Interactive Learning Environments
Vol. X, No. X, Month 200X, 000–000

Automatic generation of questionnaires from domain and multimedia ontologies

The aim of this paper is to present an approach for generating questionnaires in an automatic way. Although other approaches have been already reported in the literature, the approach proposed in this paper is based on ontologies, representing both domain and multimedia knowledge. The paper also reports on a prototype implementation of such an approach which automatically creates questionnaires using the Semantic Web standard technology OWL (Ontology Web Language) as well as RDF annotations of images. The proposed approach is independent of specific domain characteristics, since question items are generated according to generic ontology-based strategies. In the presented prototype implementation simple natural language generation techniques are used, in order to project the items in the questionnaires.

Keywords: Ontologies; multimedia; computer aided assessment

Introduction

Electronic questionnaires are a very popular means of assessment and self-assessment in both traditional and electronic learning settings. They are appealing to the examinees, they can be automatically graded and they provide the capability of frequent testing, almost immediate feedback on the performance. The most common type of electronic questionnaires comprises of text-based Multiple Choice Questions (MCQ). Such a questionnaire comprises a number of questions named *items*. Each item consists of a short text describing a question or a sentence to be tested, called *stem*, and a number of alternative *choices*, typically four. In single-response MCQ, one of the choices is the *correct answer* and the wrong alternatives are called *distractors*.

Typically, the number of items constituting a questionnaire must be large enough in order for a questionnaire to provide credible evaluation. Furthermore, the construction of question items requires specialized knowledge. Thus, the creation of MCQ questionnaires is a resource-consuming task in terms of time and human effort, which would be benefited by automation.

Automatic creation of MCQ questionnaires can be considered as a specialized application of natural language generation which is based on the following:

1. the existence of a knowledge base expressed in a knowledge representation language, which contains a set of facts about a specific domain. From these facts, question items together with correct answers are extracted for the questionnaire (Bateman, 1997; Bontcheva & Wilks, 2004);
2. the use of the semantic relationships between various elements in the knowledge base in order to assert 'false' statements. These statements are used for generating the distractors in question items;

3. the application of Natural Language Generation (NLG) techniques for actual sentence generation based on the semantic descriptions generated in the first two steps.

Beyond text-based MCQ, other types of question items exist, which incorporate different types of media, such as images, sound and video. Questionnaires comprising these types of question items can be used in both formal education, in domains with emphasis on audio-visual information, as well as in informal educational activities combined with entertainment (edutainment). In order for the later type of questionnaires to be automatically generated, the above process must be enhanced by enriching the knowledge base with media-related semantics.

Ontologies contain domain knowledge in the form of definitions of terms, individuals belonging to these terms and relationships between these terms and individuals. The above constitute the asserted knowledge, that is, explicitly defined facts within the ontology. Ontologies also incorporate a reasoning mechanism, in order to derive facts from explicitly defined knowledge (Baader, Calvanese, McGuiness, Nardi, & Patel-Schneider, 2003). These facts, not explicitly defined in the initial ontology, constitute the inferred knowledge. In the approach presented in this paper, reasoning is applied *before* question generation and thus, generated questions are based on both asserted and inferred knowledge. As a result, a student performing a test is assessed on recalling factual knowledge, but also is expected to apply some 'lower level intellectual skills', in the sense of simple domain specific rules, in order to answer questions based on inferred knowledge. These skills are referred by Gagné, Briggs, & Wager (1992) as *concrete* and *defined concepts* and are related to the ability to *identify* and *classify* specific individuals as members of particular concepts. Nevertheless, domain ontologies are not capable of specifying 'procedural knowledge' and thus they cannot be used alone for assessing higher order cognitive skills (Holohan, Melia, McMullen, & Pahl, 2006).

The use of ontologies in educational settings is ever-increasing. In these settings, domain specific ontologies can be obtained as inputs for generating questionnaires in the following ways:

- the manual summarisation of a domain by ontology engineers and domain/ pedagogic experts, as performed in this work;
- the manual summarisation of a domain in the form of concept maps, generated either by the teacher, or typically, collaboratively by the students themselves. Concept maps can be converted to ontologies by using appropriate tools (Simón, Ceccaroni & Rosete, 2007);
- the automatic ontology generation from text using appropriate tools. Although this constitutes an open research problem, it is possible to create domain ontologies from text corpora such as textbooks, manuals and tutorials;
- the reuse of ontologies created for specific educational technology purposes, such as educational content organisation (Boyle & Pahl, 2007), searching and planning, (Dicheva & Dichev, 2006; Karampiperis & Samson, 2004) and knowledge representation for intelligent tutoring systems ;
- the reuse of existing domain ontologies for educational purposes. These ontologies are typically created by domain experts, for example, as annotations of historical archives and museum digitized resources (Trant, Bearman, & Richmond, 2002). Assessment and entertainment activities can be supported by automatically generating questionnaires based on such existing ontological descriptions.

Furthermore, multimedia ontologies are becoming available for the annotation of digital libraries, archives and multimedia databases in order to enhance human user and agent access to multimedia content (Hunter, 2001; Garcia, & Celma, 2005; Tsinaraki, Polydoros, & Christodoulakis, 2007). These ontologies are mostly based on MPEG-7 (Martínez, 2002), which is the prominent multimedia description standard and they cover media-related aspects of annotated media, while they provide poor support for abstract description of multimedia content. In order to describe the semantics of the domain associated with content, domain ontologies are used.

This paper describes an approach for the automatic generation of questionnaires, both text-based and media rich, from both domain ontologies and multimedia annotations. Multimedia questionnaires are restricted to items with images, but the approach can be generalized to sound and video media as well. For experimental purposes the paper reports on results produced with a number of domain ontologies for text-based questionnaires. Domain ontologies are represented in OWL format thus conforming to Semantic Web technology standards (W3C, 2004), while multimedia annotations used are provided in RDF format (RDF, 2004). Based on this approach, a prototype tool was developed, which accepts as input ontology OWL ontologies and provides as output multiple choice questionnaires. Certain strategies are used for selecting the correct answers in question items, as well for selecting distractors. These strategies are analytically presented and constitute the main contribution of this paper.

The rest of this paper is organized as follows: In Section 2 related work is presented; in Sections 3 and 4 the strategies for text and image question generation are discussed, while Section 5 describes the generation of questions and insights of the implementation of the prototype system. In Section 6 an evaluation of the approach is presented; conclusions are outlined in Section 7.

Related work

Up to our knowledge, there is no method for question generation based on multimedia annotations. Regarding text-based questions, the methodology presented by Mitkov, Ha, & Karamanis (2006) generates multiple choice questions based on text corpora in a specific domain by employing ontologies, such as WordNet (Miller et al., 1995). The proposed system functionality can be divided in three steps: term extraction concerning frequent concepts inside the text, stem generation and distractor selection. The extraction of the terms occurs by shallow parsing of scanned text corpora. Afterwards, a frequency measure is applied so the noun or noun phrase with occurrence frequency above a customizable threshold is selected. The stem generation actually filters the clauses and transforms the selected ones to the stem of an item. This is done by utilizing a simple set of rules that are assisted by WordNet. The last part, namely the distraction selection part is dictionary-based and uses mostly WordNet to obtain the candidate distractors. Apart from the fact that our approach can deal with media questionnaires, OWL ontologies are used for representing the domain knowledge, which can provide richer semantics/axioms than Wordnet or any other lexicon, but more important they support the reasoning with the existing knowledge for the production of new (inferred) knowledge.

Holohan, Melia, McMullen, & Pahl (2005) describe the OntoAWare system, which provides a set of tools useful for educational content authoring, management and delivery. It exploits the semantic web technology along with knowledge-representation standards and knowledge-processing techniques. Moreover, the authoring environment that is introduced by the system concerns the semi-automatic generation of the learning objects (standard e-learning and courseware elements). In order to generate the learning objects, one can customize existing ontologies or even create a new one from scratch. One of the features of the presented system is the generation of questionnaires from ontology elements, which is the focus of our paper. However, the focus of OntoAWare is on adaptivity and personalisation. Thus, the generated questionnaires are based on subsumption axioms (class-subclass relationships). No further strategies are applied, and thus, the expressiveness of OWL-DL in describing domain knowledge is not utilized for evaluation. The delivery environment of this system can also be configured and can vary from free navigation to learning technology standards-based course delivery in the form of Simple Sequencing specification.

Holohan, Melia, McMullen, & Pahl, (2006) present an advancement of the OntoAWare system towards generating assessments for problem solving skills in the domain of relational databases. These assessments are produced by utilizing an ontology which describes the domain in question. Students may customize the system in order to produce personalized problems. While this approach goes one step further by assessing higher order skills such as problem solving, it is confined in a single knowledge domain.

Soldatova & Mizoguchi (2007) describe an ontology-based approach for test composition. There is a threefold use of ontologies: a test ontology provides a detailed specification of test items; a student model describes the level of understanding of topics comprising the domain model under consideration. Finally, a set of rules governing the test construction process. In this approach emphasis is given to constructing tests delivering items of appropriate difficulty with regards to a particular user model. As exemplified in (Slodatova & Mizoguchi, 2003), for some types of knowledge, question items are automatically generated based on facts, events and terms contained in the domain model. Our approach does not require the use of a predefined ontology, but rather uses the standard semantics of OWL for assessing the knowledge of a domain.

Tsumori & Kaijiri (2007) propose a methodology similar to ours for MCQ generation based on ontologies. These ontologies are used as a knowledge base for item generation based on predefined templates. The ontology used relates each concept (term) with a synonym, a definition, a description a figure, a superconcept and a potential concept with a part-of relationship. This ontological description is not as expressive as OWL, used in our approach. It focuses on estimation of question difficulty and student assessment. Furthermore, although MCQs with images are supported, more advanced questions with images are supported by our approach, as discussed in section 5.

AquaLog (Lopez, Uren, Motta, & Pasin, 2007) is an integrated system for answering questions by users expressed in natural language. Questions are mapped to triples representing queries applied to an OWL-based knowledge base. Query results are also triples, which must be converted to natural language sentences, just as in our approach. While AquaLog provides a sophisticated methodology for mapping from natural language queries to ontology triples, there is no mechanism for doing the opposite, that is, conversion from query triples to natural language, which is of interest in our approach.

Li & Sambasivam (2005) provide a method for generating questions that involve students in solving equations of multiple variables. These variables correspond to quantities related to terms that are specified appropriate ontologies in specialized domains. While this is an advanced method for problem solving questions generation from ontologies, its use is confined in specific domains, while our method is domain/independent and furthermore can take advantage of media annotations.

Text-based multiple-choice question generation

The overall architecture of the proposed approach for question generation is illustrated in Figure 1. A domain ontology, in OWL format, is provided as input. Reasoning is applied for class subsumption relationships identification and classification of individuals. Text/based strategies are applied for identifying the the semantics of both correct answers and distractors for each question item. Then, simple natural language generation techniques are applied for creating the actual items. For media (image) based questions, multimedia annotations are used in combination with a related domain ontology, together with the appropriate image.

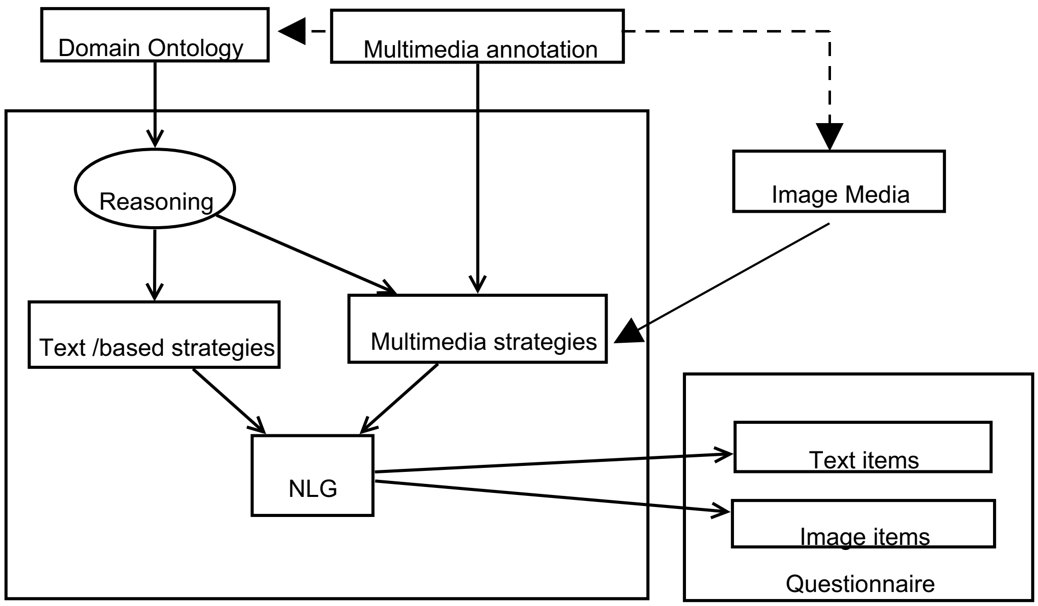

Figure 1. Questionnaire generation approach

OWL is the standard Web ontology language with well defined semantics. OWL is based on Description Logics knowledge representation formalism (Baader, Calvanese, McGuiness, Nardi, & Patel-Schneider, 2003) for expressing concept definitions and basic relationships between concepts, which is considered as adequate level of expressiveness. Furthermore, a number of software tools are available for ontology management and reasoning. Thus, OWL was chosen as input formalism for the description of domain ontologies. Media annotations can be provided in various formats; in the current version an RDF description is supported, as discussed in section 5. The approach presented in this paper follows specific ontology-related conventions: *A*, *B, C*, *D* are names of *concepts* (also known as *classes)*, *R*, *S* are names of *roles* (also known as *relationships or properties)* and *a*, *b*, *c* are names of *individuals* (also known as *instances)*. Based on these conventions, we produce the following statements:

A(*a*): states that *a* is an individual of class *A.*
R(*b*,*c*): states that individuals *b* and *c* participate in binary role *R.*

In the presented examples, individuals are typeset in italics, while classes and properties are typeset in larger fonts, e.g. *Eupalinos* and *EupalinosTunnel* are both individuals, Engineer and Tunnel are both concepts that describe the type of the related individuals respectively (i.e. *Eupalinos* is an Engineer and *EupalinosTunnel* is a Tunnel), and constructed(*Eupalinos*, *EupalinosTunnel*) is a property that relates two individuals (binary role).

Snapshots of the domain ontologies used for experimentation and presentation are depicted in Figures 2 and 4. A rectangular denotes a class or individual, a line with an *io* symbol denotes an *instance_of* relation between a class and an instance, a line with an *isa* symbol denotes a subclass relation between two classes and finally a dashed line with a role attached denotes a binary relation between two classes/instances.

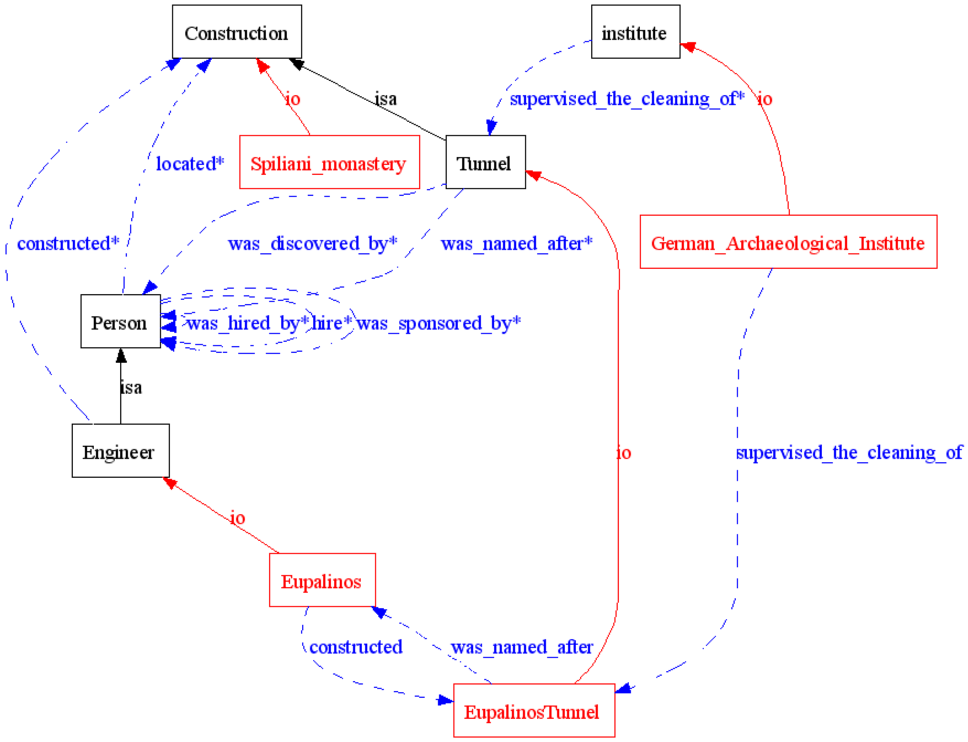

Figure 2. Example snapshot from the EupalinosTunnel domain ontology

The strategies presented in this section deal only with the semantics and not with the syntactic aspects of question formation. Sentence generation is discussed in Section 5. All strategies were selected, so as to provide distractors semantically as similar as possible to the correct answers, so that they successfully mislead students not knowing the correct answer. In the following subsections, these strategies are presented together with examples taken from a domain ontology in the Greek ancient history domain called ‘Eupalinos Tunnel’, which is partially illustrated in Figure 2 due to space limitations. Strategies are distinguished into three major categories, depending on the elements in the ontology that are used to extract the appropriate knowledge for sentence creation.

Class-based Strategies

In ontologies, individuals are members of collections named concepts or classes. These classes are organised in subsumption (class/subclass) hierarchies, that is, *isa* relationships, as depicted in Figure 2. This category contains strategies that generate distractors based on classes and their individuals. For all strategies, correct answers are of the following type: ‘Instance *a* is a Class A’, e.g. ‘*Eupalinos* is an Engineer’. In ontology engineering terms, the above sentence means that *Eupalinos* is an instance of Engineer or that *Eupalinos* is of type Engineer.

Distractors are formed by creating sentences in the same format as the correct answer, by choosing proper individuals or classes different than those that appear in the correct answer.

Strategy 1. Choose individuals which are not members of a given class, provided that they are members of one of its superclasses. More specifically, if *A(a)* for some *a,* then correct answer is: *A(a)*. For the distractors selection, we assume that *B* is a superclass of *A*. Then, if *B(b)*, *b≠a* and *b* is not an individual of *A*, then *A(b)* is a distractor.
Example: '*Ampelos Hill* is a Mountain' is the correct answer, since *Ampelos Hill* is an instance of class Mountain. '*North Opening of main tunnel* is a Mountain' is a distractor, since *North Opening of main tunnel* is an instance of concept Location, which is a superclass of class Mountain. As shown in the example, distractors formed by this strategy differ from the correct answer in the name of individual used as subject.

Strategy 2. Choose individuals belonging to disjoint siblings of a given class, in order to generate distractors. If *A(a), b≠a*, *B(b)* and *B* is a sibling class (disjoint or not) of *A,* then *A(b)* is a distractor. Note that if *B* is not a disjoint sibling of *A*, the strategy still applies, but in this case there is a possibility that a distractor is a correct answer, which leads to an invalid distractor.
Example: '*Eupalinos* is an Engineer' is the correct answer, since *Eupalinos* is an instance of class Engineer. '*Polykrates* is an Engineer' is a distractor, since *Polykrates* is an instance of concept Politician and Engineer and Politician are disjoint subclasses of class Person.

Strategy 3. Choose individuals belonging to a class that has a non empty intersection with a given class. If *A(a),* there exist an individual *b* different than *a* and a class *B,* such that *B(b)* and *A(b)* and there exists individual c such that *c≠a* and *B(c),* then *A*(*c*) is a distractor.
Example: '*Eupalinian Aqueduct* is a Remarkable Achievement' is the correct answer, since *Eupalinian Aqueduct* is an instance of class Remarkable Achievement. '*Dyros* is a Remarkable Achievement' is a distractor, since *Dyros* is an instance of class Tunnel and *Eupalinian Aqueduct* is a member of both classes Tunnel and Remarkable Achievement (Tunnel and Remarkable Achievement have a non empty intersection).

Strategy 4. Choose sibling classes (disjoint or not) to a given class. If *A(a), B* is a sibling of *A*, disjoint or not, then *B*(*a*) is a distractor. Distractors differ from correct answers in the name of the class. This strategy is dual to strategy 2.
Example: '*Eupalinos* is an Engineer' is the correct answer, since *Eupalinos* is an instance of class Engineer. '*Eupalinos* is a Politician' is the distractor, since Engineer and Politician are disjoint subclasses of class Person.

Strategy 5. Choose subclasses of a given class. If *A(a)* and, *B* is a subclass of *A* and *a* is not a member of *B* then *B*(*a*) is a distractor. Again, distractors differ from correct answers in the name of the class in generated sentence. This strategy is dual to strategy 1.
Example: '*Aristrachus* is a Person' is the correct answer, since *Aristrachus* is a member of class Person. '*Aristarchus* is an Engineer' is a distractor, since Engineer is a subclass of Person.

Property-based Strategies

This category contains strategies that create question items and distractors based on properties (roles), that is, relationships between individuals in the ontology. A property has a *domain*, which is the "class of individuals to which this property can be applied" and a *range*, which is the "class of individuals that a property can have as its value" (W3C, 2004). There are two kinds of properties in OWL: object properties, which are relationships between individuals and datatype properties, that is, relationships between individuals and basic types, e.g. numerical or string. In terms of OWL, R is an *object property* and b, c are individuals, which are related by this particular property. Correct answers are generated from property instances in the ontology, $R(a,b)$, that is, individuals a,b related with property R.

Strategy 6. Choose individuals from a class equal or subclass of the domain of a given property. If $R(a,b)$, $c \neq a$ and c an individual of a class which is equal to or subclass of the domain of property R then $R(c,b)$ is a distractor.
Example: '*Polykrates* hired *Eupalinos*' is the correct answer, since the domain of this property is class Person. '*Herodotus* hired *Eupalinos*' is a distractor, since *Herodotus* is an instance of class Historian which is a subclass of class Person.

Strategy 7. Choose individual members of a class which is equal or subclass of the range of a given property to generate distractors. If property R, $R(a,b)$, $c \neq b$ and c an individual of a class equal or subclass of the range of property R then $R(a,c)$ is a distractor.
Example: '*Polykrates* hired *Eupalinos*' is the correct answer, since the range of this property is class Person. '*Polykrates* hired *Herodotus*' is a distractor, since *Herodotus* is an instance of class Historian which is a subclass of class Person (the property range).

Strategy 8. Choose a property having both domain and range equal or subclass of the domain and range of the property of the correct answer. More formally, if a property S has a domain and a range that are equal or subset to the domain and range of property R correspondingly and $R(a,b)$ is a correct answer, then $S(a,b)$ is a distractor.
Example: '*Eupalinian Aqueduct* brings water to *ancient city of Samos*' is the correct answer. '*Eupalinian Aqueduct* leads to *ancient city of Samos*' is a distractor, since property leads to has range Location and domain Tunnel.

Strategy 9. Choose a numeric *datatype property* value by taking multiples and submultiples of a given property value. This strategy is based on numeric datatype properties, that is, on properties that relate individuals to numerical values.
Example: If '*Eupalinian Aqueduct* years spent for completion 10' is the correct answer, then '*Eupalinian Aqueduct* years spent for completion 16' is a distractor.

Terminology-based Strategies

Strategies in this category are based solely on concept/subconcept relationships, without dealing with ontology individuals at all.

Strategy 10. Choose sibling classes of a given class to substitute the *subject* of the correct answer sentence. If class A is a subclass of B, then A *is a* B is the correct answer. If C is a sibling of class B then a distractor is: C *is a* B. Distractors differ from correct answers in the class name used as subject.
Example: 'Sovereigns are politicians' is the correct answer, since Sovereign is a subclass of Politician. 'Monks are politicians' is a distractor, since Monk is a sibling class of Politician.

Strategy 11. Choose sibling classes of a given class to substitute the *object* of the correct answer sentence. If class *A* is subclass of *B,* then, again, *A is a B* is a correct answer. If *C* is a sibling of class *B,* then a distractor is: A is C. Distractors differ from correct answers in the class used as object. Strategies 10 and 11 use the same technique for substituting the subject and object of a correct answer, correspondingly, for producing distractors.
Example: 'Sovereigns are politicians' is the correct answer, since Sovereign is a subclass of Politician. 'Sovereigns are monks' is a distractor, since Monk is a sibling class of Politician.

Multimedia question items generation

Beyond text-based multiple-choice question items, our approach handles the generation of multimedia items. In the following paragraphs we discuss additional strategies, in order to support the integration of multimedia content in questions based on simple multimedia semantics.

Annotation of content with multimedia semantics, i.e. semantics for describing multimedia knowledge about objects, has been lately used in a variety of applications (i.e Tsinaraki, Polydoros, & Christodoulakis, 2007; Dasiopoulou, Tzouvaras, Kompatsiaris, & Strintzis, 2008). Latest efforts such as COMM[1] (Core Ontology for Multimedia) are based on multimedia annotation standards, such as the MPEG-7 standard and are proposed as formal descriptions compatible with existing (semantic) web technologies (Arndt, Staab, Troncy, & Hardman, 2007). Multimedia ontologies are intended to be used in combination with domain ontologies. The latter formalize entities depicted at multimedia content and their relationships.

We have been experimenting with the COMM API as well as with other semantic annotation multimedia content solutions, such as PhotoStuff[2] in order to semantically annotate multimedia objects (currently images) using both domain and multimedia knowledge represented in domain and multimedia ontologies respectively. Although COMM API is a modern approach towards standardization of semantic multimedia annotation, it was not used eventually in the extended approach for multimedia-based question items construction, due to incompatibility with the ontology management framework[4] that we were using for the domain ontologies. Alternatively, we have annotated the example image with the same domain ontology using the PhotoStuff tool. Although the MPEG-7 standard is not fully supported in the multimedia ontology of this tool, there is adequate knowledge represented for experimenting with spatial semantics. Other MPEG-7 based descriptions can be supported as well, though not in the present version of our tool. As an example, we illustrate the semantic annotation of a sample image available in COMM web site[1] depicting a picture from Yalta Conference illustrated in Figure 3. Using PhotoStuff tool, we have created an RDF annotation file containing definitions of image regions illustrated in the picture, i.e. SR1, which corresponds to the face of Winston Churchill. This file also contains a mapping between image regions and individuals in the domain ontology, illustrated in Figure 4, which is described in OWL format. In the domain ontology, "*Winston_Churchill*" is an individual associated with the above still region.

Figure 3. Yalta Conference example image with 3 regions selected for annotation. Note that regions have different identifiers in the PhotoStuff description[1].

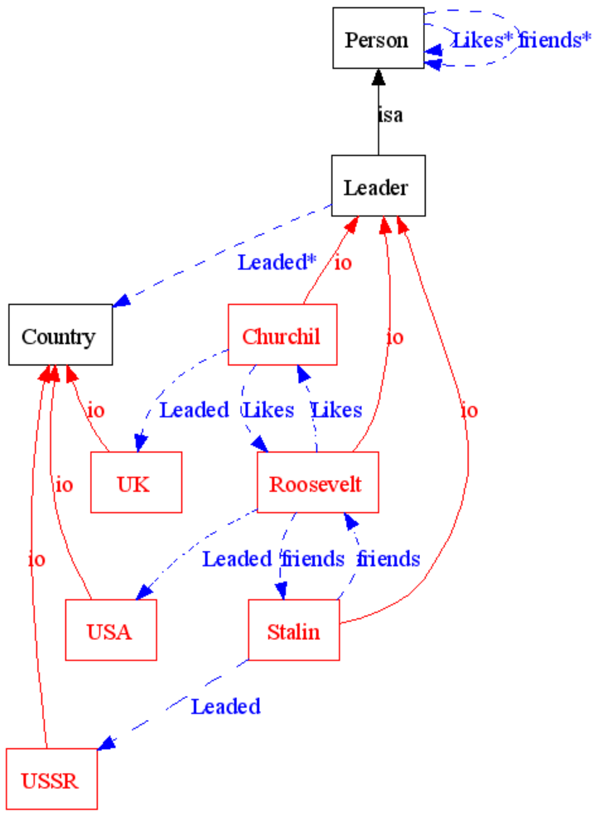

Figure 4. A snapshot of the domain ontology that represents knowledge about the Yalta Conference event. Such knowledge is used to semantically annotate the multimedia object (Yalta Conference image).

Multimedia-based strategies

In this section we describe strategies for multimedia-based question item generation. Questions are generated automatically from a knowledge repository which contains the following:

- a domain specific ontology which is composed from an ontology scheme, i.e. classes and relationships between these classes in a subject domain and a set of individuals (e.g. the Yalta Conference domain ontology);

- a set of images which are related to the aforementioned domain (e.g. the Yalta Conference image);
- annotations, facilitated by PhotoStuff, that relate images, as well as particular image regions to individuals of the domain ontology.

In order to generate questions, a combination of techniques from processing of multimedia ontology files, basic image processing and natural language generation are incorporated. More specifically, in PhotoStuff ontology we specify *image regions,* which are associated with specific domain ontology individuals. The questions generated belong to various types of image-related question items. In the following, we have adopted the terminology of the IMS QTI specification (IMS, 2005) for question types.

Multiple choice questions with image

Multiple choice questions with images are types of questions presenting an image and prompting learners to select among one or more options concerning information related to the image. The following strategy is related to this kind of questions:

Strategy 12. Highlight an image region which is associated with an individual *a* of a class *A* in the domain ontology to indicate the area in question to the learner. Highlighting can be performed by an image filter algorithm, for example by changing the colour of the region in question. Possible distractors are different individuals of class *A* which are also illustrated in the picture.
Example: in the Yalta Conference picture a question item generated with this strategy is: '*The person highlighted in the picture is*'. If the highlighted person is 'Stalin', then possible distractors are '*Franklin Roosevelt*', '*Winston Churchill*'.

Hotspot interaction questions (single and multiple answers/responses)

In this type of questions an image is presented to the learner, who is asked to identify a specific region in the presented image. One or multiple selections may be correct. Each region can be marked by a hot spot, which is a visual sign, indicating an image region, in order to facilitate selection. Alternative false hotspots can be given as distractors. The following strategies apply to this kind of questions:

Strategy 13. Identify an image region instantiated in the multimedia ontology, which is associated with an individual *a* of class *A* in the domain ontology. Then, construct an item with stem: 'Identify *a* in the picture'. Distractor hotspots correspond to individuals of class A or a superclass of *A*, different than *a* in the picture. An example output of this strategy is the stem '*Identify Winston Churchill in the above picture*'. Possible distractors are '*Stalin'* and '*Franklin Roosevelt*', as illustrated in Figure 4.

Strategy 14. Identify an image region instantiated in the multimedia ontology. Find an individual *a* in the domain ontology, which is related with an individual *b* through an object property *R*, i.e. *R(a,b)* specified into the domain ontology. Distractor hotspots correspond to individuals different than *a* belonging to the *domain* of property *R*.
Example: If leaded is an object property in the Yalta Conference domain ontology, and sentence leaded(*Stalin, USSR*), then '*Identify a* person *which* leaded *USSR in the picture*' is an example

output of this strategy. Distractors are, again, the hotspots of Churchill and Stalin, individuals of class Person depicted in the picture.

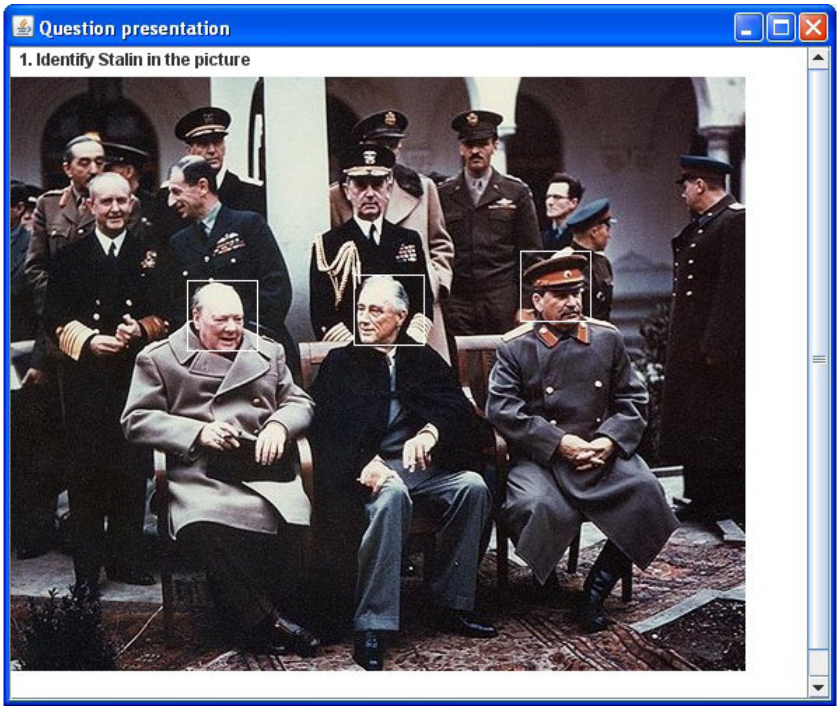

Figure 4. An example of Strategy 13. Hotspots are displayed as rectangles.

Strategy 15. Identify an image region, *r,* instantiated in the multimedia ontology. Find an individual *b* in the domain ontology, which is an individual of class *B* and is related with an individual *a* through an object property *R*, i.e. *R(a,b)* is specified into the domain ontology. Distractor hotspots correspond to individuals different than *b* in the *range* of property *R*.
Example: If likes is an object property in the domain ontology describing Yalta Conference, and sentence likes(*Roosevelt, Churchill*) is included in the domain ontology, then '*Identify a* person *which Roosevelt* likes *in the picture'* is an example output of this strategy.

Strategies 14 and 15 differ in the individual participating in the relationship. In Strategy 14 it is the first participant (role) in the relationship that is associated with a region in the picture, while in Strategy 15 it is the second participant in the object property. It thus leads to a difference in the form of generated sentence between the two strategies.

Other types of interaction

Graphic association interaction question items are types of questions prompting the learner to connect two regions of an image, which are associated with some semantic relationship. In a question delivery environment, a learner typically connects these regions by linking together appropriate hotspots, as these depicted in Figure 3. A strategy for generating questions of this type involves the generation of a graphic association item connecting hotspots that corresponds in an image that correspond to individual parts of a specific property. Distractors are formed by choosing image regions or hotspots referring to individuals belonging to the domain or the range of the object property.

Although not implemented in current version of our prototype, we provide an example of this strategy:

If likes(*Roosevelt,Churchill)* is a fact in the domain ontology, as presented in previous examples, then a stem for an item of this type can be '*Connect Roosevelt with a* person *which Roosevelt* likes'. This strategy is similar to Strategy 15 above in the sense that they share the same semantics in terms of both domain and multimedia ontologies. They differ only in the type of generated item.

Spatio-temporal semantics of multimedia annotations in combination with domain ontologies can be used for utilizing other types of media such as video and audio in order to more sophisticated ways of assessment. This can be achieved by generalizing the above strategies, so that they use other types of media segments apart from still regions. Thus, questions can be generated using video or audio segments associated with domain classes/individuals to be recognized in a video or audio sample, respectively. As an example of generalizing strategy 12, after displaying a properly annotated video about dance positions, a question can have the form: '*After arabesque, the dancer performed:*' with possible answers '*Fouetté', 'En pointe',* and '*Jeté'.* The other strategies can also be generalized. In this case, a question delivery system enabling real time interaction with video in needs to be utilized.

Automatic question generation prototype

A prototype tool was developed which accepts as input OWL documents and multimedia annotations and generates questionnaires using the above strategies. The format of questions is illustrated in Figure 5.

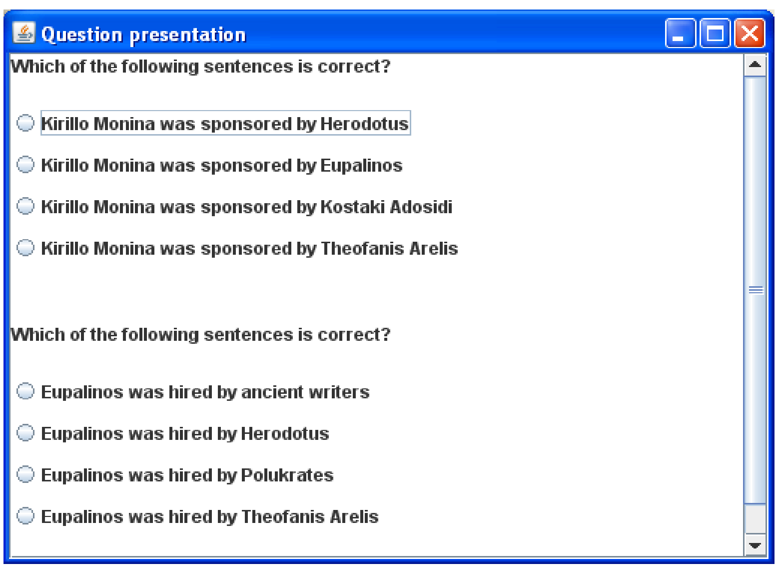

Figure 5. The MCQ generation output for a text MCQ item.

In all types of text-based MCQ questions, the stem is '*Which of the following sentences is correct?*'. In question items based on instance-of relationships, that is, for class-based strategies, declarations in the form Concept(*Individual*) in the ontology are transformed in sentences of the form '*Individual* is a(n) Class'. As an example, '*Eupalinos* is an engineer'. For strategies based on subclass relationships, that is, for questions generated by terminology-based strategies, class names appear in plural number. For questions generated by property-based strategies, sentences are generated in the form '*Individual* propertyName *Individual*'. 'was_sponsored_by' is the name of an object property and thus, an example of a generated sentence is '*Kirillo Monina was sponsored by Kostaki Adosidi*'. The name of the property is tokenized according to simple rules, for example, underscore is recognized as a separating character. Sentence generation is performed using the SimpleNLG natural language generation framework[3].

Input ontologies should adhere to certain conventions in order to generate syntactically correct sentences, with the NLG techniques adopted. Properties' names should be written as verbs or verb-like phrases. The names of classes, individuals and properties must contain words connected with underscores, hyphens, or multiple concatenated words with first word letter capital, such as 'hasValue'.

The MCQ presentation application is implemented in Java. JENA Semantic Web framework[4] is used for OWL ontologies management and storing and thus for the implementation of strategies presented in previous section. Pellet open source Description Logics reasoner[5] is used as an inference engine, that is, for subsumption and automatic classification of individuals in the ontology. Both text and multimedia (image) question items are presented using the Java Swing graphics toolkit. This solution was preferred to exporting questionnaires in QTI format, due to the fact that we were not able to find an (open source) QTI player implementation to support image questionnaires.

Evaluation of multiple-choice question items generation

A number of ontologies from different domains were used for evaluating the proposed approach for text-based questions (strategies 1 to 11). Some metrics pertaining to the number of classes, individuals and properties contained in these ontologies are presented in Table 1. From the example ontologies, *Eupalineio Tunnel* ontology was developed by domain experts and ontology engineers as a test-case for the method presented in this paper.

Table 1. Example ontologies used for evaluating the proposed approach

	Eupalineio Tunnel	*MSc Program*	*Travel v.1*	*Travel v.2*	*Grid Resources*	*Food ontology*
Individuals	40	100	145	38	21	12
Classes	29	25	72	21	54	63
Object prop.	25	38	22	13	26	4
Datatype prop.	16	23	13	0	24	0

The generated questionnaires were evaluated in three dimensions: Pedagogical quality, linguistic/ syntactical correctness and number of questions produced. These dimensions were considered for each strategy category.

The generated questions from the Eupalineio Tunnel ontology were reviewed by two domain/educational experts. All questions were found satisfactory for assessment by the experts. Nevertheless, all questions are not syntactically correct. Especially, Travel 1 and Msc Progr ontologies have particularly poor performance, because in these the names of various elements are far from the conventions required for natural language generation, which were described in previous section.

Table 2. Multiple choice question items per question generation strategy

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*Total*
Eupalineio T.	3/3	5/8	5/5	5/8	1/2	0/0	0/0	3/3	0/6	3/3	3/3	66/88
Eupalineio T-R.	9/12	6/9	6/7	12/12	3/3	32/41	6/6	3/3	0/6	3/3	3/3	83/99
Travel 1		3/17		5/14		1/3	0/39		0/55	19/19	19/19	47/166
MSc Progr		3/6		0/5					0/59			3/70
Grid Res.				0/1					0/1	6/6	6/6	12/14
Grid Res.-R.	5/6	14/16		2/18	10/13				0/1	17/22	13/20	61/96
Food				1/2						7/19	6/19	14/40
Food-R.	8/11	6/15		8/13	4/6					31/40	38/52	95/137

Table 2 depicts the number of syntactically correct items and the total number of questions per strategy for each domain ontology. For the sake of comparison, first row in the above table displays results for the Eupalinos ontology without reasoning (automatic classification and computation of instances' inferred types), while second row displays results after applying reasoning. The same comparison is displayed for two more ontologies, Food and Grid Resources. The application of reasoning has two main consequences. First, the total number of items increases, since inferred individuals and subsumed classes are taken into account. Second, not only direct subclasses/superclasses are taken into account, but also the subsumed ones. As a result, more distant classes are used in generating distractors, which are semantically distant from the correct answer. For example, Strategy 4, after applying reasoning, generates distractor '*Pantheon is a subtunnel*', which is much distant from the correct answer '*Pantheon is a unique construction*' and thus is easier to be rejected by the learner. However, there is a trade off between shortage of distractors and availability, albeit of easy ones.

Meaningfulness depends heavily on the ontology structure. If input ontological descriptions are correct, then OWL management mechanisms guarantees the meaningfulness of the question items generated. When items are produced from concepts with large semantic distance, then items are easier, as stated before. Strategies involving individuals seem to produce more difficult questions than terminology-based ones. Property-based are also more difficult than class-based, since they involve the association between concepts or individuals, thus requiring a more thorough understanding of a particular domain.

Property-based strategies may produce a large number of multiple choice questions but are very difficult to manipulate syntactically. Class and terminology-based strategies on the other hand are much easier to handle syntactically but generate fewer questions for ontologies of the same depth and population.

While the proposed approach works well in defining the semantics of questions, the problem of generating syntactically correct question items is only partially tackled.

Evaluation of multimedia strategies was based on two domains: *Yalta Conference* and *Eupalineio Tunnel*. A number of related images were annotated using PhotoStuff and the related domain ontologies.

Table 3. Ontologies/images for multimedia strategies evaluation

	Classes	*Individuals*	*Properties*	*Images*	*Annotated regions*
Eupalineio Tunnel	29	40	26	17	21
Yalta Conference	18	27	9	13	20

For multimedia strategies evaluation we run experiments with ontologies/images presented in Table 3, using strategies 12 to 15. Question items generated were evaluated based on the same criteria as in text-based generated question items. Table 4 illustrates the results per strategy.

Table 4. Multimedia items per question strategy

	12	*13*	*14/15*
Eupalineio Tunnel	8/11	0/2	0/1
Yalta Conference	20/25	11/15	5/10

As it is shown, some strategies generate more than one question item per image. The users of the system must select items according to the pedagogical needs of a particular questionnaire. As previously, some items are not correct, because property or individual names do not conform to certain conventions previously described. Furthermore, there are images in the form of a map in the *Yalta Conference* domain, in strategy 13, where countries to be identified are already labeled in the map. This kind of problem is expected to occur in other cases as well. Nevertheless, question items are meaningful and adequate for evaluation use. The more engaging and difficult strategies are 14/15, grouped in Table 4, and 14, since they engage relationships, followed by 13, which involves only subsumption relationships and individuals.

Conclusion

Domain and multimedia ontologies can be used in order to automatically produce multimedia rich questionnaires. In this paper, a novel approach for automatic generation of questionnaires for self assessment has been presented. The proposed approach is based on strategies that use ontological axioms and asserted/inferred knowledge (text and multimedia) of a knowledge base developed in OWL. A prototype tool has been developed for evaluation reasons, proving that the proposed approach, when used with semantically-rich and fully populated domain ontologies, can provide successful cases.

Future work on this direction includes the pedagogic evaluation of the approach with elementary school students, as well as improvements on the NLG subsystem. Furthermore, initial experiments have been also started in order to provide an automatic mechanism for enriching domain ontologies either in the level of concepts/properties (ontology learning) or in the level of individuals (ontology population). Our first experiments on this direction include information sources such as the Web using search engines, such as Google to 'fish' individuals from on-line lexicons or other linguistic resources.

The list of strategies which are described here should not be considered as exhaustive. Other strategies can be further implemented which utilize rich semantics of knowledge representation formalisms using more expressive constructs of OWL, such as defined classes and cardinality constraints. Moreover, as already discussed, support for spatial and temporal annotations is planned in order to generate assessment activities incorporating video, music and sound, based on semantically annotated media.

Notes

1. http://comm.semanticweb.org/

2. http://www.mindswap.org/2003/PhotoStuff/
3. http://www.csd.abdn.ac.uk/~ereiter/simplenlg/
4. http://jena.sourceforge.net/index.html
5. http://pellet.owldl.com/

References

Arndt, R., Staab, S., Troncy, R., & Hardman, L. (2007). Adding Formal Semantics to MPEG-7: Designing a Well-Founded Multimedia Ontology for the Web (Tech. Rep Nr. 4/2007). Koblenz: University of Koblenz.

Baader, F., Calvanese, D., McGuiness, D., Nardi, D., & Patel-Schneider, P. (eds) (2003). *The Description Logic Handbook: Theory, Implementation, and Applications*. USA: Cambridge University Press.

Bateman, J. (1997). Enabling technology for multilingual natural language generation: the KPML development environment, *Natural Language Engineering*, 3, 15–55.

Bontcheva, K., & Wilks, Y. (2004). Automatic Report Generation from Ontologies: the MIAKT approach. *Nineth International Conference on Applications of Natural Language to Information Systems (NLDB'2004)*. Manchester, UK.

Boyce, S. and Pahl, C. (2007). Developing Domain Ontologies for Course Content. *Educational Technology & Society*, 10(3), 275–288.

Dasiopoulou, S., Tzouvaras, V., Kompatsiaris, I., & Strintzis, M. (2008). Capturing MPEG-7 Semantics. *Metadata and Semantics*, pp. 113–123. Springer.

Dicheva, D. and Dichev, C. (2006). TM4L: Creating and Browsing Educational Topic Maps, *British Journal of Educational Technology*, 37(3), 391–404.

IMS (2005). *IMS Question and Test Interoperability Implementation Guide. Version 2.0 Final Specification*. Retrieved April 30, 2007, from IMS Web site: http://www.imsglobal.org/question/qti_v2p0/imsqti_implv2p0.html.

Gagné R., Briggs, L., & Wager, W. (1992). *Principles of Instructional Design* (4th ed.). New York: Harcourt Brace.

Garcia, R., & Celma,Ò. (2005). Semantic Integration and Retrieval of Multimedia Metadata. *Proceedings of 5th International Workshop on Knowledge Markup and Semantic Annotation (SemAnnot 2005)*.

Hearst, M. (1992). Automatic acquisition of hyponyms from large text corpora. *Proceedings of COLING*. pp. 539–545.

Holohan, E., Melia, M., McMullen, D., & Pahl, C. (2005). Adaptive e-learning content generation based on semantic web technology. *Proceedings of Workshop on Applications of Semantic Web Technologies for e-Learning (SW-EL@ AIED'05)*, Amsterdam.

Holohan, E., Melia, M., McMullen, D., & Pahl, C. (2006). The Generation of E-Learning Exercise Problems from Subject Ontologies, *Proceedings of the Sixth International Conference on Advanced Learning Technologies (ICALT'06),* Kerkrade.

Hunter, J. (2001). Adding Multimedia to the Semantic Web - Building an MPEG-7 Ontology. *International Semantic Web Working Symposium (SWWS),* pp. 261–281.

Jurafsky, D., & Martin, J. (2000). *Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition*. Englewood Cliffs: Prentice Hall.

Karampiperis, P., & Sampson, D. (2004). Adaptive instructional planning using ontologies, *Proceedings of International Conference on Advanced Learning Technologies,* pp. 126–130.

Li, T., & Sambasivam, S. (2005). Automatically Generating Questions in Multiple Variables for Intelligent Tutoring, *The Journal of Issues in Informing Science and Information Technology,* (2), 471–480.

Lopez, V., Uren, V., Motta, E., & Pasin, M. (2007). AquaLog: An ontology-driven question answering system for organizational semantic intranets. *Journal of Web Semantics*, 5, 72–105.

Martínez, J. (2002). Overview of MPEG-7 Description Tools, Part 2, *IEEE Multimedia*, 9(3), 83–93.

Miller, G. et al. (1995). *Five papers on WordNet* (CSL Rep. No. 43). Cognitive Science Laboratory, Princeton University.

Mitkov, R., Ha, L.A., & Karamanis, N. (2006). A computer-aided environment for generating multiple-choice test items. *Natural Language Engineering,* 12(2), 177–194.

W3C (2004). RDF Primer, Retrieved June 30 from W3C site: http://www.w3.org/TR/rdf-primer/.

Simón, A., Ceccaroni, L., Rosete, A. (2007). Generation of OWL Ontologies from Concept Maps in Shallow Domains, in D. Borrajo, L. Castillo, and J.M. Corchado (Eds.): *CAEPIA 2007, LNAI 4788*.

Soldatova, L., & Mizoguchi, R. (2003). Ontology of tests. *Proc. Computers and Advanced Technology in Education*, Greece, pp. 175–180.

Soldatova, L., & Mizoguchi, R. (2007). Testing and understanding by use of an ontology methodology. *Proc. of Joint Workshop of Cognition and Learning,* Berlin, pp.202–205.

Trant, J., Bearman, D., & Richmond, K. (2002). Open concepts: museum digital documentation for education through the AMICO Library. *Visual Resources Association Bulletin.* Retrieved April 30 from http://www.amico.org/docs/papers/2002/ArtDoc0302.pdf.

Tsinaraki, C., Polydoros, P., & Christodoulaki, S. (2007). Interoperability Support between MPEG-7/21 and OWL in DS-MIRF. *IEEE Transactions on Knowledge and Data Engineering*, 19(2), pp. 219–232.

Tsumori, S., & Kaijiri, K. (2007). System design for automatic generation of multiple-choice questions adapted to students' understanding. *Proceedings of the 8th International Conference on Information Technology Based Higher Education and Training*, Kumamoto, Japan, pp. 541–546.

W3C (2004). *OWL Web Ontology Language Overview, W3C Recommendation.* Retrieved April 30 from W3C Web site: http://www.w3.org/TR/owl-features/.