Ontologies for Student and Domain Models in Adaptive and Collaborative Learning System

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Abstract. Any educational environment must use different sources of information such as the Student Model and the Domain Model to be able to adapt learning to the individual characteristics of every student. The fundamental components of these models are the learning style of the student and the learning objects respectively. In addition to learning individually, the student can also increase his knowledge collaborating with others. This way, it turns out to be useful to contemplate in the Domain Model activities that need the participation of more than one student. In this article the characteristics that we include in the Student Model and in the Domain Model using both ontologies are described.

1 Introduction

The educational community has not made use yet sufficiently of the new information and communication technologies to advance substantially. It is habitual to find subjects in the educational environments in which the profile of every student is not born in mind; that is to say, they present the same materials and activities to all the students. On the other hand, there is few possibility of re-using the educational materials due to their little granularity.

The Semantic Web is an initiative of the W3C, which pretends to construct a new web architecture that not only provides support to store the contents, but also associates a formal semantics. A learning/teaching environment may be considered a portion of the web where ontologies are an adequate technological approach to include semantic information on the contents taught. Persons (students and professors) and agents could communicate on this semantics basis. Agents reason about the contents and reproduce them in an intelligent way according to the users' needs.

Ontologies are useful in any environment, and especially in educational environments, as they enable people and/or software agents to share a common understanding of the knowledge structure. Moreover, they permit to reuse knowledge, that is to say, it is not necessary to develop an ontology from zero if we find another ontology that is available for use in the modeling of the current domain.

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In the literature several attempts exist to classify learning objects. Wiley proposes a taxonomy that classifies the learning objects according to their possible combinations and their characteristics in terms of the number of elements, reusability and dependency grade [18]. This taxonomy defines five types of learning objects: single-type, combined-intact, combined-modifiable, generative-presentation and generative-instructional. Learning objects also can qualify according to their pedagogic use in instruction, collaboration, practice and assessment objects [2]. In these works no standard language is used to show these taxonomies in form of an ontology. Redeker proposes an educational taxonomy for learning objects (course, partial course, learning and knowledge unit) for the facilitation of generic sequencing strategies [11]. Silva describes an ontology-based metadata to achieve personalization and reuse of content in the AdaptWeb project [13]. DAML+OIL language is used to represent the ontology. Ronchetti and Saini [12] propose an architecture to aid students to find materials that present different points of view or different ways to explain concepts, but they does not make use of Semantic Web technologies.

At present, the Semantic Web is acquiring a big importance, being education one of its fields of application. In the Semantic Web, one of the main purposes is to represent the knowledge container within the Web resources in order to make it available for applications. Ontologies can be used for gathering the above mentioned knowledge, defining formally the concepts and relations that appear in the application domain. In our case, we create ontologies of the Student Model to represent the characteristics that define the profile of the student and of the Domain Model, which reflects the structure of the educational content, in which the fundamental components are the learning objects. This outline constitutes an interesting approach as it permits a uniform treatment of the problem that facilitates the interaction between both models. This way, a software agent might gain access to both ontologies to select and to show to the student the elements of the material educational that better fit to his profile. To represent the ontologies the Web Ontology Language (OWL) [19], the last standard language proposed by the W3C to represent ontologies in the Web, has been used, and the Protégé 3.0 framework [10] has been selected to edit / construct them.

Both ontologies should allow distance learning of subjects across the web, with the intention to reach two objectives. First, the subjects should adapt to the needs and peculiarities of every student. Second, learning objects should be defined with the sufficient granularity so that they could be re-used in different subjects. To achieve these aims, we model the profile of the student and his knowledge, as well as the knowledge of the educational domain according to this profile. The learning style of the student is one of the fundamental elements that constitute the profile of the student, since it determines what his preferences are in his learning process. In particular, we use the Felder-Silverman Learning Style Model (FSLSM) [3] to recognize the typical learning styles of the students.

The article is structured as indicated next. In section 2 we define what a learning object is and what are its main characteristics. In section 3 the concept of learning style is defined, with a special emphasis on the FSLSM. In sections 4 and 5 the Student Model and the Domain Model ontologies, respectively, are introduced. Finally some conclusions are offered.

2 Learning Object Definition

At present there is no definition commonly accepted of the term learning object inside an educational environment. For major confusion, in addition to the different definitions that we can find, there is no agreement on the term used to describe it (learning resource, educational object, information object, reusable information object, etc.) [7]. The definition of the LOM working group is too general [5].

We only consider in our research resources that may be transmitted through the Internet. Thus, Wiley's definition is the more appropriate one to our objectives. Wiley defines a learning object as "any digital resource that can be reused to support learning" [17]. The proposed definition is sufficiently narrow to define a reasonably homogeneous set of things (reusable digital resources), and it explicitly rejects non-digital and non-reusable resources. This definition includes anything that can be delivered across the network on demand, be it large or small (text, images, audio, video, animations, applets, entire web pages that combine several media types, and so on). Nevertheless, in spite of the different interpretations on what learning objects are, most educators would agree that learning objects incorporate the following features [8]: a) s*elf-contained* - each learning object is self-contained and can be used independently of other learning objects, b) *reusable* - learning objects are reusable and the same learning object can be used in multiple contexts for multiple purposes, c) *can be aggregated* - learning objects can be grouped into larger collections of content to create more substantial learning units, and, d) *tagged with metadata* - all learning objects are tagged with metadata that describes the learning object and allows it to be easily retrieved in a search.

3 Learning Style Definition

A learning style is defined as the unique collection of individual skills and preferences that affect how a person perceives, gathers, and processes information. A learning style affects how a person acts in a group, learns, participates in activities, relates to others, solves problems, teaches, and works [6]. We have chosen the FSLSM so that it is a part of the profile of the student because it has been used successfully in many computer-based educational systems (e.g., [9], [4], [16], and [1]).

Table 1. FSLSM learning dimensions

Definitions	**Dimensions**		**Definitions**
Do it	Active	Reflective	Think about it
Learn facts	Sensing	Intuitive	Learn concepts
Require pictures	Visual	Verbal	Require reading or lecture
Step by step	Sequential	Global	Big picture

As shown in Table 1, the FSLSM [3] distinguishes four dichotomous dimensions to learning styles (active/reflective, sensing/intuitive, visual/verbal, sequential/global), which gives place to sixteen combinations of learning styles. The student answers to a questionnaire called Index for Learning Styles (ILS) [14], which enables to determine his learning style.

4 Ontology for the Student Model

In the Student Model ontology the knowledge about the student is represented, that is to say, which is his profile and how he is acquiring the domain knowledge taught. This ontology, showed graphically in Figure 1, consists of the central class *Student* whose properties describe the personal information (name, surname, identification card, e-mail, birth date and sex).

Property *hasLearningStyle* indicates the learning style that the student has. The dimensions of the FSLSM have been represented as four properties of type *integer* in class *LearningStyle*. The properties *hasLearningGoal* and *learnsUnit* point at the subjects (class *Unit*) that the student wants to learn and to the subject that he is studying at present, respectively. The property *knowsSection* serves to indicate the sections that the student already knows. The classes *Unit* and *Section* are defined in the ontology of the Domain Model. The property *hasNC* reflects the type of network connection that the student has in a learning session. To know the speed of the student's network connection can help to decide what objects are most adapted to show the educational contents. For instance, if there is a slow connection it will not be adequate to show elements that are hard to download to the client computer.

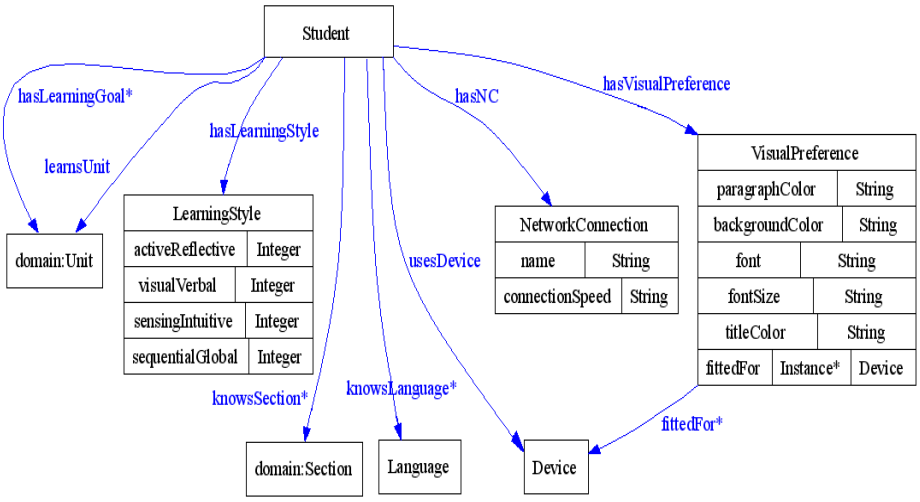

Fig. 1. Ontology for the Student Model

The property *hasVisualPreference* reflects how the student likes the pages to be shown (colours and characteristics of the letter, basically). The property *fittedFor* indicates that the visual preferences chosen by the student must be supported for the device used (PDA, standard monitor, etc). The property *usesDevice* indicates the device that the student uses to study the subject. These three properties will allow adapting the content in accordance with the visual preferences and the device in particular that the student uses.

The colour has been included as an important subjective distinctive feature of the profile of the student. It allows the user to process the information of a web page in a more effective way and simultaneously to increase his memorisation capacity. The properties *backgroundColor*, *titleColor* and *paragraphColor* in class *VisualPreference* reflect the background colour of the pages, the colour of the headers and words that are highlighted in the text, and the colour of the text of the paragraphs, respectively. On the other hand, the properties *font* (values Arial, Verdana, Courier, Times New Roman, etc.), and *fontSize* of class *VisualPreference* they are used to reflect the type and size of the used font.

Finally, property *knowsLanguage* of class *Student* reflects the languages that the student knows and dominates.

5 Ontology for the Domain Model

First we present the field to which the subjects belong. Our domain is framed inside the university context, although it might adapt easily to any other educational environment with a different organizational structure. As shown in Figure 2, a University is structured in departments (property *hasDepartment*), and every department is divided into a series of knowledge areas (property *hasKnowledgeArea*).

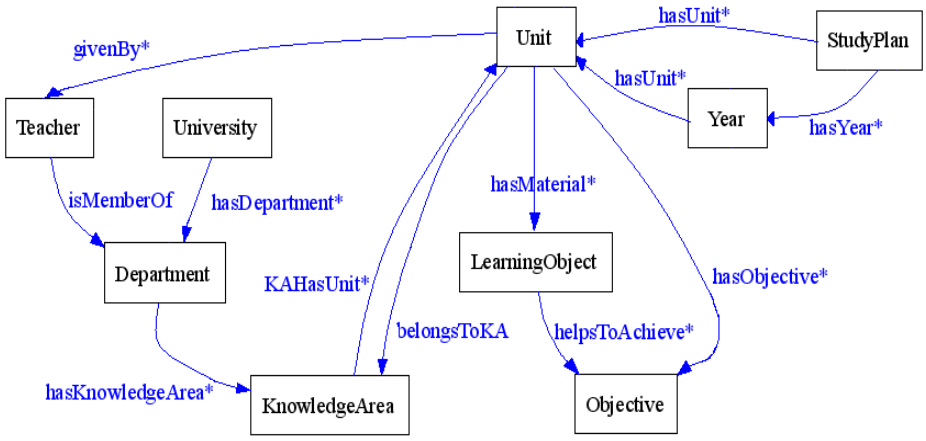

Fig. 2. Organizational structure

Every subject (*Unit*) belongs to a knowledge area of a department (property *belongsToKA*) and can be taught by several teachers of a department (property *givenBy*). In every unit a set of objectives have to be reached (property *hasObjective*). A collection of learning objects constitutes the material in order to teach the subject (property *hasMaterial*). Every learning object helps to reach a few objectives (property *helpsToAchieve*).

To describe the learning objects we will use metadata. As you may observe on Figure 3, a learning object (a) is created by one or several authors (property *createdBy*), (b) it has a set of key words that describe it (property *hasKeyword*), (c) it needs a certain network connection speed (property *requiresNC*), (d) it helps to reach a few objectives (property *helpsToAchieve*), (e) it may be visualized in certain devices (property *requiresDevice*), (f) it is located in a certain direction, and, (g) it is written in a given language -this way, we can locate the same object in several languages- (property *isLocated*). Also, a learning object has a description (property *description*), a type of interactivity -it can take values active, exhibition and mixed- (property *InteractivityType*) and a grade of difficulty -very easy, easy, average, difficult, and very difficult- (property *difficultyLevel*). The type *active* of interactivity applies for documents in which it is needed that the student interacts and/or performs operations (for example, simulations, exercises, test questionnaires), whereas *exhibition* is applied to documents whose objective is that the student gets the content (for example, text, images, sound).

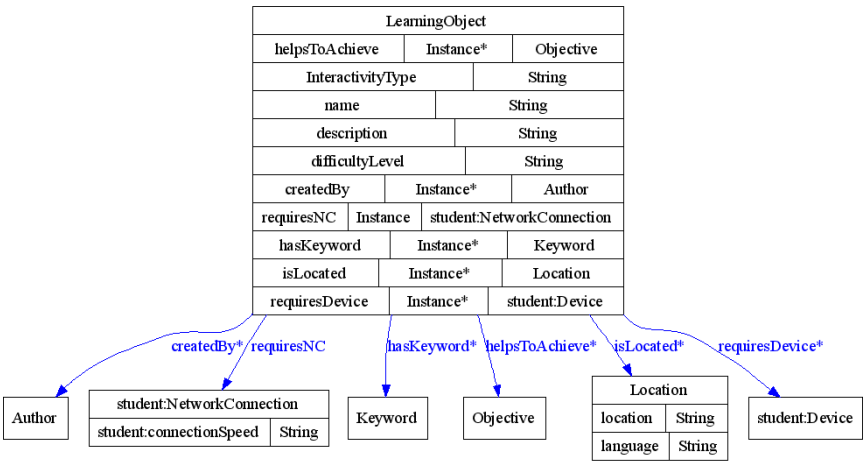

Fig. 3. Description of a learning object

To determine the grade of granularity of a learning object is a fundamental decision in any project. To obtain a high grade of reusability of a learning object is largely a function of the grade of granularity of the objects. That is to say, the more granular an object, the more reusable it will become [15]. Granularity is related to the relative size of the objects. For example the grade of granularity of a topic is minor than that of a section. To our judgment, we must fragment the educational contents into very little connected elements. In other words, we consider every element that

can be a part of a page -text, images, video, and so on- has a meaning for itself and may be reused on different pages. Hence, if there are several elements with the same meaning we will be able to show the one that better fits to the preferences of the student.

Thus, we consider three types of learning objects of different granularity: *Topic*, *Section* and *Support* (see Figure 4). A topic has a thick granularity and it is formed by a set of sections (granularity increases). Sections are explained based on a collection of support material (granularity increases), choosing in every moment the objects that better adapt to the preferences of a beginner student. Thus we can reuse learning objects at three different levels, that is to say, we can reuse an entire topic, sections of a topic or fragments that explain a section.

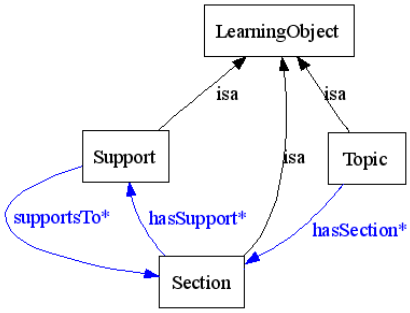

Fig. 4. Types of learning objects

The classes *TheoreticalExplanation* and *PracticalExplanation* represent the theoretical and practical explanations, respectively, that appear to the students (see Figure 5).

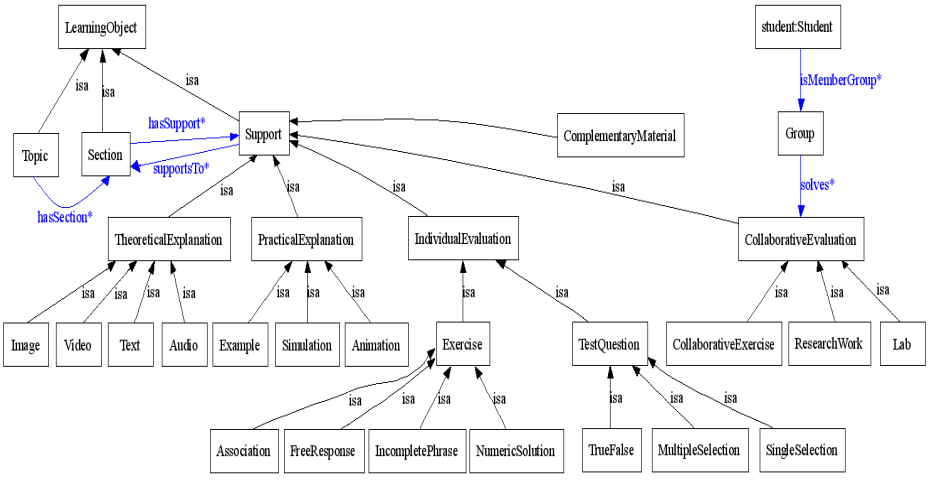

Fig. 5. Environment of class *Support*

This distinction allows showing to the sensory students first the practical applications of the theory and later the purely theoretical contents -and vice versa for the intuitive students. To compose the theoretical explanations several types of formats there are proposed (classes *Text*, *Audio*, *Video*, *Image*). This way, the theoretical explanations that appear to the verbal students are formed by text and/or audio, whereas videos and images are shown to the visual students. In order to realize practical explanations, examples, simulations and animations (classes *Example*, *Simulation*, *Animation*) can be used.

The individuals of classes *IndividualEvaluation* and *CollaborativeEvaluation* are used to evaluate the knowledge acquired by the student. The class *IndividualEvaluation* contains the exercises (class *Exercise*) and the test questionnaires (class *TestQuestion*) that a student has to solve without help of other partners, whereas the works (class *ResearchWork*), practices (class *Lab*) and some exercises (class *CollaborativeExercise*) of class *CollaborativeEvaluation* may be performed between several students.

The class Exercise contains the four following subclasses:

- *NumericSolution*. A statement in which a set of information are included is presented, and a question is posed so that the student has to answer with a numerical solution using the starting information.
- *IncompletePhrase*. A statement that the student has to complete in one or more points with a phrase, a word or a cipher is presented. There are two types of statements: one in which a list of elements is provided and the student must place the appropriate element in the correct place of the statement; and another in which the student must complete the statement without any type of help.
- *Association.* It consists of presenting a series of elements in two parallel columns where every word, symbol or phrase of a column can collaborate with the elements of another column. The student must establish the relations between the elements of two columns.
- *FreeResponse*. A statement appears in the form of a question and the student has to answer with one or several paragraphs. This type of exercises cannot be corrected automatically.

The class *TestQuestion* has several subclasses to highlight the different types of test questions that are shown to the student. They are the following ones:

- *TrueFalse*. The student has to choose among one of two alternatives.
- *SingleSelection*. A question of multiple elections with one single response. A situation or a problem and several options that provide possible alternatives are presented. There is only one valid option. A variant of this type of questions is that all options are valid but there is one that is better than all others.
- *MultipleSelection*. A question of multiple elections with multiple responses. A situation or a problem and several options that provide possible alternatives are presented. There are several valid options and the student has to select all the correct ones.

In addition to learning individually, a student can also increase his skills by collaborating with others. That is to say, learning in addition to being an individual process is also a social process. By means of the collaborative work it is possible to learn to work with others. To work of in a cooperative way allows individual knowledge to serve as a knowledge resource for all the components. This is why class *CollaborativeEvaluation* has been introduced as a new type of learning object. The property *isMemberGroup* of class *Student* indicates in what groups the student is included to realize the activities that need the participation of more than one student. The property *solves* of class *Group* indicates the problems that a certain group of students has to solve.

We can distinguish among several types of objects of collaborative evaluation. The class *CollaborativeExercise* represents the exercises that are proposed to several students to be solved in group. It turns especially out to be interesting to propose an exercise to a group in such a way that a part of the components of the group generate arguments in favour of the raised question whereas the rest generate arguments in against. Other examples of collaborative activities are the research works (class *ResearchWork*) proposed to the students so that they study in depth a topic, and the laboratory practices (class *Lab*) proposed to apply the skills and knowledge acquired in a real case.

Finally, class *ComplementaryMaterial* is added as a subclass of class *Support* to represent the additional materials accessible to the students that want to learn more.

6 Conclusions

The selection of the learning objects most adapted for every student is one of the interesting topics that are investigated in educational systems. The above mentioned selection is realized principally bearing in mind the students learning styles and preferences.

Another question to bear in mind is the reuse of learning objects, as creating teaching material is a task that needs a lot of time. To achieve a major reuse we think that the learning objects created must be as small as possible (image, video, text, audio, and so on), and from the smaller fragments more complex objects (sections, topics) should be constructed.

The new generation of the Web, the Semantic Web, appears already as a promising technology to provide the Web contents of meaning. The ontologies constitute one of the principal tools of the Semantic Web to specify explicitly the concepts of a concrete domain, its properties and its relationships. The OWL language has been used to represent the Student Model and the education Domain Model.

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