Including Quality Properties into an E-Learning Ontology *

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Abstract. This work proposes the inclusion of quality properties management into an e-learning ontology. Including the representation of quality properties in the ontology gives more information to the process that intends to find an appropriate learning object (e.g., a course) for a certain student. Our goal is to evolve the ontology with constructions that allow representing quality properties, so that each learning object can include quality information that may be contrasted with quality requirements that each user can pose at search time. In addition we define and analyze a set of quality properties that are appropriate for this context. The contribution of this work is twofold: the extension of the ontology for quality representation, and the proposal of some quality properties that may be useful in the e-learning context.

1 Introduction

Quality management is a valuable ability for most types of information systems. In general, a set of quality properties, which constitute a group of relevant characteristics such as *freshness*, *correctness* or *completeness*, can be defined on these systems. Additionally, the users of the systems may pose quality requirements based on these properties. Based on quality properties and requirements the system may make decisions, such as information selection, in order to provide the user with the most adequate results as possible [1].

Research works about quality metadata in information systems include proposals for quality management in Data Warehouse systems (DW) based on metadata. [2] presents a formal meta-model for representing quality goal formulation and quality measurement in a DW. Analysis of the DW quality must be done through queries over the meta-model. In [3] they also present an approach for managing quality in DWs through a metadata based system. For a more general context, in [4] they make a proposal for selection and ranking of data sources, based on metadata about content and quality of the sources data.

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The EduCa project [5] focuses on the conceptual modeling, development and implantation of a software platform for retrieving courses, which would be available on the Web, with cultural characteristics. The courses must be adaptive in relation to the students profiles, which refer, for example, to their style of learning, general knowledge background, etc. One of the specific goals of this project is to develop a conceptual model of the learning objects using ontologies, so that the courses can be represented in a standard way, allowing adaptability and interoperability on the web. A recent work [6] proposes an ontology for the learning objects, which is constructed following the IEEE standard for e-learning LOM (Learning Object Metadata) [7] and is represented using the DAML+OIL language [8], which combines expressiveness with capacity for automated reasoning [9].

This work proposes the inclusion of quality properties management into the ontology proposed in [6]. Including the representation of quality properties in the ontology gives more information to the process that intends to find an appropriate learning object (e.g., a course or a part of one) for a certain student. Our goal is to extend the existing ontology with constructions that allow to represent quality properties, so that each learning object can include quality information that may be contrasted with quality requirements that each user can pose at search time. In addition we define and analyze a set of quality properties that are appropriate for this context.

The contribution of this work is twofold: the extension of the ontology [6] for quality representation, and the proposal of some quality properties that may be useful in the e-learning context.

In Section 2 we present the proposed ontology extension, including the extension to the conceptual model, the analysis of LOM reusability for this context, and the extension to the ontology itself. In Section 3 we present a set of quality properties applicable to learning objects. In Section 4 we present the conclusion.

2 Ontology Extension

In this section we present the extensions we propose in order to represent quality properties in the ontology [6].

In the AdaptWeb project two models are defined for the system: (i) a knowledge space model containing the model of the domain to be taught, (ii) a student model containing the learner's profiles. A conceptual design is done (represented in ER model) for the domain knowledge space and for the learner's profile. An application profile of the LOM (this concept will be explained later in this section) is developed for the knowledge space. Lastly, one ontology is developed for representing the knowledge space and another for the student model.

We work in the same stages as in [6]: (i) conceptual model design, (ii) application profile design, and (iii) ontology design.

2.1 Conceptual Model Extension

Figure 1 shows the conceptual model proposed in [6]. This conceptual model includes the domain knowledge model and the student model.

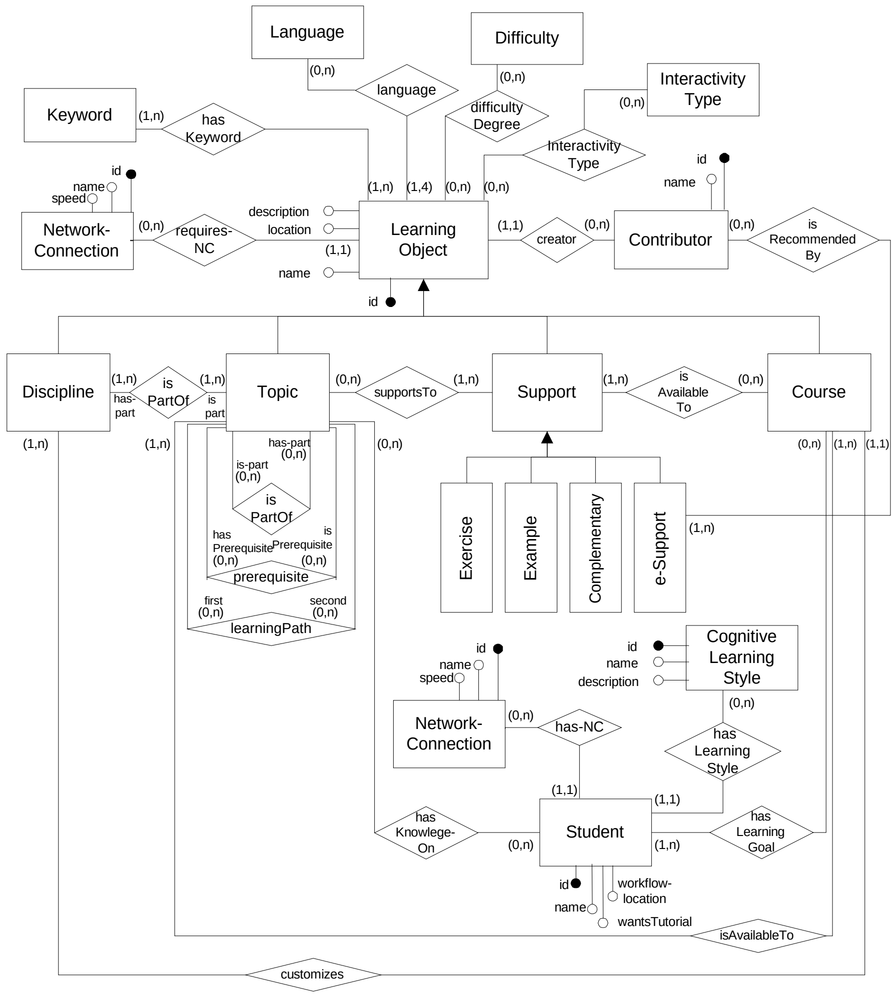

Figure 1: Existing Conceptual Model

For the extension to the conceptual model there are two design alternatives, which we analyzed in order to choose one of them.

The first alternative is to add to the model the representation of each of the selected quality properties. Considering that the different quality properties usually have very heterogeneous characteristics (e.g. the scale used in the measure), the advantage of this approach is that each quality property may have a different representation. The disadvantage is that if someone (e.g. the learning object creator) wants to add a new quality property, the model must be modified, having to deal with the problems of evolution at all the levels of the system.

The second alternative is to add a new entity that represents quality properties in general, and each particular quality property is represented at the moment of instantiation, i.e. when a learning object is created the creator may also create the quality properties he wants to add, if they are not yet created. In this approach we find an important advantage: the flexibility of the model. The quality properties are not pre-defined, any new property can be added without modifying the model.

We opted by the second alternative. We add the entity Quality Property categorizing it into three sub-entities: Numeric Measure, Boolean Measure, 1..10 Measure. This categorization is intended to contemplate some of the different ways a quality property measure can be expressed. Then we relate these sub-entities with the entities of the existing model Learning Object and Student. There are three relations each of which connects one of the sub-entities with the Learning Object entity. These relations have an attribute named ActValue that represents the actual value that the learning object has for the corresponding property. On the other hand, there are three relations each of which connects one of the sub-entities with the Student entity. These relations have an attribute named ReqValue that represents the value that the student requires for the corresponding quality property. Finally, there are three relations, each of which connects the pairs <student, quality property> with the pairs <learning object, quality property> (i.e. they connect the aggregations). These relations are intended to establish for each student, quality property and learning object, the degree of satisfaction achieved. Figures 2 and 3 show the added constructions. In order to improve visualization Figure 2 shows only the representation of the quality properties, and Figure 3 shows how the learning objects and the students relate with the quality properties, but including only one of the quality properties' sub-types since it is analogous for the other two.

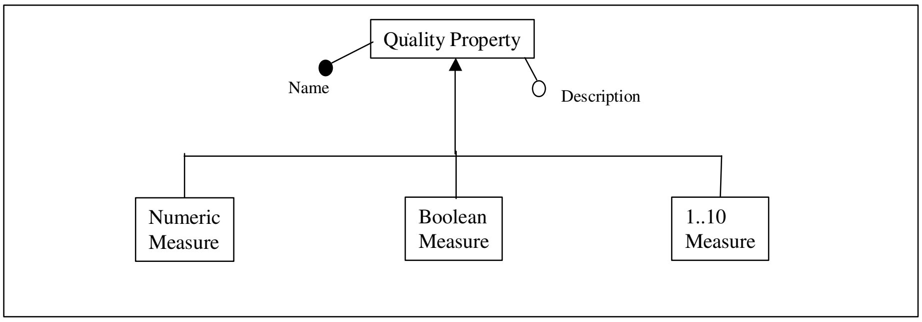

Figure 2: Conceptual representation for quality properties

In addition to the proposed categorization for Quality Property we could model an orthogonal categorization intended to represent different types of properties, each of which relates to the different types of learning objects (represented by the sub-entities Discipline, Topic, Exercise, etc.). This is useful because certain quality properties have no sense for certain types of learning objects, and the model would allow to represent only the relations between quality properties and learning objects that are valid. For example the property quantity of exercises may be applied to the type of learning object Course and may not be applied to the type Exercise, while the property freshness may be applied to any type of learning object (the mentioned quality properties are explained in Section 3).

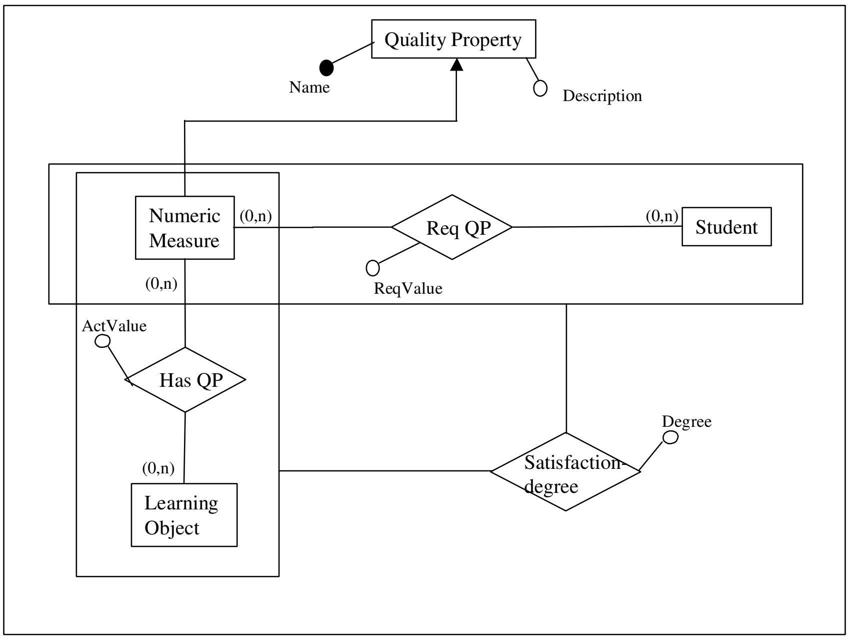

Figure 3: Conceptual representation for quality properties

This possibility does not add a significant complexity from the ER modeling point of view (further than the visualization problem). However, from the instantiation point of view it generates some possible consistency problems that must be taken into account. For example, the quantity of exercises of a Course must be equal to the sum of the quantity of exercises of each of its Topics.

For simplicity reasons this extension is not included in the scope of this work.

2.2 Application Profile Extension

In the work of [6], in order to achieve a standard representation based on the standards LOM, Dublin Core [10] and Vcard [11], they define an Application Profile. An application profile allows to adapt or combine existing schemas into a package appropriate to a particular application, while maintaining interoperability with the original base schemas.

During the construction of the application profile three situations may appear with respect to each element we want to represent: (i) we directly reuse existing LOM metadata that corresponds to the element, (ii) we refine existing metadata that can be considered as a generalization of the element, or (iii) we cannot use nor refine any existing metadata element, therefore they define a completely new one.

In the present work, we should find LOM metadata that can be used or refined for representing the concept QualityProperty and the concepts related to it. After studying the existing LOM elements we find that neither of them is eligible for this purpose; we conclude that quality properties metadata was not considered in the present LOM definition.

We think that it would be useful to propose an extension of LOM, including a new category with the representation of quality metadata. This category could be analogous to the existing Classification category of LOM, as we show in Table 1.

Table 1. Proposed LOM Extension

Nr.	Name	Explanation
10	Quality Property	This category describes the quality properties that are applicable to the learning object.
10.1	Name	The identifier of the quality property.
10.2	Description	Description of the quality property.
10.3	Measure	Measure of the quality property.
10.4	Value	Value for the quality property of the learning object. Restricted to the measure range.

2.3 Ontology Extension

As said before, in [6] the proposed ontology is represented in the DAML+OIL language. For doing this, they define the correspondences between the ER constructions used in the proposed conceptual model and the DAML+OIL constructions. Table 2 shows these correspondences.

Table 2. Correspondences between ER and DAML+OIL elements

ER element	DAML+OIL element
Entity	Class
Relation, eventually with specified roles	ObjectProperty relation, eventually defining the Inverse relation
Attribute	DataTypeProperty
Specialization	SubClassOf
Cardinality restrictions on participation of entities in relations	Cardinality restrictions and properties values for classes

In this work we need to extend this set of correspondences, adding two ER model constructions that were not considered before. In Table 3 we show the added correspondences.

Table 3. Added correspondences between ER and DAML+OIL elements

ER element	DAML+OIL element
Relation between two aggregations	ObjectProperty relation, between ObjectProperty and ObjectProperty
Attribute of a relation	DataTypeProperty between an ObjectProperty and a DataType

In the following we show how we represent in DAML+OIL a portion of our conceptual model, which uses the new correspondences. We only show the portion corresponding to the subtype *Numeric Measure* of *Quality Property*, since the rest is analogous.

```
<daml:Class rdf:about=”#QualityProperty”>
      <rdfs:comment xml:lang=”en-US”>Quality property
      that will be associated to a learning ob-
      ject<rdfs:comment>
</daml:Class>

<daml:Class rdf:about=”#NumericMeasure”>
      <rdfs:comment xml:lang=”en-US”>Quality property
      that is measured by numeric values<rdfs:comment>
      <rdfs:subClassOf>
            <daml:Class rdf:about=”#QualityProperty”>
      </rdfs:subClassOf>
</daml:Class>

<daml:ObjectProperty rdf:about=”#HasQP”>
      <rdfs:domain rdf:resource=”#LObject”>
      <rdfs:range rdf:resource=”#NumericMeasure”>
<daml:ObjectProperty>

<daml:DataTypeProperty rdf:about=”#ActValue”>
      <rdfs:domain rdf:resource=”#HasQP”>
      <rdfs:range rdf:resource =
”http://www.w3.org/2000/10/xmlSchema#nonNegativeInteger”>
</daml:DataTypeProperty>

<daml:ObjectProperty rdf:about=”#ReqQP”>
      <rdfs:domain rdf:resource=”#Student”>
      <rdfs:range rdf:resource=”#NumericMeasure”>
</daml:ObjectProperty>

<daml:DataTypeProperty rdf:about=”#ReqValue”>
      <rdfs:domain rdf:resource=”#ReqQP”>
      </rdfs:range rdf:resource =
”http://www.w3.org/2000/10/xmlSchema#nonNegativeInteger”>
</daml:DataTypeProperty>

<daml:ObjectProperty rdf:about=”#SatisfactionDegree”>
```

```
      <rdfs:domain rdf:resource="#HasQP">
      <rdfs:range rdf:resource="#ReqQP">
</daml:ObjectProperty>

<daml:DataTypeProperty rdf:about="#Degree">
      <rdfs:domain rdf:resource="#SatisfactionDegree">
      <rdfs:range rdf:resource =
"http://www.w3.org/2000/10/xmlSchema#nonNegativeInteger">
  </daml:DataTypeProperty>
```

2.4 Application Scenario

We following present an scenario where this proposal is applied.

The ontology has information about the quality actual values for the represented learning objects and quality properties. This information was provided by the author of the learning object. On the other hand, the ontology has information about the students' quality requirements. This information could be deduced from the student profile and from questions made to the student.

At a certain moment the student asks the system for a course with certain characteristics. The searching sub-system searches for a course that fullfils the required characteristics and also that satisfies the student quality requirements existing in the ontology.

Besides providing the students with the courses that may be adequate for him, the system registers for statistical purposes the degree of satisfaction achieved by the different courses for this student.

3 Quality Properties

We propose a set of quality properties that may be of interest for the search and selection of learning objects. We analyzed these properties in order to define them in this context and to determine their characteristics.

Freshness

This property corresponds to the quantity of days that has passed since the most recent update to the object, i.e. the age of the object. It gives an idea of how "up to date" is the learning object. The way of measuring it may be through inspection into the meta-information of the files, or through information provided by the author. The value range for the corresponding measures may be the set given by non negative integers.

Update-Frequency

This property corresponds to the estimated frequency of updates applied to the object. It may be useful as a complement of the freshness property, for knowing the date of the next update. In this case we have a relationship between two properties, where the consistency of them should be controlled. This property may be measured considering statistical information, or through information provided by the author. The value range for the corresponding measures may be the set given by non negative integers.

Self-Explanatory
This property represents the degree of detailed explanations included in the learning object as well as of the information needed to completely understand it. It may be measured through students surveys, by some intelligent authomatic process that spies inside the object content, or it may be an information provided by the author. Its values range over 1 to 10.

Exercise-quantity and Example-quantity
These properties give the quantity of exercises/examples contained in the learning object. They are of special interest for determining to which kind of learning style the learning object better applies. For example, a course containing a large quantity of exercises is more suited for students that like to deeply test their understanding of a studied topic. The measurement of this property may be done through an authomatic process, or through information given by the author. Its values range over the set of non negative Integers.

We consider that the properties ***Difficulty***, and ***Interactivity-Type***, which are defined in LOM, are inherently quality properties of the learning object. Therefore we propose as a further change to LOM the elimination of these properties and the inclusion of them as instantiations of the Quality Property class.

With respect to the quality properties measurement we make some considerations. When the learning object's author is who provides the actual values of the quality properties, it may be considered that this information is subjective in the sense that they are values that the author declares, but that not necessary correspond with reality. On the other hand, when authomatic processes are used, the results are not always totally accurate because they depend of the accuracy degree of the process.

4 Conclusions

In this work we propose an extension to an existing e-learning ontology, which allows the representation of quality properties. For the construction of this extension we apply the same methodology used for the creation of the ontology [6], which intends to maintain the compatibility with the existing e-learning standards.

The conceptual model of the existing ontology was extended with the necessary elements for representing the quality properties and its related concepts. The reuse of LOM concepts for the representation of these elements was not possible, since they are not considered in this standard. Therefore the ontology was extended using the same language (DAML+OIL) as in [6], but with constructions that fall outside the LOM scope. On the other hand, it was necessary to extend the set of correspondences between ER model and DAML+OIL proposed in [6], in order to transform ER constructions that were not considered in the original work.

In addition, with the goal of illustrating the proposal and as a first approximation to quality properties definition, we propose a set of quality properties that may be used as instances of the proposed model.

Finally, as a further contribution, we suggest an extension to LOM that enriches it with the support of quality concepts.

In ongoing work we are migrating from DAML+OIL to OWL [12], which is the most used language for ontologies nowadays. We also have the intention of evaluating if the constructed ontology has desirable computational properties for reasoning systems. This characteristic can be achieved, for example, using the sub-language OWL-DL, which guaranties it, although, we should verify if its expressiveness is enough for our needs.

This work has shown us an interesting research problem, which is the study of evolution of ontologies that were constructed following certain standards. The management of evolution should maintain as much as possible the standard compliance and solve the problems related to the impact of the changes.

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