MDA and Semantic Web Technologies for Assessment Systems

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Abstract. This paper focuses on how Semantic Web (SW) based knowledge representation and Model Driven Architecture (MDA) can be brought close together in designing assessment systems. The system is based on the IMS QTI standard Question and Test Interoperability. The central idea is using Description Logic (DL) reasoning techniques for intelligent analysis of students' solutions of the problems they are working on during assessment sessions with the system, in order to process simple choice questions.

Keywords: Assessment Systems, Description Logics, Model Driven Architecture, Semantic Web.

1 Introduction

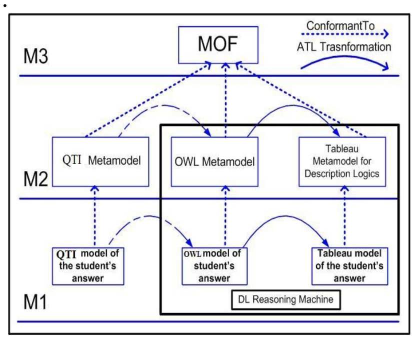
In assessment systems the huge possibilities of the Semantic Web [3] in the data representation and exchange are limited by the fact that the end user still needs to take care of the data.

This paper proposes a way to create a flexible, interoperable assessment system that can be easy to maintain and reuse. It is based on the IMS Question and Test Interoperability (QTI) standard [5] and designed using the Model Driven Architecture (MDA) standards [8]. The core concept here is to change the system's specification rather than implementation using the Unified Modeling Language [10].

One of the main ideas the paper proposes is using Description Logics (DLs) [2] reasoning techniques for intelligent analysis of students' answers to and solutions of the problems they are working on during assessment sessions with the system. The use of a DL reasoner enables processing of simple choice questions. This is the way for applying a framework for data sharing and reuse across heterogeneous applications, which is the core of the Semantic Web. The paper is organized as follows. The next section describes the model of the QTI-based assessment system using the MDA standards. Section 3 describes reasoning with QTI models. The last section shows the conclusions and indicates directions for future work.

2 Modeling the QTI-based Assessment System Using MDA Standards

The main reason for applying the MDA standards [8] in development of assessment systems is to make a clear difference between conceptual and concrete modeling, in order to automate transfer and sharing of information and knowledge.



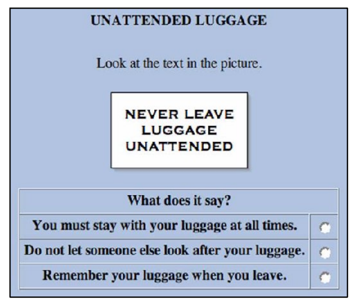


Fig. 1. Analysis of Students' Solutions **Fig. 2.** A simple choice item example [5]

First step in developing a QTI system using the MDA standard is to create a metamodel that captures the main concepts of QTI (Fig. 1) [9].

Having the QTI-based metamodel that is located at the M2 level of the MDA hierarchy (Fig 1), we can create models that correspond to a given metamodel. There is a lot of examples of *assessmentItem*s that are proposed in the IMS QTI standard (see [7]). In order to illustrate the creation of models that correspond to a given QTI metamodel (Fig. 1), we present an example the Simple Choice item shown in Fig. 2.

In order to use a DL reasoning techniques in the process of analyzing of students' solutions, it is necessary to perform the transformation the QTI-based models into the equivalent QTI-OWL model (Fig. 1).

This process is automated using the Atlas Transformation Language (ATL) [1]. The result of qti2owl.atl transformation is the QTI metamodel as well as the QTI models in Ecore that are OWL based (Fig. 4).

3 Reasoning with QTI models

In this section, we focused on the intelligent analysis of the semantics of students' solutions to the problems they solve during assessment (students' solutions, for short). For explanation our idea, we present two very easy examples of using DL reasoner in analyzing student's answer, using simple choice item (Fig. 3 and 4).

3.1 Examples of application DLs reasoning in Intelligent Analysis of Student's solutions

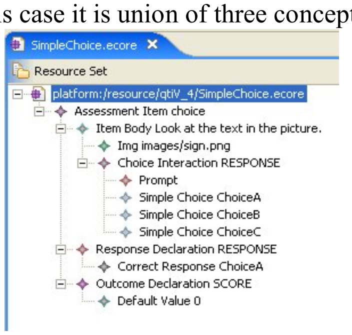
Among a few possible answers, a student may choose one or more ones. Using DLs terms, the items correspond to TBox (Rbox) (Table 2), where questions are presented as a concept using a description logic language.

If student choice one among a few answers, reasoner can check if this answer is satisfiable w.r.t knowledge base (OWL model). QTI standard proposes possibility of saving answers in "ReponseDeclaration" [IMS QTI, 2006] (Fig .3).

Table 2. DLs expressions corresponds to OWL model (Fig. 5)

DLs expressions	Formula number
$(\text{ChoiceB} \sqcap \text{ChoiceC}) \sqsubseteq \text{ChoiceA}$	(1)
$\text{ChoiceA} \sqcup (\neg\text{ChoiceB} \sqcup \neg\text{ChoiceC})$	(2)

Table 2 presents how OWL model (Fig. 4) can be described as Tbox axioms (1), i.e. only question, without answer. It means that OWL model (Fig. 4) is satisfiable if and only if (iff) formula (1) is satisfiable. It means that formula (1) is satisfiable iff formula (2) is. . In this case it is union of three concepts.



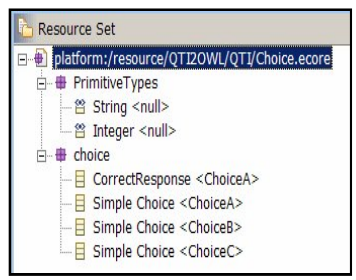


Fig. 3. Simple choice QTI model **Fig. 4.** OWL model transformed from QTI model

As solution, reasoner generates tableau models (conforms to tableau metamodel [6]) for both cases. Reasoning process is done during the model transformations, and it is main differences between our reasoner and existing ones, like FACT [4]. It means that tableau model saves implicit knowledge of reasoning process, i.e. using tableau models we may find out useful information about student's semantically mistakes. We can use the reasoner to test how some pedagogical strategies can help in progress of student learning.

3.1.1 Example of unsatisfiable student's answer

Suppose that a student submitted "**ChoiceA**" as answer with the question presented on Fig. 4. Reasoner takes this answer as OWL class (model), and calculates (un)satisfiability of the class with respect to OWL model (Fig 4) and generates tableau model as presented on Fig. 6. For explanation reasoning mechanisms on OWL models, we used DLs notation.

$$ChoiceA \sqsubseteq ChoiceA \sqcup (\neg ChoiceB \sqcup \neg ChoiceC) \quad (2)$$

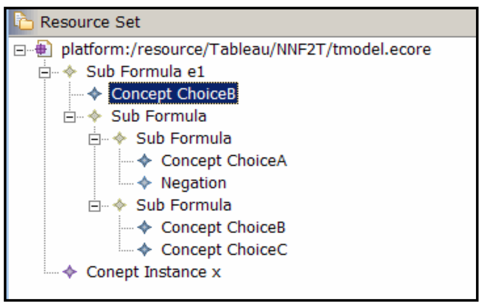
$$(ChoiceA \sqcap \neg ChoiceA) \sqcap (ChoiceB \sqcap ChoiceC) \quad (3)$$

Checking subsumption can be reduced to the satisfiability of concepts [4]. Constraint system as beginning point in reasoning processes can be presented as finite set of classes (models), as follows:

$$L(x) = \{ ChoiceA \sqcap \neg ChoiceA \sqcap (ChoiceB \sqcap ChoiceC) \} \quad (4)$$

Individual "x" (Fig. 6) is an instance of all subconcepts in this set. Using reasoning rules (in this case it is intersection rule for ALC logic) [4], this constraint system, described by formula (4), can be extended in new ones:

$$L(x) = \{ ChoiceA, \neg ChoiceA\} \cup L(x) \quad (5)$$



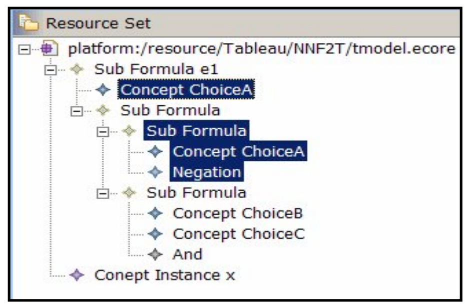


Fig. 5. Tableau model of SAT answer **Fig. 6.** Tableau model of unSAT student's answer

Constraint system consists of clash and formula (3) is not satisfiable, which implies that question subsumes answer and student give true answer. Unsatisfiable points of the beginning model are represented by blue color on Fig. 6.

3.1.2 Example of satisfiable student's answer

Suppose that student submitted a wrong answer. It means that student submitted "**ChoiceB**" or "**ChoiceC**". Reasoning process goes as follows: The question (similar as in true case) is whether answer is subsumed by question. This can be described by formula (6).

$$(ChoiceB \sqcup ChoiceC) \sqsubseteq ChoiceA \sqcup (\neg ChoiceB \sqcup \neg ChoiceC) \quad (6)$$

The subsumption relation can be reduced to concept satisfiability, as follows:

$$(ChoiceB \sqcup ChoiceC) \sqcap \neg ChoiceA \sqcap (ChoiceB \sqcap ChoiceC) \quad (7)$$

To fulfill this question, answer must be unsatisfiable of formula (7). Reasoning process starts, as usual, with the constraint system (Formula 8):

$$L(x) = \{ (ChoiceB \sqcup ChoiceC) \sqcap \neg ChoiceA \sqcap (ChoiceB \sqcap ChoiceC)) \} \quad (8)$$

Applying intersection and union reasoning rules on formula (8), we will have:

L(x) = { (ChoiceB , ¬ChoiceA, ChoiceB, ChoiceC }	(9)

It is easy to check that there is no clash. It implies that beginning OWL model (Fig. 5) is satisfiable, and it implies that question does not subsume answer. Individual "x" has the same meaning as in previous example.

4 Conclusions and Future Work

The main idea proposed in this paper is how Semantic Web (SW) based knowledge representation and Model Driven Architecture (MDA) can be brought close together in designing assessment systems. The paper also describes how to use main power on SW based on DL reasoning techniques in intelligent analysis of the students' solutions. Analysis of the semantics of the student's answer is the key for providing the response processing of open-ended questions (simple choice) in the IMS QTI standard. Our future work will be focused on integration of the IMS QTI standard and other logic-based reasoning techniques.

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