Adaptive Course Generation in Semantic Web Context

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Abstract. Personalized support for learners becomes very important in the context of increasing re-use of resources from heterogeneous and distributed learning repositories. This paper presents OrPAF, an Adaptive Educational Hypermedia (AEHS) and web-based System which integrates semantic web models and technologies like ontologies, semantic annotations and learning standards 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 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 web resources in order to reuse and share them.

1 Introduction

The Web is becoming a standard platform for providing various kinds of learning resources to support teaching in universities or technical training companies. One of the greatest benefits of the Web is that learning resources created to support a specific course no longer remains the only resources that students can use during the course. Thus, reusing and sharing learning resources distributed in several web repositories reduce the cost and the effort of developing e-learning systems (Dolog, et al., 2004).

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 concepts (e.g. the concept *Function* in the Algorithmic and Programming Languages domain) and the most relevant learning web resources (e.g. the *Definition* of the concept *Function*) at any moment. Optimal learning concepts 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 life-long learning.

More precisely we propose a learning organizer which generates adaptive hypermedia courses and reuses learning resources from distant web repositories, called « Organisateur de Parcours Adaptatifs de Formation» (OrPAF). 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 systems (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 (Aroyo et al., 2004; Yessad, et al., 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 organizer, the learner is assisted to construct a «correct» representation of a particular domain of knowledge and the learning is self regulated (Pintrich et al., 2002). For this purpose, we apply filters on the domain model to generate a map of relevant learning concepts. We call this map Adaptive Cognitive 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 paper is organized as follows: section 2 presents an overview and a positioning of our learning organizer approach. Section 3 shows how we represent e-learning knowledge in a meta-model and how we use it to construct different e-learning models. We explain in section 4 the generation of an adaptive structure and an adaptive content of the hypermedia course. Section 5 is dedicated the implementation of OrPAF and our evaluation protocol.

2 Overview and Positioning

Representative examples of personalized support for learners are adaptive textbooks constructed with AHA! (De Bra et al., 2003), InterBook (Brusilovsky et al., 1998) and Net-Coach (Weber et al., 2001), or adaptive courses within ELM-ART (Brusilovsky et al., 1996), PAT (Ritter, 1997) and AIMS (Aroyo et al., 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 organizer which is an adaptive educational hypermedia and web-based system (AEHS). Our learning organizer integrates semantic web technologies like ontologies, semantic annotation and learning standards in order to achieve interoperability with e-learning systems.

Similarly to the Dynamic Course Generation system (Brusilovsky, et al., 2003) and researches of (Ullrich, 2004) and (Dehors et al., 2006), the core of our learning organizer 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 *ObjectModeling* 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 concepts of a specific domain (e.g. *ArithmeticOperator* 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). In contrast, in our approach, the structure of the course is an Adaptive Cognitive Map (ACM), i.e. a sub-graph of the graph of concepts which represents the domain model. In fact, we use the structure of the domain model as a roadmap to generate course paths. Given a certain goal concept (e.g. *Arithmetic Operator*) that the learner wants to acquire and given his/her learner model, our learning organizer generates a map of learning concepts to the learner in order to achieve his/her goal.

Moreover, our learning organizer implements a query component which uses a measure of the relevance of a particular learning resource for the learning context of the learner. Many researches propose to query resources from the web by relaxing the concepts of the query to other concepts close to them in the domain model. Close concepts are identified by using distance measures. In all these researches (Corby et al, 2004; Zhong et al., 2002; Rada et al., 1989), the distance measure is based on types of learning concepts in the domain model where the distance between concepts is always a constant value. The originality of our approach stands in the use of a relative weight-based relevance measure. Weights of learning concepts depend of the learning context and are not fixed in advance.

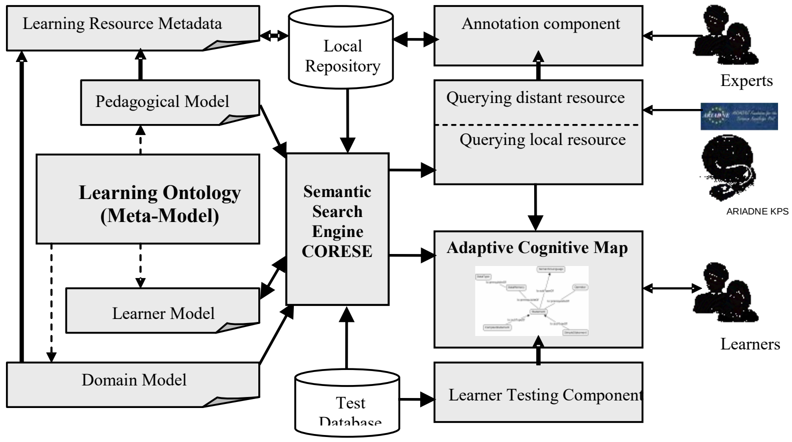

Fig. 1. Architecture of the OrPAF system

3 Meta Model and Models

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 organizer knowledge in two levels: meta-model level and model level.

3.1 Learning Ontology

The learning ontology we developed is the meta-model and the backbone of the learning process. It describes classes and properties that are instantiated in order to specify the domain of interest (e.g. the Algorithmic and Programming Languages domain), profiles of the learners (e.g. a beginner) and pedagogical strategies (e.g. deductive strategy). Classes 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 concepts of a domain (e.g. a *GoalConcept*) and relationships between these types (e.g. *prerequisiteOf* relationship) whereas in the domain model we describe concrete learning concepts and their relationships. For instance, the concept *Operator* and the concept *Statement* are instances of the class *LearningConcept* defined in the meta-model (cf. fig. 2); and in the domain model, the concept *Operator* is related to the concept *Statement* by the relationship *prerequisiteOf* (cf. fig. 3.1).

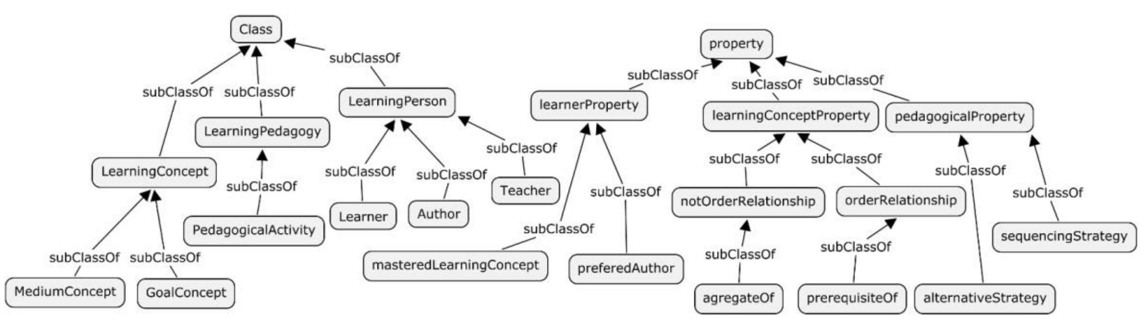

Fig. 2. An excerpt of learning ontology

3.2 Learning Models

The learning ontology is instantiated into three learning models: the domain model, the learner model and the pedagogical model.

Domain Model. The domain model represents the domain of interest where the learner evolves. A specific domain of interest (e.g. the Algorithmic and Programming Languages domain) is described by learning concepts and their mutual relationships in a specific discipline. In fig. 3.1, we show a fragment of the domain knowledge covering learning concepts of Algorithmic and Programming Languages domain, including the *subClassOf* and the *prerequisiteOf* relationships between learning concepts.

Learner Model. The learner model captures knowledge and preferences of the learner. It represents what the system knows about the learner. For instance, as shown in fig.3.2, if the learning concept *Operator* is mastered by the learner *Laura*, the knowledge <*Laura, masteredLearningConcept, Operator*> occurs in the learner model, else the concept *Operator* is unknown by the learner. The learner model changes during the learning process when the learner passes tests. In this way, our learning organizer provides mechanism for self regulated learning (Pintrich et al., 2002).

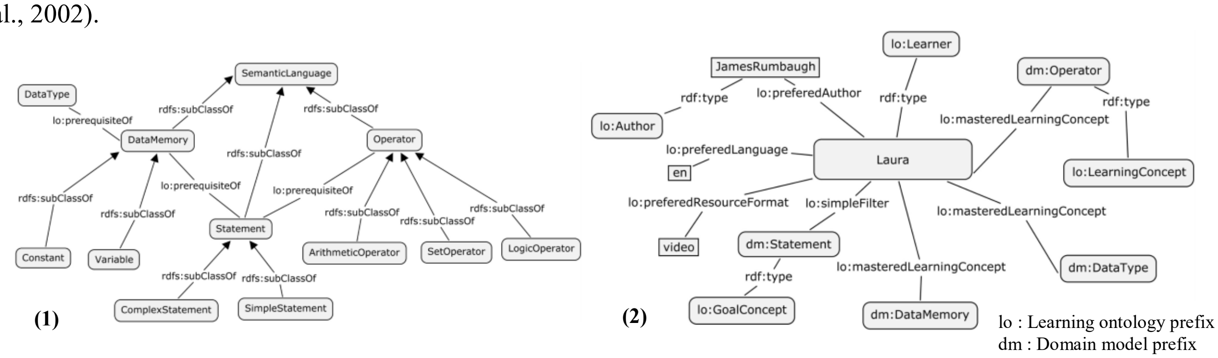

Fig. 3. (1) An excerpt of the domain model «Algorithmic and Programming Languages » (2) An excerpt of a learner model

Pedagogical Model. The structure of the domain model alone is not sufficient to decide how to present the selected learning concept 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 concept. For this purpose, we define a pedagogical model which describes pedagogical strategies to teach learning concepts. It describes different pedagogical activities (e.g. exercise, lecture) and their relationships. For instance, as shown in fig. 4.1, the *Definition* activity (instance of the class *PedagogicalActivity* in the meta-model) must precede the *Exercise* activity; both activities are related by the *sequencingStrategy* property 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.

4 Adaptive Course Generation

4.1 Adaptive Cognitive Map (ACM)

An ACM is a course structure generated and displayed by the learning organizer 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 concepts that the learner must learn to achieve his goal in required time. We distinguish between three cognitive maps constructed on the goal concept set G of the domain model:

- Simple $M_s(G)$ is the smallest map. It is composed of the goal concept and all concepts related to it directly or by transitive closure of order relationships.
- Hierarchical $M_h(G)$ is the cognitive map that extends the simple cognitive map to descendants and ascendants of the goal concept.

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

OrPAF implements each of these three filters. For the same concept 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. Only the concepts which pass the filter are displayed to the learner. An additional adaptation layer is applied on the ACM. It consists of applying rules in order to annotate each learning concept similarly to link annotation technique in adaptive Hypermedia (De Bra et al., 1999). Therefore, graphical icons are used to distinguish between mastered, accessible, and not accessible learning concepts (cf. fig. 5).

4.2 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 organizer, we propose: (1) A conceptual annotation process for annotating learning resources and (2) a query component for querying learning resources from the local repository.

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 classes and properties from both the domain model and the pedagogical model. For instance, in fig. 4.2, the learning resource R1 is an *Exercise* (defined as *PedagogicalActivity* in the pedagogical model) and teaches the learning topic *ComposedStatement* (defined as a *LearningConcept* 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).

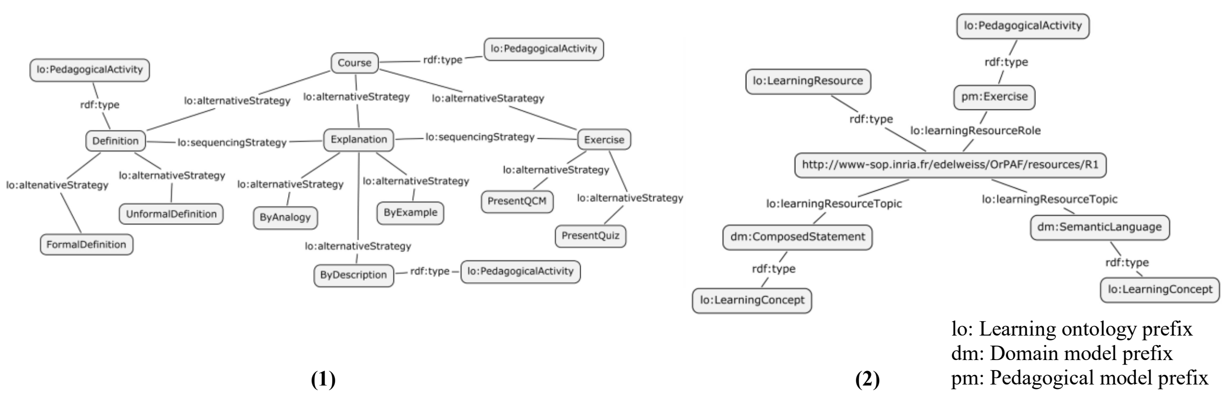

Fig. 4. (1) An excerpt of the pedagogical model (2) An excerpt of conceptual annotations of a learning resource R1

Querying a Learning Resource. The learner can consult resources about accessible learning concepts 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 concept (the concept clicked by the learner) and the state of the ACM. Only learning concepts 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 concept related to the learning resource. These relative weights depend on the current concept in the ACM and the type of relationships that connect the current concept to concepts related to the learning resource.

Let P<c_1, c_2, c_3, .. c_n > be a learning path of length n and composed of concepts c_i . Let wc_i/c_1 (i>1) be the weight of concept c_i relative to the current c_1 concept in the ACM. Let wc_1 be the weight of the current concept c_1. We define the relative weight as follows:

$$w_{ci/c1} = (1/a)\, w_{ci-1/c1}$$

where i>1, $w_{c1/c1} = w_{c1} = N$ (with N a maximal number) and a is a variable whose value is as follows:
a=2 (if the relationship between c_{i-1} and c_i is subClassOf or the inverse relationship)
a=3 (if the relationship between c_{i-1} and c_i is prerequisiteOf or the inverse relationship)
a=5 (if the relationship between c_{i-1} and c_i is aggregationOf or the inverse relationship), etc.
When there are several relative weights for one learning concept (due to graph cycles) we take the smallest value. Once defined the relative weight of each learning concept related to the learning resource, the semantic relevance SR of the learning resource can be measured as follows:

Let E be the set of concepts present in the learning resource annotations and present in accessible concepts of the ACM, let F be the set of concepts present in the learning resource annotations and not present in accessible concepts of the ACM, and let c be the current concept of the ACM,

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

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

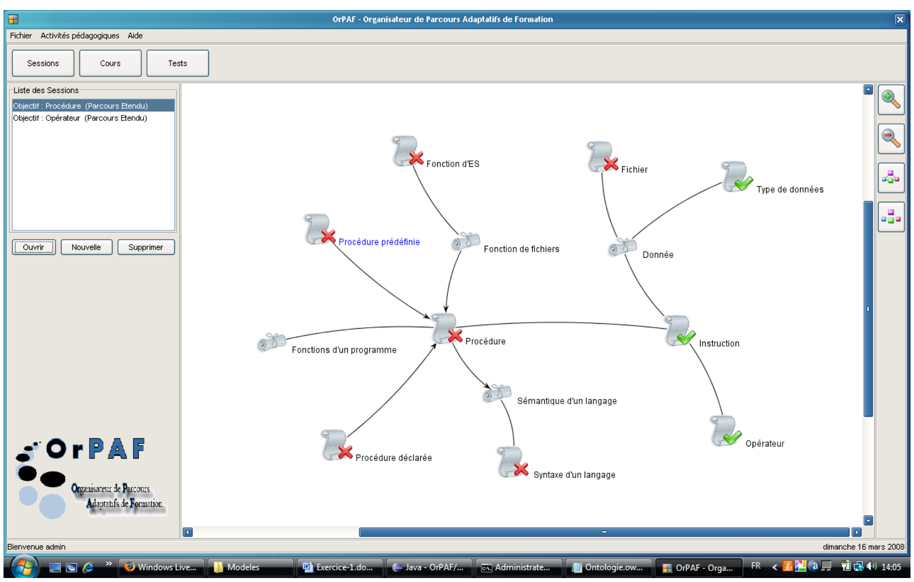

Fig. 5. A screenshot of course structure

5 Implementation and Evaluation

5.1 Implementation

The implemented prototype of the learning organizer integrates several functions to fulfill requirements for the generation of adaptive courses. We used JAVA language for all user interfaces and functions in OrPAF. The interoperability between the 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 et al. 2006). Corese is used to extract concepts and properties of learning models and conceptual annotations. OrPAF prototype is experimented to teach learning concepts of the domain Algorithmic and Programming Languages on a group of thirty learners in graduation of mathematics and computer sciences.

5.2 Evaluation

We experimented OrPAF on a group of thirty learners who belong to different graduation levels. We applied an accurate evaluation protocol: we divided the group into two subgroups A and B. In the first step of the protocol, the learners of group A used the OrPAF whereas the learners of group B used paper-support resources. In the second step of the protocol, the learners of group B were invited to use OrPAF. After each step, an exercise was performed by learners of both groups. It aimed to detect the conceptualization capabilities of learners before and after the use of OrPAF. The purpose of this evaluation protocol was to analyze behavior/judgments of learners according to three orthogonal directions: the usability of OrPAF, the conceptualization capabilities acquired by learners and the learners' judgments about the relevance of learning resources recommended by OrPAF. For each direction interviews were presented to learners in order to capture their feedback.

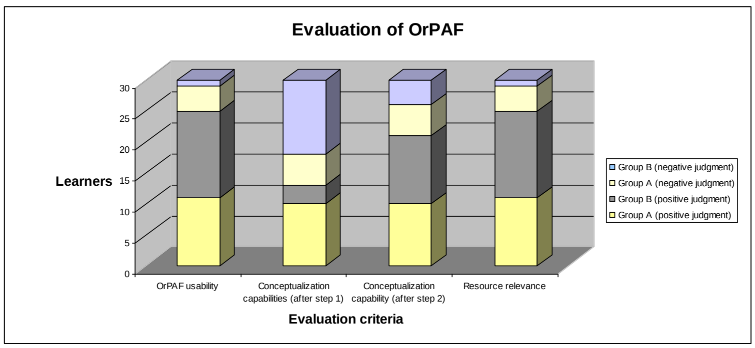

Fig. 6. Results of the experimentation of OrPAF on learners

Fig. 5 presents results which reflect global positive judgments of learners about the usability and the utility of OrPAF. The learners of group B appreciated OrPAF more than those of group A - certainly because they made a comparison between learning without and with the learning organizer. They found more assistance with OrPAF. Other experimentation is currently held for evaluating our relevance measure but it is out of the scope of this paper.

6 Conclusion

This paper presents OrPAF, a learning organizer 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 a 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 organizer is multi-domain and multi-learner profile with minimum changes in the learning models, and the common description of all learning characteristics in the learning ontology improve the reusability of external resources. In contrast with e-learning systems, cited in section 2, the learning organizer provides hypermedia course adaptation for both course structure and course content; and it is an efficient personalization 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 concepts. 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 concepts 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 concepts related to the learning resource. These relative weights depend on the learning context. Experiences with OrPAF led to positive results, both for the usability and the utility of the learning organizer. We concluded that concept-based course structure develop conceptualization capabilities of learners.

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