated by filtering the domain model and applying two layers of adaptation: (1) a first adaptation according to the learning goal and the temporal constraints of the learner; and (2) a second adaptation according to the knowledge of the learner by annotating the topics of the map. On the other hand, an adaptive content consists of relevant learning web resources. We propose a measure of the semantic relevance of a learning resource for a specific learning context. It is based on relative weights of learning topics related to the learning resource. These relative weights depend on the learning context. The experiments of the OrPAF prototype give positive results, both for the usability and the utility of the learning environment. In addition, we can conclude that topic-based course structure develops the conceptualization capabilities of the learners and their mental representation of domains.

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