Ontological Knowledge and Language in Modelling Classical Architectonic Structures

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Abstract

This article will concern the specification of the conceptual and linguistic constraints for the construction of a knowledge base in classical architecture, an operation that involves the structuring of the concepts of the domain to which appropriate linguistic terms must be associated. Our approach will take into account models of conceptual dictionaries proposed in computational linguistics as well as knowledge representation and ontological formalisms proposed in artificial intelligence and ontological engineering.

1. Introduction

This article will concern the specification of the conceptual and linguistic constraints for the construction of knowledge bases to be used for applications in human language technology. We shall focus on a particular domain, the representation of classical architectonic structures, for which a knowledge base has been developed.

The construction of a knowledge base is an operation that involves the structuring of the concepts of a domain to which appropriate linguistic terms must be associated – this is often called an ontology.

As a principle, we assume that the knowledge base must exhibit a high degree of clearness, coherence, and correctness mandatory to develop applications involving an advanced treatment of its content, as required by many knowledge based applications. These characteristics can be obtained by controlling the process of creation, either human or automatic, by imposing a set of integrity constraints regarding the ways of structuring concepts and associating terms to them.

Our approach will take into account certain models of conceptual dictionaries proposed in computational linguistics as well as knowledge representation and ontological formalisms proposed in artificial intelligence and ontological engineering. We are confident that the representation of the lexicon will benefit from the integration of different methodologies capable of providing more insight about the complex relationships between lexicon and knowledge.

The relation between language and knowledge is one of the major problems studied for years in linguistics, psychology, philosophy and, recently, in computational linguistics and artificial intelligence, in particular, in knowledge representation and ontological engineering.

In cognitive science, the distinction of the reality into classes of objects is used in order to study the human process of acquisition of knowledge (Keil, 1989). Part-whole relations have been investigated in order to account for the conceptual processes underlying linguistic terms used for expressing the concept of "part". The result of this analysis has been the specification of a taxonomy of part-whole relations and of the logic underlying them (Winston et al., 1987; Cruise, 1979).

Computational linguistics is interested in finding a global organization of the lexicon into classes related to each other, in order to represent word meanings and to improve natural language understanding systems. Different approaches have been adopted which combine linguistic, cognitive and lexicographic aspects. However, the results are sometimes far from being coherent with clear logical and ontological assumptions (Hirst, 2004). The methods underlying certain conceptual dictionaries, like WordNet (Miller et al., 1990; Vossen, 1998) and Dicologique (Dutoit, 1992), are the results of a number of investigations trying to integrate multidisciplinary issues in the representation of the lexicon

The design of knowledge representation formalisms frequently integrates conceptual and linguistic considerations. As an example, the semantic network has been designed to represent word meaning and knowledge representation languages based on this formalism are relevant tools for the representation of the semantic aspect of the lexicon (Brachman and Schmolze, 1985; Caligaris et al., 1992; Cappelli & Mazzeranghi 1994; Patel-Schneider et al., 1996; Woods and Schmolze 1992).

Recently, a new generation of knowledge representation languages has been introduced, in which general abstract means for structuring knowledge can interact with a set of ontological constraints regarding the inner content of concepts. As an example, OWL is a language for defining structured, Web-based ontologies which can enable richer integration and interoperability of data across application boundaries. With OWL it is possible for information contained in documents to actually be processed by applications, rather than just presented to humans. OWL facilitates greater machine interpretability of Web content than that supported by XML, RDF, and RDF Schema (RDF-S) by providing additional vocabulary along with a formal semantics. OWL has three increasingly-expressive sublanguages: OWL Lite, OWL DL, and OWL Full (Bechofer et al., 2004).

Ontology is a fundamental field of research, critical of many advanced applications in computer science and information science, but also in medicine, education, and industries.

In the "Stanford Glossary of Ontology Terms", ontology is "an explicit specification of some topic, … a formal and declarative representation which includes the vocabulary (or names) for referring to the terms in that subject area and the logical statements that describe what terms are, how they are related to each other, and how they can or cannot be related to each other. Ontology therefore provides a vocabulary for representing and communicating knowledge about some topic and a set of relationships that hold among the terms in that vocabulary".

In this definition, philosophical intentions are as important as the conceptual and linguistic modelling of a specific domain for practical applications. Conceptual and linguistic modelling are important for representing and communicating knowledge, in other words, for implementing knowledge-based systems more immediately applicable to industrial problems.

Following Gruber (1995), “An ontology is a formal explicit specification of a shared conceptualization”. For Gruninger and Lee (2002), this notion of conceptualization refers to an abstract model of how people think about things in the world, usually restricted to a particular subject area. In this way, an ontology can be intended as a formal representation of a domain, instead of as a formal characterization of what exists in the world.

A philosophical and clear notion of ontology is invoked by Guarino and Welty (2000; 2002a; 2002b), who define ontology: a discipline of philosophy that deals with what *is*. Recognizing that “the accepted industrial meaning of ‘ontology’ makes it synonymous with ‘conceptual model’ and is nearly independent of its philosophical antecedents”, they draw the distinction between “conceptual model”, as an “actual implementation of an ontology that has to satisfy the engineering trade-offs of a running application”, and “ontology design”, whose only goal “is to specify the conceptualization of the world underlying such application” and is “independent from run-time considerations”. In this perspective, they try to specify a methodology (OntoClean) based on formal philosophical notions general enough to be used independently of a particular domain. In other words, formal notions are used to define a set of metaproperties, which are used to characterize relevant aspects of the intended meanings of the properties, classes, and relations. Formal notions, such as identity, essence, unity, and dependence are defined in order to specify a logical framework to make an intended meaning of a taxonomy more explicit.

Because of the interest for ontology in many application sectors, a new discipline has emerged, ontological engineering, whose goal is to investigate the entire ontology life cycle, which is composed of the following steps: design, evaluation, validation, and revision (Holsapp & Joshi, 2002).

A formal methodology for the entire life cycle of ontology building is Methontology (Blazquez et al., 2002). The aim of this methodology is to bridge the gap between how people think about a domain and the language into which the ontology is formalized. Intermediate representations, whose conceptual model is implicit, are constructed and translated into a coherent ontology.

The possibility to share and reuse ontology for different applications, directly or with minor modifications, is another goal of ontological engineering. Besides, sharability and reusability are considered two important characteristics of ontology built for industrial applications.

Our model has been specified for a specific domain. However, we are now investigating its applicability to other domains, i.e. legal, economical and social security for which we have developed applications in conceptual information retrieval and in text generation. The comparison of the result of the testing of the model on these fields, which have very different characteristics (architecture is characterised by functional artefacts, the others on nominals), will help in finding the variant and the invariant functional and material characteristics of each domain.

This problem is not only fundamental from a theoretic point of view, but it is also very relevant for applicative purposes. The solution of this problem should suggest a realistic view of reusability, especially in the development of efficient and robust methodologies for the total or partial modification of the body of knowledge for new knowledge based applications.

2. Description of the Domain

The modelling of the classical architectonic structures consists in the representation of very articulated and fine-grain descriptions of complex artefacts in accordance with a very subtle degree of granularity and by using descriptive parameters concerning, among others, the morphology of the composition of the subparts, their form, the material they are made of, and their function (Allsopp, 1965).

This domain is composed of complex artefacts with a precise identity.

A rich terminology, progressively specialized and structured following a rich tradition of classification and interpretation studies, enables us to precisely refer to the subtle descriptive distinction among objects, their functions, and their uses. The lexicon is then strictly related to the conceptual aspect of the domain, since it has been modelled in accordance with the “observable” structure of the artefacts. In other terms, by structuring the lexicon, it is also possible to account for the majority of the knowledge of the domain, since lexical items precisely refer to specific classes of objects or to specific descriptive parts of the objects themselves.

Let us introduce an example in order to highlight some characteristics of the domain. In classical architecture, the structure of the temple is composed of three parts: *stylobate*, *colonnade*, and *entablature*.

The *colonnade* is a range of columns.

The *column* is composed of a *base*, a *shaft*, and a *capital*.

The *base* is the lowest member of a column and therefore usually appears only in the Ionic and Corinthian order, rarely also in the Doric.

So, the *Doric column*, has, in general, no base and is composed only of a shaft and a capital.

The *shaft* is the main body of a column or a pier, in general, which is between the base and the capital. In the most ancient buildings, monolithic shafts can be found, but in general, in the classic period, the shaft was composed of several *drums*. A *drum* is one of the cylindrical sections or courses of a column shaft. A shaft also has some *flutes*, vertical channels, segmental, elliptical, or semicircular, in a horizontal section. The flutes, twenty in general, in the classical period, were separated one from the other by an *arris* in the Greek Doric and early Ionic orders, and by a *fillet* in the developed Ionic and Corinthian orders. In Doric columns, the flute was usually segmental, or in order to emphasize the *arris*, it was formed of three arcs constituting what is known as false ellipse. A deeper curve was given to the flutes in Greek Ionic and Corinthian columns and, in later work, the flute was semicircular. In rare examples, the flutes were carried spirally round the columns.

In the flutings of the Doric column, the *arris* was present: a sharp edge formed by two surfaces meeting at an external angle.

From this sequence of descriptions taken from the literature, certain regularities can be extracted, regarding both the nature of the objects and their mutual relationships.

The objects of the domain have an intrinsic structure made of parts described following precise descriptive parameters. The distinction between the objects and their assignment to well-defined classes are performed by the evaluation of specific descriptive parts and modalities, which vary in accordance to structural, historical, and cultural parameters. The domain is thus structured in classes and subclasses, which generalize descriptions of specific objects.

Due to this very cohesive conceptual organization, the lexicon is strongly structured in a rich technical terminology; its terms precisely refer to the objects of the conceptual organization. Objects and parts are univocally identified on the basis of subtle distinctions and have specific names. This helps in individuating singular descriptive characteristics in the vast variability of the artefacts, which can correspond to a specific sign of a period, school, or stylistic movement.

3. Formal Model of Knowledge

Starting from this representation, a formal model of the organization of knowledge has been specified, which explicitly accounts for all inherent characteristics of the knowledge. This model integrates knowledge representation techniques, lexical representation tools, and ontological engineering techniques which, together, contribute to the formal representation of the taxonomy of objects, of the association between objects and lexical terms, and of the typology of properties which describe objects as the grammar in Figure 1 shows (Cappelli et al., 2003).

3.1. Epistemological Parameters

We consider epistemology as the specification of certain basic means to structure knowledge independently of any content. In other terms, they constitute a general abstract grammar to organize knowledge (Brachman, 1979). The basic data structure of our representation is the concept, which aggregates information concerning its description, which is realized by the specification of its local descriptive subparts and its collocation inside the terminology.

A concept is an intensional representation of a class and has a structure, as shown in the following. A concept has a unique identifier, which unambiguously identifies it in the map and can aggregate a list of terms in different languages, which are the synonyms with respect to the concept. Concepts can be related the one to the other in order to specify their topological position inside the conceptual map, in terms of:

1. Superconcept. Between two concepts belonging to the same inheritance chain, one of which is more “general” than the other (*column* / *Doric column*); once inserted in the generalization chain, a concept follows the logic of subsumption
2. Thematic. Between two concepts associated by a sort of “point of view” relation, which cannot be defined in terms of a precise logic; thematic relations can be used for establishing relationships between different “semantic fields” for instance, the fact that the Doric order is characterized by the Doric column is represented putting in relation “Doric order” and “Doric column” by the relation “characterized by” which is not a clear meaning to be specified in terms of a precise type of semantics.

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<Concept> → <Concept identifier> <Synonyms> <Superconcept>
    <Thematic relation>  <Descriptive parts> <Glossa>
<Concept identifier> → <Integer>
<Synonyms> → <Terms>*
<Terms> →  <Lexicalized terms> <Non-lexicalized terms>
<Lexicalized terms> → <Word>
<Non-lexicalized terms>  → <Extracted terms> <New categorizations>
<Extracted terms>  → <Idioms>
<Idioms>  → <Multiword>
<Multiword> → <Word> <Word>+
<New categorization>  → <Expression>
<Word> →  <String of characters>
<Expression>  → <Text>
<Superconcept> → <Concept identifier>
<Thematic relation>  →  <Label> <Concept identifier>
<Label>  → is characterized by | is studied by | . . .
<Descriptive parts> → <Non meronimy parts> <Meronimy parts>
<Non meronimy parts>  → <Part name> <Concept identifier>
<Part name>  →  form | aim | stuff | . . .
<Meronimy parts>  → <Components> <Place>
<Components> → <Concept identifier> <Parameters>* <Nexus>
<Parameters> → <Descriptive parameters> <Structural parameters>
<Descriptive parameters>  → <Cardinality> <Dimensions>
<Cardinality>  →  <Cardinality label> <Integer>
<Cardinality label> → atleast | atmost | exactly
<Dimension> → <Dimension label> <Measure>
<Dimension label> → height | depth | length | diameter | . . .
<Measure> → <Real>
<Structural parameters>  → <Function> <Position>
<Function>  → <Predicate> <Arguments>*
<Predicate> → carry | decorate | link | channel | throw | . . .
<Position>  → <Preposition> <Arguments>*
<Prepositions> →  upon | under | between | in | behind | in front of | . . .
<Arguments>  → <Meronimy parts>
<Place>  → <Concept identifier> <Nexus>
<Nexus>  → <Concept identifier> <Chain>
<Chain>  → <Concept identifier> <Meronimy parts>
<Glossa>  → <Text>
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Figure 1: Formal grammar

3.2. Linguistic Parameters

Terms can be lexicalized or not lexicalized; for lexicalized we intend words (*temple*) present in a dictionary and multiwords (*Doric column*), which correspond to significant co-occurrences of words found in the literature. In this way, a concept represents one-word meaning (*column*) or that of a multiword expression (*Doric column*). Non-lexicalized terms are those sequences of words used as names of new concepts, which correspond to conceptualizations used for introducing technical and sharable distinctions, i.e., “the Doric Temple in B.C. 400”.

3.3. Ontological Parameters

Concepts are described by the declaration of their parts, which are related to the following concepts in accordance to the following types of links:

- Meronimic, which follow the logic of meronimy;
- non-meronimic, for all the others.

This distinction is very shallow, but it enables one to clearly separate those parts that can be manipulated in accordance with a well-defined logic and those which cannot.

Non-meronimic parts are those that are not constrained by a specific type of logic. They declare an association between a concept and another concept as one of its proper descriptions.

They can be used in order to explain certain standard properties, such as, for instance: the form (*a cover tile is normally semicircular or triangular*), the stuff (*the cover tile is made of terracotta or marble*), or the aim (*a palaestra is a training school for physical exercises*). They can also be used to express any other properties with no precise semantics, such as, for instance, the date of a building, its position in a catalogue, etc.

Meronimic parts follow the meronimic logic. We give examples about two types of meronimic relationships: component/object, which covers all the rich typology of structural descriptions of architectonic structures, and place/area, which allows us to distinguish, as an example, between buildings of the same type built in different areas (the Doric temple in Greece and in Sicily).

The place/area type has not yet been structured: only a nexus with a part of the same type, belonging to another concept is specified, since it follows the logic of transitivity.

Component/object type can have some descriptive and structural parameters. The descriptive parameters are:

- Cardinality: used to explain a fact, such as, for instance, *that a shaft bears sixteen flutes*.
- Dimensions: used to explain the dimension of a part in terms of a metric measure (*a column is four meters high*).

Structural parameters are used to express structural relationships between parts of concepts and realize a simplified notion of structural description of classical KL-One. They express:

- Position: to define the relative position of a part with respect to other parts, for instance: *the architrave is carried from the top of one column or pier to another*; the position is expressed by using preposition and declaring some parts as their proper arguments.
- Function: to define the role of a part in its relationship with another, as *in a pier has the function of carrying an entablature or arch*; the function is expressed by using predicates with their arguments.

Given that meronimic parts follow the logic of meronimy, they can be linked to each other in order to create long-distance association chains between descriptive parts of concepts to be exploited by a meronimic reasoning process. This enables us to compute the well known meronimic syllogism based on transitivity, for instance, if a frieze is part of an entablature and an entablature is part of a temple, then a frieze is part of a temple.

4. Conclusions and Future Works

This model has been applied in the creation of a knowledge base in archaeology starting from a list of terms extracted from glossaries and specialized texts. A question arises whether or not this model could be successfully applied to other domains. So, we are currently investigating the application of the model to politics, social security, law, economics and space science, in which we have already produced knowledge bases in accordance to other models not so deeply formalized as the one presented in this paper.

By comparing the work for creating a conceptual dictionary about politics and social security (Bagnasco et al., 2000), and the organization of knowledge for the development of a system for the semi-automatic generation of legal contracts, in which we have developed a grammar which integrates textual (structure of the document), linguistic (lexicon and syntax), and conceptual parameters, certain preliminary conclusions can already be drawn.

The distinctions we have introduced prove to be functional for the individuation of the generic and invariant aspects of a domain and for the specification of the means used for the creation of the concepts and of their relative lexical realizations.

As we have already noted, in classical architecture, a rich terminology has been created which enables one to precisely refer to the subtle descriptive distinctions among objects, their functions, and their uses. In other words, terms have been created by multiplying words or by applying morphological processes. In social security and, partly, in law, concepts are created by using synonymy or quasi-synonymy and by the creation of multiwords, through the variation of syntactic connectors (complex noun phrases).

Epistemological parameters appear to be very relevant for the dynamic and flexible construction of the topological structure of knowledge. Besides, being the most abstract part of the grammar for representing knowledge, they proved to be useful for the representation of those conceptual processes regarding, for instance, the organization of the world from the legislator's point of view, in particular, in definitions, attributions of rights, duties, etc.

Concerning the ontological aspects, some distinctions we have introduced, especially between meronimic and non-meronimic parts, proved to be particularly important, due to the relevant presence of nominal objects in politics and law. In these domains, the tendency is to make use of shallow associations between parts and whole not subjected to a precise type of logic.

This aspect should be more deeply explored, in particular for investigating the possibility of individuating abstract classes of concepts characterized by specific types of properties. This has been the aim of many approaches to ontology, in particular in the specification of the structure of a general and standard “top level” which, in our opinion, sometimes appear to be too rigid. We are now investigating the problem by using, as a paradigm, the flexible creation of concepts as permitted by new knowledge representation languages.

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