

Automatic Construction of a Grounded Multimedia Ontology of Objects to Illustrate Concepts in a Learning Process

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Abstract

When building an e-learning system, we need a way of organizing the information to be presented to the user. Formal ontologies are one way of resolving this knowledge structuring task. The main use of ontologies in e-learning systems concerns the modelling of the domain of interest and this is equally our approach. Here we present a technique for automatically transforming unstructured data (from text and images) about domains into grounded ontologies that can then be used for e-learning applications. The chosen domain is “tools”, a collection that contains only picturable objects. We implement a grounded ontology that provides exemplars (definitions and images) at each node in the hierarchy. These exemplars can be used to illustrate concepts and ideas presented during learning, or in response to a learner's questions. One main characteristic of our method is the fully automatic population of large scale ontology.

1. Introduction

With the exponential increase of the quantity of data to be manipulated in computer applications, it becomes essential to efficiently organize and manipulate information. The richness of the included information is an essential condition for a good interactive application, but it raises serious problems concerning the management of this information. One successful solution for information organization is the use of formal ontologies [6]. It is undisputed that the hierarchical organization of concepts is proper to the way humans model entities in the world and this fact supports the use of ontologies in interactive computer applications, such as e-learning systems [1], [3], [10]. Our approach is close to that in [1] in that we propose the use of images and text organized as a multimedia

ontology as fundamental layer for an e-learning application.

The rest of this paper is organized as follows. We continue, in Section 2, by situating our work in the context of the Semantic Web [4] and by briefly discussing the relation between this initiative and e-learning. In Section 3, we discuss current approaches to ontology construction and present the methodology we developed for automatically building multimedia ontologies. We equally describe the way entities are represented in the created ontology. We illustrate, in Section 4, the utility of our work for e-learning by presenting an example of a learning situation. As we speak about an ongoing project, before concluding, we present the perspectives for enlarging and ameliorating both the linguistic and the image parts of the ontology.

2. Semantic Web and e-Learning

The Semantic Web (SW) initiative [4] aims at better structuring the data on the Internet. It proposes a stack, with layers going from unique description of entities (URI's) to a trust level that is, for the moment only theoretically described. From our point of view, the most interesting layer is the ontological one. It provides means for formally describing a domain in the world. Moreover, this level is technologically specified enough to allow the easy creation of applications. There exists an associated language, OWL (Ontology Web Language) as well as easy to use dedicated software, like Protégé [12].

As underlined in [13] the Semantic Web and e-Learning applications are strongly related. Through our approach, we propose a tight relation as we build an ontology, intended to be central in e-learning applications, using OWL component of the SW. This way, the integration of e-Learning applications in the SW framework becomes straightforward, as they are based on the same technology.

3. Ontology Building

We briefly present two approaches to ontology construction. We then describe our methodology that represents a compromise between the two and leads to the creation of a multimedia ontology.

3.1. Approaches to Ontology Construction

When one wants to model a domain under the form of an ontology, there are two main options that appear: manual or automatic ontology building. The first method has the advantage of good quality resulting knowledge, but this knowledge is obtained with costly time efforts. One good example for this approach to ontology construction is WordNet [8], a long time project started in the early 1990's that is still an ongoing work. WordNet is constructed by lexicographers and is meant to capture lexical knowledge into a computer usable database. It represents one of the largest commonsense knowledge resources existing.

The second option one has is to automatically build ontologies using a document corpus related to a domain. Interesting results for this approach are reported in [5] where several methods of automatic ontology construction are compared. Here, the time effort is smaller than in the manual construction of ontologies, but current techniques only provide means for limited domain ontology building. We are not currently able to use such methodology in order to create general interest ontologies.

The two approaches to ontology construction described above are not mutually exclusive and we are convinced that a compromise between the two can result into a valuable result. We describe such a tentative in the next section.

3.2. Multimedia Ontology Construction

We built a multimedia ontology for concepts found under *tool* in WordNet. It is important to mention that the methodology is domain independent and the subtypes of *tool* were chosen only for exemplification purposes. This lexical database has already been used in a number of applications in the ontology engineering, but in a different manner than the one described here. One example is to be found in [9], where WordNet is used for the validation of automatically constructed ontologies.

We used WordNet as taxonomical base for our ontology. The fundamental units in the database are

synsets (sets of synonyms). A synset contains the term(s) characterizing an entity in the modelled domain and all these units in the hierarchy were translated into an OWL classes in our ontology. The first term (if several exist) in a synset represents the class name. We equally preserved, in the class name, the sense number for the entity. This way, we preserve one important property in WordNet, the sense separation for ambiguous concepts. For example, *knife* is transformed into the OWL class *knife__1*.

The *tool* ontology we constructed contains a total of 347 classes, with a depth of 8 levels. In order to give an idea about the knowledge in our ontology, we present, in figure 1, an excerpt of the ontology corresponding to the subclasses of *scissors*.

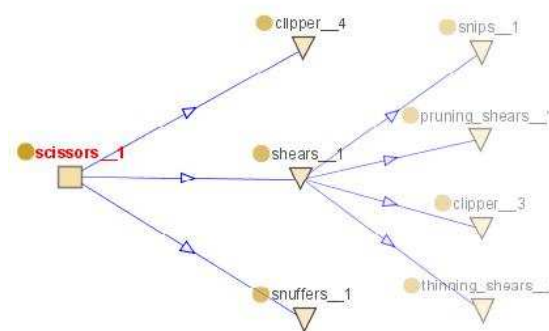


Fig.1 Subclass tree for scissors

We underline that there exist two types of concepts in figure 1:

-terminals (or leaves) – terms that do not have any subtypes in WordNet

-non-terminals – terms that have subtypes

This distinction is important in view of the discussion concerning the image classes attached to concepts. We observe, in figure 1, that *scissiors* is a non-terminal concept and has three direct subtypes while *clipper* and *snuffers* are terminals. *Shears*, who is at the same depth level in the hierarchy as *clipper* has itself four subtypes and is a non-terminal.

Beside the use of WordNet as taxonomical base, we equally imported the glosses (definitions) associated to concepts in our ontology and preserved the synonymy relations. The definitions were implemented as RDFS comments in the OWL ontology. If one synset contains more than one term (the others being synonyms to the first), we retain all terms beside the one giving the class name into a separate RDFS comment.

We employed VIKA [14], a tool for automatic image gathering and clustering to obtain the image clusters associated to the concepts in the *tool* hierarchy. The source for raw image data is the Internet and we used

the Alltheweb search engine [2] to gather the pictures. For a detailed discussion about VIKA we point to [14].

A dictionary containing all terms in terminal synsets was created and we performed picture searches with all terms in a synset. The rationale for associating images to terminal leaves in the hierarchy was that, as these concepts are the most specialized, the amount of noise in the raw image sets is minimal. Even so, there remain some ambiguous concepts and in these cases we use composed queries in order to disambiguate them. For example, *clipper* has two senses in our hierarchy. We separate the two senses by using the immediate supertype in the two situations. In consequence, we query for *clipper shears* and *clipper scissors*.

The only way we can associate images to the ontology is by attaching links towards external resources (URIs). The image clusters are stored in these external locations and it is easy to visualize them with Protégé.

In figure 2, we present an excerpt from an image cluster obtained for *thinning shears*.



Fig. 2 Clustered images for *thinning shears*

We observe that all images in figure 2 are representative for the illustrated concept. If we want to obtain pictures associated to *scissors*, we can use the hierarchical relation between this concept and the related subtypes present in WordNet. The same procedure can be applied for all non-terminal nodes in the hierarchy.

4. Ontology Use in e-Learning

As we mentioned, we follow a similar approach to the one theoretically described in [1]. We propose to use the created ontology in learning situations like the enrichment of knowledge related to a known concept.

We already mentioned that we present a work in progress and, at the end of the section, we discuss future directions for our work.

4.1. Concept description

We currently dispose of a multimedia description of concepts in our ontology. The textual side contains a definition of the concept as well as its synonyms, if existing. On the image side, the ontology contains clustered pictures for each node of the hierarchy. If we talk of a terminal, the images correspond exclusively to that synset. For the other nodes, the associated pictures are obtained using the type – subtype relation existing in hierarchies. Thus, we obtain good coverage for the non – terminal concepts. Moreover, we have a well structured representation of entities.

One problem that appears is the fact that not all clustered images are relevant for the given concept. A way to eliminate this difficulty would be to select one image cluster for each synset. This cluster should be the cluster that best represents the concept.

4.2. Use Case

We take the example of someone who wants to learn more about *scissors* than it is commonly known. An ontologically driven e-learning system can provide information about: the supertype(s) of the given concept concept, *edge tool*, about all types of *scissors* that exist (presented in figure 1) and their definitions. Thus we easily learn that there exist several types of scissors, like: *clipper*, *shears*, or *snuffers*. Moreover, we see that *shears* is further specialized into *clipper*, *pruning shears*, *snips* and *tinning shears*. Moreover, it is easy to offer well structured illustrations of the concept using the associated image clusters. As we mentioned, the illustrations are offered in an ordered manner as they correspond to the division of the concept into subtypes.

We can also find out what other types of *edge tools* exist. Other immediate subtypes of this category are: *axe*, *knife*, *sickle*, or *wire cutter*. If we go one step further, we learn that the supertype of *edge tool* is *cutter*. We can iterate one step further and find out which is the parent of *cutter*. This until we reach *tool*, the root of the hierarchy.

4.3 Future development

We described an ongoing work and there is much improvement to be realized. We plan to enlarge the textual side of the ontology by adding knowledge about

each node in the hierarchy. For example, we can integrate information about the uses we make of a *tool*, about the object it is in relation with, about its typical locations. One way to do this is to use ConceptNet [7], an easy to use comprehensive semantic network. An alternative is to parse documents on the web referring to the target concepts and try to extract valuable information from those documents.

On the image side, we currently test solutions designed to reduce the quantity of irrelevant images in the clusters. One proposition is to use semantic filtering [14] prior to the image indexing phase. There exist a lot of off topic pictures containing human faces and, as it is possible to detect the faces, we can eliminate those pictures. Image segmentation can help us filter pictures containing partial views of objects or those containing several objects.

In the current stage, we did not taken into consideration the role of the user. The e-learning applications are highly interactive and it is necessary to adapt the application to the users' needs. One possible adaptation is the creation of a proactive application that proposes future actions considering the actual and the past states of the system.

One other direction of development is the creation of multilingual ontology. There exist variants of WordNet aligned to the English version in several languages [11]. This is particularly interesting for e-learning as it might allow the use of the ontology when learning foreign languages. The existence of images corresponding to concepts would be of particular use as the pictorial representations of objects are generally common between languages. The presentation of images could trigger the learning process, permitting a better fixation of the concepts learned in the new language.

5. Conclusions

In this paper, we presented a possible way to use formal ontologies in e-learning systems. We briefly discussed the relation between the Semantic Web Initiative and the e-learning application. We describe the methodology we employed to implement our multimedia ontology and gave a practical example of ontology use for a learning situation.

Further work will focus on the extension of the current ontology as well as on the improvement of the adequacy of the images associated to concepts in the hierarchy. It is also important to try to better adapt the content of the ontology to an utilisation in an e-learning

system. We notably think of taking into account the users' needs when constructing the ontology.

6. References

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