Deliverable2

SOME-SEMANTIC ONTOLOGY MODEL

This document is the deliverable of the Task 1.2 of the Virtual Mobility Grant SOME-SEMANTIC ONTOLOGY MODEL founded by the COST Action: CA19136 with Reference number: E-COST-GRANT-CA19136-d93c2bbe

The reference task is related to the representation of SHAFE knowledge with a general ontology model based on linguistic features.

The definition of this model should be a valid contribution to solving some issues related to the identification of different dimension of SHAFE knowledge mosaics and to defining their meanings in a common and shared way.

The process of decoding SHAFE knowledge objects demonstrates the need for a new methodology for reading the SHAFE domain that takes into account its conceptual evolution and the multi-disciplinarity of this subject. The importance of representing SHAFE with new languages related to this novel cultural approach is thus evident.

These languages should allow the user to transmit the complexity of involved concepts and their meanings in the SHAFE context.

The development of an ontology-based model for knowledge representation, one that features universal terminology and basic criteria for information exchange, will allow the comparison of experiences in both cultural and operational contexts.

We explicit point out that a first core glossary to use for a first instance of the model has been reported in the first Grant Deliverable for task 1.1.

I give a systematic introduction to theoretical approaches to knowledge representation using formal models and languages to better understand the used methodology.

My approach starts from the modeling view of knowledge acquisition (Clancey, 1993), where the modeling activity must establish a correspondence between a knowledge base and two separate subsystems: the agent's behavior (i.e., the problem-solving expertise) and its own environment (the problem domain) (see also Gaines, 1993; Schreiber, 1993; Gruber, 1993). This vision is in contrast with the transfer view, wherein a knowledge base is a repository of knowledge extracted from one expert's mind. Using the modeling view approach, knowledge is much more related to the classical notion of truth as correspondence to the real world, and it is less dependent on the particular way an intelligent agent pursues its goals.

Although knowledge representation is a basic step in the whole process of knowledge engineering, a part of the AI research community seems to have been much more interested in the nature of reasoning than in the nature of ‘‘real world” representation. This tendency has been especially evident among the disciples of the called logicist approach: in their well-known textbook on AI, Genesereth and Nilsson (1987) explicitly state the ‘‘essential ontological promiscuity of AI” and devote just a couple of pages to the issue of conceptual modeling. They admit, however, that it is still a serious open problem. The issues of representation are also addressed in the same way in Russell and Norvig (2003).

The dichotomy between reasoning and representation is comparable with the philosophical distinction between epistemology and ontology, and this distinction is important to better understand my aim and approach.

Epistemology can be defined as ‘‘the field of philosophy which deals with the nature and sources of knowledge” (Nutter, 1998). The usual logicistic interpretation is that knowledge consists of propositions whose formal structure is the source of new knowledge. The inferential aspect seems to be essential to epistemology (at least in the sense that this term assumes in AI): the study of the ‘‘nature” of knowledge is limited to its superficial meaning (i.e., the form), since it is mainly motivated by the study of the inference process.

Ontology, on the other hand, can be seen as the study of the organization and the nature of the world independent of the form of the knowledge about it.

Previous approaches to the need for ‘‘tools” to represent knowledge, both for inferring and organizing it. From this point of view, one of the most important advances in the KR applications is derived from proposing (Minsky, 1974), studying (Woods, 1975; Brachman, 1977; Brachman, 1979) and developing (Brachman, 1985; Fox, 1986; Bobrow, 1976) languages based on the specification of objects (concepts) and the relationships among them. The main features of all KR languages are the following. Object-orientedness: all information about a specific concept is stored in the concept itself (in contrast, for example, to rule-based systems). Generalization/specialization: these properties are basic aspects of the human cognition process (Minsky, 1974); the KR languages have mechanisms to cluster concepts into hierarchies where higher-level concepts represent more general attributes than the lower-level ones, which inherit the general concept attributes but are more specific, presenting additional features of their own; reasoning: the capability to infer the existence of information not explicitly declared by the existence of a given statement; classification: given an abstract description of a concept, there are mechanisms to determine whether a concept can have this description. This feature is a special form of reasoning. Object orientation and generalization/specialization help human users in understanding the represented knowledge; reasoning and classification guide an automatic system in building a knowledge representation, as the system knows what it is going to represent.

My approach arises from the above considerations and is also suggested by the work of Guarino (1994). When a KR formalism is constrained in such a way that its intended models are made explicit, it can be classified as belonging to the ontological level (Guarino, 1994) introduced in the distinctions proposed in Brachman (1979), where KR languages are classified according to the kinds of primitives offered to the user.

At the (first-order) logical level, the basic primitives are predicates and functions, which are given formal semantics in terms of relations among objects of a domain. No particular assumption is made, however, regarding the nature of such relations, which are completely general and content independent.

The epistemological level was introduced by Brachman in order to fill the gap between the logical level, where primitives are extremely general, and the conceptual level, where they acquire a specific intended meaning that must be taken as a whole, without any consideration of its internal structure.

At the ontological level, the ontological commitments associated with the language primitives are specified explicitly. Such a specification can be made in two ways: either by suitably restricting the semantics of the primitives or by introducing meaning postulates expressed in the language itself. In both cases, the goal is to restrict the number of possible interpretations, characterizing the meaning of the basic ontological categories used to describe the domain: the ontological level is therefore the level of meaning.

At the conceptual level, primitives have a definite cognitive interpretation, corresponding to language-independent concepts such as elementary actions or thematic roles. The skeleton of the domain structure is already given, independently of an explicit account of the underlying ontological assumptions.

Finally, primitives at the linguistic level refer directly to lexical categories.

The proposed model is independent from a particular domain of interest because it is based on a linguistic approach that provides a simple and general way to represent knowledge.

The Model

I will now define the model, which is composed of a triple <S, P, C> where:

- S is a set of objects;
- P is the set of properties used to link the objects in S;
- C is a set of constraints on P.

In this context, we consider words as objects. The properties are linguistic relations, and the constraints are validity rules applied to linguistic properties with respect to the term category considered. In my approach, knowledge is represented by an ontology implemented with respect to a semantic network. A semantic network can be seen as a graph where the nodes are concepts and the arcs are relations among concepts. A concept is a set of words that represents an abstract idea.

In recent years, several languages have been proposed to represent ontologies. It is the author opinion that OWL is the best language for my purpose due to its expressive power. Therefore, we describe the semantic network implementing the ontology in OWL (Ver. 2.0) using the defined model. We use the DL version of OWL, because it is sufficiently effective to describe the ontology. The DL version allows the declaration of disjoint classes, which may be used to assert that a word belongs to a syntactic category. Moreover, it allows the declaration of union classes used to specify domains and property ranges used to relate concepts and words belonging to different lexical categories.

I formally describe the ontology schema and corresponding semantic network representation using OWL. Every node (both concept and word) is an OWL individual. The connecting edges in the semantic network are represented as ObjectProperties. These properties have constraints that depend on the syntactic category or kind of property (semantic or lexical). For example, the hyponymy property can only relate nouns to nouns or verbs to verbs. In contrast, a semantic property links concepts to concepts, and a syntactic property relates word forms to word forms. Concept and word attributes are considered with DatatypeProperties, which relate individuals to pre-defined data types. Each word is related to the concept it represents by the ObjectProperty hasConcept, whereas a concept is related to words that represent it using the ObjectProperty hasWord. These are the only properties that can relate words to concepts and vice versa; all of the other properties relate words to words and concepts to concepts. Concepts, words, and properties are arranged in a class hierarchy resulting from both the syntactic category for concepts and words and the semantic or lexical property type.

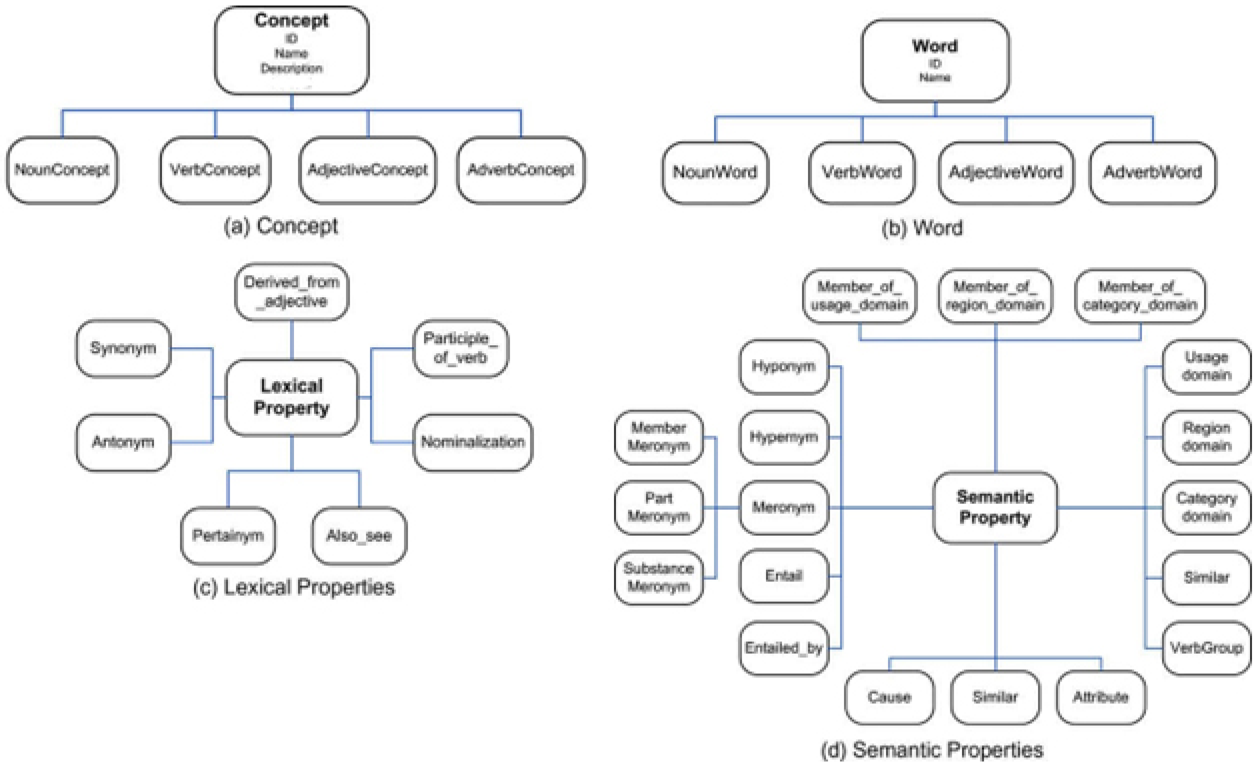

Figure 1: Model components

In Figure 1, the hierarchies used to represent the objects of interest in the model are shown. Figs. 1(a) and 1(b) show that the two main classes are Concepts, in which all objects are defined as individuals, and Words, which represent all of the terms in the semantic network.

These classes are not supposed to have common elements; therefore, we have defined them as disjoint. The class Word defines the logical model of the word forms used to express a concept. On the other hand, the class Concept represents the word meaning related to a word form. We can see that the subclasses have been derived from related categories. There are some union classes that are useful for defining the properties of domain and codomain.

We also define attributes for the Concept and Word classes. In particular, a Concept has: a Name representing the concept name, a Description that gives a short description of the concept.

In contrast, a Word has only a Name attribute representing the word name. For all elements, we define an ID based on the WordNet offset number or user definition.

The semantic and lexical properties are arranged in a hierarchy (see Fig. 1c and 1d). Table 1 shows some of the properties considered and their domains and ranges of definition.

Table 1: Model properties

Property	Domain	Range
hasWord	Concept	Word
hasConcept	Word	Concept
Hypernym	Noun and VerbConcept	Noun and VerbConcept
Holonym	NounConcept	NounConcept
Entailment	VerbWord	VerbWord
Similar	AdjectiveConcept	AdjectiveConcept

The use of domain and codomain reduces the property range application; however, the model as described so far does not exhibit perfect behavior in some cases. For example, the model does not know that a hyponymy property defined on sets of nouns and verbs would have (1) a range of nouns when applied to a set of nouns and (2) a range of verbs when applied to a set of verbs.

Therefore, we must define several constraints to express the ways that the linguistic properties are used to relate concepts and/or words.

Table 2 shows some of the defined constraints, and we specify the classes to which they have been applied with respect to the properties considered. The table also shows the matching range.

Table 2: Model constraints

Costraint	Class	Property	Constraint range
AllValuesFrom	NounConcept	Hyponym	NounConcept
AllValuesFrom	VerbConcept	Hyponym	VerbConcept
AllValuesFrom	NounConcept	Attribute	AdjectiveConcept
AllValuesFrom	AdjectiveConcept	Attribute	NounConcept
AllValuesFrom	NounWord	Synonym	NounWord
AllValuesFrom	VerbWord	Synonym	VerbWord
AllValuesFrom	AdjectiveWord	Synonym	AdjectiveWord
AllValuesFrom	AdverbWord	Synonym	AdverbWord
AllValuesFrom	VerbWord	Also_see	VerbWord
AllValuesFrom	AdjectiveWord	Also_see	AdjectiveWord

Sometimes, the existence of a property between two or more individuals entails the existence of other properties. For example, since the concept ‘‘dog” is a hyponym of ‘‘animal”, we can assert that animal is a hypernym of dog.

We represent such characteristics in OWL by means of property features.

Table 3 shows several of those properties and their features.

Table 3: Property features

Property	Features
hasWord	Inverse of hasConcept
hasConcept	Inverse of hasWord
Hyponym	Inverse of hypernym; transitivity
Hypernym	Inverse of hyponym; transitivity
Cause	Transitivity
verbGroup	Symmetry and transitivity

APPENDIX 1 – OWL SCHEMA

In this appendix the OWL representation of the proposed model is shown.

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        <rdfs:domain rdf:resource="#nounConcept"/>
        <rdfs:range rdf:resource="#nounConcept"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="part_holonym">
        <rdfs:subPropertyOf rdf:resource="#holonym"/>
        <owl:inverseOf rdf:resource="#part_meronym"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="hasConcept">
        <owl:inverseOf rdf:resource="#hasWord"/>
        <rdfs:domain rdf:resource="#Word"/>
        <rdfs:range rdf:resource="#Concept"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="hasWord">
        <owl:inverseOf rdf:resource="#hasConcept"/>
        <rdfs:domain rdf:resource="#Concept"/>
        <rdfs:range rdf:resource="#Word"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="antonym">
```

```
        <rdf:type
rdf:resource="http://www.w3.org/2002/07/owl#SymmetricProperty"/>
        <rdfs:subPropertyOf rdf:resource="#LexicalProperty"/>
        <rdfs:domain rdf:resource="#Word"/>
        <rdfs:range rdf:resource="#Word"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="also_see">
        <rdfs:subPropertyOf rdf:resource="#LexicalProperty"/>
        <rdfs:domain rdf:resource="#VerbsAndAdjectivesWord"/>
        <rdfs:range rdf:resource="#VerbsAndAdjectivesWord"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="member_of_region_domain">
        <rdfs:subPropertyOf rdf:resource="#SemanticProperty"/>
        <owl:inverseOf rdf:resource="#region_domain"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="LexicalProperty">
        <rdfs:domain rdf:resource="#Word"/>
        <rdfs:range rdf:resource="#Word"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="attribute">
        <rdf:type
rdf:resource="http://www.w3.org/2002/07/owl#SymmetricProperty"/>
        <rdfs:subPropertyOf rdf:resource="#SemanticProperty"/>
        <rdfs:domain rdf:resource="#NounsAndAdjectivesConcept"/>
        <rdfs:range rdf:resource="#NounsAndAdjectivesConcept"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="region_domain">
        <rdfs:subPropertyOf rdf:resource="#SemanticProperty"/>
        <owl:inverseOf rdf:resource="#member_of_region_domain"/>
    </owl:ObjectProperty>
    <owl:DatatypeProperty rdf:ID="peso">
        <rdfs:domain rdf:resource="#Word"/>
        <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#float"/>
    </owl:DatatypeProperty>
    <owl:ObjectProperty rdf:ID="cause">
        <rdf:type
rdf:resource="http://www.w3.org/2002/07/owl#TransitiveProperty"/>
        <rdfs:subPropertyOf rdf:resource="#SemanticProperty"/>
        <rdfs:domain rdf:resource="#verbConcept"/>
        <rdfs:range rdf:resource="#verbConcept"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="derived">
        <rdfs:subPropertyOf rdf:resource="#LexicalProperty"/>
        <rdfs:domain rdf:resource="#adverbWord"/>
        <rdfs:range rdf:resource="#adjectiveWord"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="part_meronym">
        <rdfs:subPropertyOf rdf:resource="#meronym"/>
        <owl:inverseOf rdf:resource="#part_holonym"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="category_domain">
        <rdfs:subPropertyOf rdf:resource="#SemanticProperty"/>
        <owl:inverseOf rdf:resource="#member_of_category_domain"/>
    </owl:ObjectProperty>
    <owl:DatatypeProperty rdf:ID="lemma">
        <rdfs:domain rdf:resource="#Word"/>
        <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
    </owl:DatatypeProperty>
    <owl:DatatypeProperty rdf:ID="z">
        <rdfs:domain rdf:resource="#Concept"/>
        <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
    </owl:DatatypeProperty>
    <owl:ObjectProperty rdf:ID="substance_holonym">
```

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        <rdfs:subPropertyOf rdf:resource="#holonym"/>
        <owl:inverseOf rdf:resource="#substance_meronym"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="entailment">
        <rdf:type
rdf:resource="http://www.w3.org/2002/07/owl#TransitiveProperty"/>
        <rdfs:subPropertyOf rdf:resource="#SemanticProperty"/>
        <owl:inverseOf rdf:resource="#entailed_by"/>
        <rdfs:domain rdf:resource="#verbConcept"/>
        <rdfs:range rdf:resource="#verbConcept"/>
    </owl:ObjectProperty>
    <owl:DatatypeProperty rdf:ID="y">
        <rdfs:domain rdf:resource="#Concept"/>
        <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
    </owl:DatatypeProperty>
    <owl:DatatypeProperty rdf:ID="x">
        <rdfs:domain rdf:resource="#Concept"/>
        <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
    </owl:DatatypeProperty>
    <owl:ObjectProperty rdf:ID="usage_domain">
        <rdfs:subPropertyOf rdf:resource="#SemanticProperty"/>
        <owl:inverseOf rdf:resource="#member_of_usage_domain"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="participle_of_verb">
        <rdfs:subPropertyOf rdf:resource="#LexicalProperty"/>
        <rdfs:domain rdf:resource="#adjectiveWord"/>
        <rdfs:range rdf:resource="#verbWord"/>
    </owl:ObjectProperty>
    <owl:DatatypeProperty rdf:ID="p">
        <rdfs:domain rdf:resource="#Concept"/>
        <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#integer"/>
    </owl:DatatypeProperty>
    <owl:ObjectProperty rdf:ID="synonym">
        <rdf:type
rdf:resource="http://www.w3.org/2002/07/owl#SymmetricProperty"/>
        <rdf:type
rdf:resource="http://www.w3.org/2002/07/owl#TransitiveProperty"/>
        <rdfs:subPropertyOf rdf:resource="#LexicalProperty"/>
        <rdfs:domain rdf:resource="#Word"/>
        <rdfs:range rdf:resource="#Word"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="substance_meronym">
        <rdfs:subPropertyOf rdf:resource="#meronym"/>
        <owl:inverseOf rdf:resource="#substance_holonym"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="pertainym">
        <rdfs:subPropertyOf rdf:resource="#LexicalProperty"/>
        <rdfs:domain rdf:resource="#adjectiveWord"/>
        <rdfs:range rdf:resource="#NounsAndAdjectivesWord"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="member_holonym">
        <rdfs:subPropertyOf rdf:resource="#holonym"/>
        <owl:inverseOf rdf:resource="#member_meronym"/>
    </owl:ObjectProperty>
    <owl:ObjectProperty rdf:ID="nominalization">
        <rdf:type
rdf:resource="http://www.w3.org/2002/07/owl#SymmetricProperty"/>
        <rdfs:subPropertyOf rdf:resource="#LexicalProperty"/>
        <rdfs:domain rdf:resource="#NounsAndVerbsWord"/>
        <rdfs:range rdf:resource="#NounsAndVerbsWord"/>
    </owl:ObjectProperty>
</rdf:RDF>
```

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