Using Ontologies to generate Learning Objects automatically

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Abstract. In this paper, the possibilities and challenges of using well known ontologies like WordNet and YAGO as knowledge bases in order to automatically compose learning objects for specific e-learning applications are explored. This approach takes advantage of those existing and free knowledge bases, combining them with concept level entities which give an outline of the course. A software system is presented which generates interactive exercises in HTML format for different courses. Based on an exercise previously generated by hand as a pattern and the already mentioned ontologies as knowledge bases, the system SIEG (System for Interactive Exercises Generation) allows creating new versions of the exercise changing its specific content. After creation, the exercises are transformed into learning objects by the AGORA learning object management platform.

Keywords: knowledge representation, automatic generation of exercises, ontology, learning object.

1 Introduction

Current World Wide Web (WWW) is a huge library of interlinked documents that are transferred by computers and presented to people. The openness and simplicity of the Web have had as a result lots of resources indexed by search engines. Also specialized collections of educational and other contents are available with catalogues and services to retrieve the information.

Semantic web [1] is an effort to enhance current web so that computers can process the information presented on WWW, interpret and connect it, to help humans to find required knowledge. The focus of semantic web is to share data instead of documents. Ontology is one of the main layers of the Semantic Web Architecture [2]

Knowledge bases are playing an increasingly important role in enhancing the intelligence of Web and enterprise search and in supporting information integration. Today, most knowledge bases cover only specific domains, are created by relatively small groups of knowledge engineers, and are very cost intensive to keep up-to-date as domains change.

The use of technology in teaching is a very active field of research. In the last years there have appear a great number of proposals to introduce innovative tools in teaching, especially in connection with the World Wide Web. With the development of information technologies many researchers and instructors are interested in the educational resources on the Web. Resources are described as Learning Object (LO) which focuses on reusability and automation. LO is a central notion of the majority of current researches to Web-based education, and many institutions are developing research projects about learning object standardization.

Most of current research concerning LO and ontologies is related with making possible the enhancement of services and capabilities of learning object repositories [3, 4, 5, 6, 7, and 6]. In order to deal with the need of sharing learning objects, recent work [8, 9, 10, and 11] argue for the use of ontologies as a means for providing a shared understanding of common domains. Two key issues are usually addressed: 1) to provide help to users describing and searching resources by organizing the knowledge covered by the learning resources and 2) to define educational systems interoperability mechanisms to create a virtual learning space.

Learning objects composition (LOC) is one of the main challenges in e-learning management systems and it can be improved exploiting ontological reasoning, using semantic technologies based on "content metadata" [12, 13] integrating explicitly instructional theories. In those examples, an ontology-based organizational memory able to act as a knowledge base for multiple training environments should be created to satisfy such an objective. Then, course development could be carried out in two phases; in the first one concept level entities are composed to obtain an outline of the course. After that, the outline is filled up with actual resources from the repository. Both phases can use ontology-based models to capture specific domain knowledge.

The evolution towards the use of (intelligent) e-learning tools is particularly appropriate and useful for the automatic test generation for courses in Mathematics [14, 15, and 16], electric ac circuits analysis [17], computer databases [14]

The teaching/learning of cognitive skills, such as problem-solving, is an important goal in most forms of education. In well-structured subject areas certain exercise problem types may be precisely described by means of machine-processable knowledge structures or ontologies [14, 18]. These ontologies can readily be used to generate individual problem examples for the student, where each problem consists of a question and its solution.

In many courses the same type of question or exercise is applied many times, just changing some particular aspect of the question and, therefore, the expected answer. There are several interactive suites (i.e. Hot Potatoes [19], TexToys [20], Clic [21]) for creating web pages which contain language-learning exercises. Those suites allow the user to create several types of exercises but one by one, that is, the user has to type each exercise by him/her self, no matter if they have the same structure, the same pattern.

In this paper, we explore the possibilities and challenges of using well known ontologies like WordNet [23] and YAGO [24] as knowledge bases in order to automatically compose learning objects for specific e-learning applications. The purpose is to take advantage of those existing and free knowledge bases, combining them with concept level entities which give an outline of the course.

In section 2, it is described how to use WordNet dictionary via Antelope-Proxem software in order to develop exercises about English grammar concerning verb tenses, plural forms and so on. In section 3, it is described how to use Wikipedia encyclopedia through YAGO ontology to develop exercises for History like courses. Then, in section 3, it is also shown how to use YAGO relations as a frame to introduce new facts about a Spanish grammar course. Finally, in section 4, a software system for automatically generation of interactive exercises, System for Interactive Exercises Generation (SIEG), is introduced. Those exercises should match a certain pattern which could be represented by some ontology. Exercises are then stored in a Learning Object Database (LOD) grouped by courses. Exercises are generated in HTML format so they can easily be incorporated to e-learning platforms or Learning Management Systems (LMS). Those exercises in HTML could be easily transformed into Learning Objects (LO) by means of AGORA system [22]

2 Using WordNet lexicon by means of Antelope-Proxem

WordNet is a semantic lexicon for the English language. It groups English words into sets of synonyms called *synsets*, provides short, general definitions, and records the various semantic relations between these synonym sets.

In linguistics a *lemma* has two distinct interpretations:

1. morphology, lexicography: the canonical form or citation form of a set of forms (headword); e.g., in English, *run*, *runs*, *ran* and *running* are forms of the same lexeme, with *run* as the lemma.
2. psycholinguistics: abstract conceptual form that has been mentally selected for utterance in the early stages of speech production, but before any sounds are attached to it.

A lemma in morphology is the canonical form of a lexeme. Lexeme, in this context, refers to the set of all the forms that have the same meaning, and lemma refers to the particular form that is chosen by convention to represent the lexeme. In lexicography, this unit is usually also the citation form or headword by which it is indexed. Therefore, a lemma is the canonical form of each word describing a WordNet synset.

WordNet version 3.0 contains about 155327 words or terms organized in over 117597 synsets for a total of 207016 word-sense pairs. The Morphosemantic Database uses 14 semantic relations, including: hypernym, hyponym, meronym, troponym, etc. Semantic relations connect most synsets to other synsets. While semantic relations apply to all members of a synset because they share a meaning and are all mutually synonyms, lexical relations can also connect words to other words: for instance, antonyms and derivationally related words.

François-Régis Chaumartin at Proxem has developed Antelope [25], Advanced Natural Language Object-oriented Processing Environment, a .NET linguistic framework, which uses and extends WordNet. It includes several taggers and parsers, and implements many algorithms: similarity measures, Word Sense Disambiguation, Semantic Role Labeling and anaphora resolution to facilitate the development of Natural Language Processing software. The Antelope lexicon also includes data coming from eXtended WordNet [26], and a small subset of SUMO [27].

The assembly Proxem.Antelope.Lexicon provides methods to find the possible base forms of an inflected word for a given part-of-speech. Thus, given the word "glasses", the optical instrument, always in plural form, it returns back the singular noun "glass"

```
IInflectedWord[] words;
words = lexicon.GetBaseForms("glasses", PartOfSpeech.Noun);
Assert.AreEqual(2, words.Length);
// The optical instrument, always in plural form
Assert.AreEqual("glasses", words[0].BaseWord);
Assert.AreEqual(EnglishWordForm.BaseForm, words[0].Form);
// The plural form of a singular noun
Assert.AreEqual("glass", words[1].BaseWord);
Assert.AreEqual(EnglishWordForm.Plural, words[1].Form);
```

Proxem Antelope can also generate all inflected forms of a base word of a given part-of-speech. Therefore, it is possible to find the plural form of a word, given its singular form and vice versa. For example, given the noun “cat” it returns the plural form, "cats".

```
// The plural of the noun "cat" is "cats"
words = lexicon.GetInflectedForms("cat", EnglishWordForm.Plural);
Assert.AreEqual(1, words.Length);
Assert.AreEqual("cats", words[0]);
```

Other possibility is, given a verb i.e. "to abide", it is possible to verify its past tenses i.e. "abided" or "abode".

```
// The past tense of the verb "to abide" is "abided" or "abode"
words = lexicon.GetInflectedForms("abide", EnglishWordForm.PastTense);
Assert.AreEqual(2, words.Length);
Assert.IsTrue(Array.IndexOf<string>(words, "abided") >= 0);
Assert.IsTrue(Array.IndexOf<string>(words, "abode") >= 0);
```

Therefore, based on WordNet lexicon and Proxem Antelope tools, it is easy to develop interactive exercises about singular and plural forms of words, present and past tenses, etc for an English course.

3 Using Wikipedia encyclopedia by means of YAGO NAGA ontology

Wikipedia [28] is a free web-based and collaborative multilingual encyclopedia. Launched in 2001 this encyclopedia is currently the largest (13 million articles, 2.9 million in English) and most popular general reference work on the Internet. It has grown into one of the central knowledge sources of mankind, maintained by thousands of contributors, having defeated even MSN Encarta [29].

Wikipedia articles consist mostly of free text, but also contain different types of structured information, such as "infobox" tables, categorization information, images, geo-coordinates and links to external Web pages. This structured information can be extracted from Wikipedia and can serve as a basis for enabling sophisticated queries against its content. Several research projects like DBpedia [30], YAGO-NAGA [31] and others are oriented to extract information from Wikipedia and to make it available for computer programs on the Web.

DBpedia is an open community project that allows users to ask expressive queries against Wikipedia and to interlink other datasets on the Web with DBpedia data. The DBpedia project uses RDF (Resource Description Framework) as a flexible data model for representing extracted information and for publishing it on the Web. The DBpedia dataset is interlinked on RDF level with various other Open Data datasets (i.e. Freebase, OpenCyc, GeoNames, etc.) on the Web. This enables applications to enrich DBpedia data with data from these datasets.

As of November 2008, the DBpedia dataset describes more than 2.6 million things. The dataset features labels and short abstracts for these things in 30 different languages; 609,000 links to images and 3,150,000 links to external web pages; 4,878,100 external links into other RDF datasets, 415,000 Wikipedia categories, and 75,000 YAGO categories.

The YAGO-NAGA project started in 2006 with the goal of building a conveniently searchable, large-scale, highly accurate knowledge base of common facts in a machine-processible representation. This project approaches to build a comprehensive repository of human knowledge from a confluence of Semantic Web (Ontologies), Social Web (Web 2.0), and Statistical Web (Information Extraction) assets towards. Their methodologies combine concepts, models, and algorithms from several fields, including database systems, information retrieval, statistical learning, and logical reasoning. This project has the goal of building a conveniently searchable, large-scale, highly accurate knowledge base of common facts using a representation able to be processed by a computer.

The semantic search system named NAGA [32] operates on a knowledge graph, which contains millions of entities and relationships derived from various encyclopedic Web sources, such as Wikipedia, the Internet Movie Database (IMDB), World Factbook, etc. NAGA allows users to pose questions to YAGO. NAGA [33] provides a simple, yet expressive query language to query this knowledge base. The results are then ranked with an intuitive scoring mechanism.

YAGO (Yet Another Great Ontology) is a huge semantic knowledge base which contains information automatically extracted from Wikipedia and uses WordNet to structure information using a carefully designed combination of rule-based and heuristic methods [24]. YAGO harvests info boxes and category names of Wikipedia for facts about individual entities. It reconciles these entities with the taxonomic backbone of WordNet in order to ensure that all of them have proper classes and the class system is consistent. This includes the Is-A hierarchy as well as non-taxonomic relations between entities (such as hasWonPrize). YAGO is based on a data model of entities and binary relations. YAGO is designed to be extendable by other sources – be it by other high quality sources (such as gazetteers of geographic places and their relations), by domain-specific extensions, or by data gathered through information extraction from Web pages.

Currently, YAGO contains more than 2 million entities such as persons, organizations, cities, etc., and 20 million facts about these entities. The facts are represented as RDF triples, with a manually confirmed accuracy of 95% [34].

As in OWL and RDFS, all objects (e.g. cities, people, even URLs) are represented as entities in the YAGO model. Two entities can stand in a relation. For example, to state that Albert Einstein won the Nobel Prize, the entity Albert Einstein stands in the hasWonPrize relation with the entity Nobel Prize.

```
AlbertEinstein hasWonPrize NobelPrize
```

Numbers, dates, strings and other literals are represented as entities as well.

```
AlbertEinstein bornInYear 1879
```

In YAGO, entities are abstract ontological objects. This makes it possible to express that a certain word refers to a certain entity, like in the following example:

```
"Einstein" means AlbertEinstein
```

Classes are also entities. Thus, each class is itself an instance of a class, the class class. Classes are arranged in a taxonomic hierarchy, expressed by the subClassOf relation:

```
physicist subClassOf scientist
```

In the YAGO model, relations are entities as well. This makes it possible to represent properties of relations (like transitivity or subsumption) within the model. For example:

```
subclassOf type transitiveRelation
```

states that the subClassOf relation is transitive by making it an instance of the class transitive-Relation

The triple of an entity, a relation and an entity is called a fact. The two entities are called the arguments of the fact.

Therefore, based on Wikipedia encyclopedia and YAGO ontology, it is easy to develop interactive exercises about when and where somebody was born or died, where is situated some mountain or some river, etc.

Based on the relations defined into the YAGO-NAGA project [34], it is possible to develop a new ontology for a Spanish course:

1. to define that subject and predicate are parts of a sentence:
   ```
   Sujeto isPartOf Oración.
   Predicado isPartOf Oración.
   ```
2. to define elements of type Oración
   ```
   "Los estudiantes trabajan en una tarea para entregar" isA Oración.
   oración1 means "Los estudiantes trabajan en una tarea para entregar".
   ```
3. to define types of subject and predicate
   ```
   Expreso isA TipoOración.
   Tácito isA TipoOración.
   Nominal isA TipoPredicado.
   Verbal isA TipoPredicado.
   ```
4. to define relations between the sentence and its parts:
   ```
   tienePredicado domain Oración.
   tienePredicado range Predicado.
   tieneSujeto domain Oración.
   tieneSujeto range Sujeto.
   ```
5. to define the subject type and the predicate type of some specific sentence:
   ```
   oración1 tieneSujeto $s, $s type expreso,
   oración1 tienePredicado $p, $p type verbal.
   ```

Using this ontology it is easy to develop interactive exercises about classifying Spanish sentences according to their subject, predicate or complements.

4 System for Interactive Exercises Generation (SIEG)

Following the main characteristics of the System for Interactive Exercises Generation (SIEG) will be explained as well as the steps in the process (see Fig. 1)

The system is based on several general ontology databases like WordNet and YAGO, and another ontology which describes the exercise patterns. The Antelope framework is used in order to generate English grammar exercises, based on the WordNet database. YAGO database is used to generate exercises about History and Geography. At the same time, YAGO relations are used as patterns in order to incorporate new knowledge about Spanish grammar into the ontology database. Those ontologies are managed using SQL Server. The system is being developed using Visual Basic .Net over Visual Studio 2008 and Java Script.

Using those ontologies, the system generate exercises in HTML format and store them in an exercise database. After that, exercises are transformed into learning objects using AGORA system [35], and stored them in a learning object repository.

The first step of the process is to recognize a type of exercise that could be applied in several situations, just changing some simple aspect of the exercise. For example, the exercise could be to ask for the date when somebody was born, i.e. 'When was born Albert Einstein?' The same pattern could be used for any other person. A similar type of exercise would be to ask for the past tense of some particular verb, i.e. 'Which is the past tense of the verb abided?', or the plural form of some specific word, i.e. 'Which is the plural form of glass?' This step should be done by manually by humans.

Having identified an exercise type, an HTML implementation of it is generated by hand using Hot Potatoes or another suite. Based on the HTML code, a description of its main characteristics (i.e. title, question, possible answers, right answer, help information, etc) is created by SIEG Graphic User Interface (GUI). This description model specifies the exercise pattern and is stored in pattern database. One part of the model

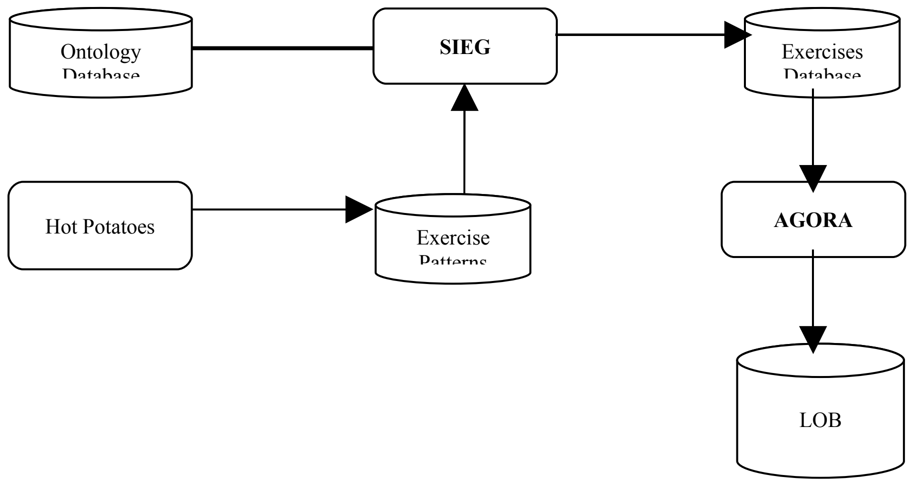

Fig. 1 General structure of the System for Interactive Exercises Generation (SIEG)

describes the presentation attributes: fonts, colours, position of the different fields in the screen, etc. Another part describes what to do with the answers of the students if they are right or not, how to calculate the marks, how to keep them, etc.

Based on an object oriented approach, a hierarchy of classes is being developed to characterize and predefine the main characteristics of the description model. In this hierarchy, the upper classes describe the generic information about the exercises (presentation attributes, answering management, etc.) while their subclasses describe the specific ones like question pattern, possible answers, the knowledge base relations involved to generate the specific question and its specific right answer, and the particular method to generate the specific question and to obtain its specific right answer. An interactive interface is being developed in order to easily create the pattern exercise and to define its attributes.

Other classes are oriented to describe and define a collection of related exercises to be used in a particular class session or in a particular evaluation. Those classes, most of all, describe how to determine and process the global evaluation that should be given to the student as a result of his/her particular answers to the different exercises that conform the session or evaluation.

Once the description model is created, including some constraining relations about the set of 'interesting' persons (respectively, verbs, words), several new exercises could be generated easily one for each one person (i.e. verb, word) without human intervention. For each exercise pattern, a method is defined which specifies how to get the specific question and its specific right answer from the knowledge bases. For example, in order to get from the Wikipedia (from YAGO) the name of a person born in Mexico in the 19th century, the following method could be used:

```
history(Person, Year):-
      bornOnDate(Person, Year),
      bornIn(Person, Place),
      locatedIn(Place, Mexico),
      after(Year, 1800),
      before(Year, 1900).
```

5 Conclusions

In this paper, the possibilities and challenges of using well known ontologies like WordNet and YAGO as knowledge bases in order to automatically compose learning objects for specific e-learning applications has been explored. Those knowledge bases contain important amounts of information that could be freely and easily used to develop exercises oriented to different subjects like History, Geography, English Grammar, etc. Those knowledge bases are being extended by our selves incorporating new relations and new facts in existing relations for Spanish Grammar. Those ontologies are managed using SQL Server.

Based on an object-oriented approach, a hierarchy of classes is being developed to model the general characteristics and attributes of exercises that allow generating automatically several specific instances of an exercise pattern, i.e. several particular and specific exercises. The already mentioned classes and objects allow to extract the right information from the knowledge bases and to integrate it into a particular exercise instance. The classes also specify how to integrate the different student answers in order to produce his/her mark.

A software system has been presented which generates interactive exercises in HTML format for different courses. Based on an exercise previously generated by hand as a pattern and the already mentioned ontologies as knowledge bases, the system SIEG (System for Interactive Exercises Generation) allows creating new versions of the exercise changing its specific content. After creation, the exercises are transformed into learning objects by the AGORA learning object management platform. The system is being developed using Visual Basic .Net over Visual Studio 2008 and Java Script. The system is being tuned in order to apply it for different courses about English and Spanish Grammar, Sustainable Development, etc.

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