What are Ontologies Useful For?

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INTRODUCTION

This article is a reasoned survey about the main roles of ontologies in the Web era. It starts by providing a background enabling the reader to understand what ontologies in Computer Science are. Then it shows the most meaningful uses of ontologies and discuss the role of inferences and reasoners about ontological knowledge.

Once the decision to use semantic knowledge has been taken, next step is to find or build the suited ontology. To this purpose, the article shows how existing ontologies can be found and reused. Moreover, it presents some methodologies for building ontologies and some tools supporting ontology development. The last section highlights open issues related to reasoning mechanisms, ontology mapping, ontology evolution, and automatic ontology development.

The main goal of this article is to provide the reader with a synthesis of the advantages and limitations that the usage of ontologies has in Computer Science, in order to enable her/him to take informed decisions concerning the exploitation of ontological knowledge within different kinds of projects.

BACKGROUND

The term *ontology* originates in Philosophy, where it is usually written with the capital initial letter and refers to the branch of this discipline that studies the basic categories of existing entities and their relationships.

In Computer Science, the term *ontology* does not usually refer to a global and unambiguous characterization of reality, but instead to the representation of a particular "viewpoint" about a portion of reality. This means that, in Computer Science, there can be many "ontologies," often "partial" (i.e., referring to a part of the existence). For these reasons, the term is usually written without the capital initial letter and used in the plural. In Computer Science, ontologies are considered more interesting if they can be implemented by "computational objects," exploitable in software applications.

Despite these considerations, Computer Scientists do not actually agree about the meaning of the term "ontology" and in the literature different definitions of the term "ontology" can be found. In Gruber (1993) it is defined as "*an explicit specification of a conceptualization*"; Borst narrows the definition by introducing the aspects of formal specification and sharing: an ontology is thus "*a formal specification of a shared conceptualization*" (Borst, 1997); in (Studer et al., 1998) the authors propose to merge these two definitions: "*An ontology is a formal, explicit specification of a shared conceptualisation*." According to Guarino and Giaretta an ontology is "*a logical theory which gives an explicit partial account of a conceptualization*" (Guarino & Giaretta, 1995). This definition further narrows the meaning, by considering ontologies only logical theories and, in particular, stressing the fact that they are usually "partial" accounts of a conceptualization.

Since this last aspect is one of major importance, in this article we will (mainly) refer to the following definition of "ontology," which integrates this concept within the previously mentioned definition provided by Studer and colleagues (Studer et al., 1998):

An ontology is a formal, explicit (possibly partial) specification of a shared conceptualisation.

In the following, we will explain this notion of ontology by adopting a rigorous, but informal, approach.

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For a formal characterization, refer to (Guarino et al., 2009), among the others.

All the previously mentioned definitions mention the notion of *conceptualization*. A conceptualization is a set of elements, considered as existing in some portion of reality, together with a set of concepts and relationships which characterize (or enable to understand or to describe) that portion of reality, from a particular perspective. Notice that here we use the term "reality" in a broad sense (including physical entities, counterfactual ones, imaginary entities, and so on).

The definition we are considering does not include "private" conceptualizations, since it admits only those conceptualizations which are, at least to some extent, *shared* by some community of people, even not universally. In order to be communicated and (recognized as) shared, a conceptualization needs to be specified by means of a language. The definition we are considering requires such a *specification* to be *explicit* (i.e., the constraints about the correct usage of terms have to be as explicit as possible) and *formal* (i.e., readable/processable by a machine). Typically, an ontology that fulfills the adopted definition is specified in a logical language (e.g., in a language belonging to the first-order predicate calculus), thus assuming the form of a logical theory, in which the constraints are expresses as axioms.

The introduction of a language to express the conceptualization and, in particular, of a vocabulary to refer to its elements, is not enough, per se, to ensure that the language and its terms are used correctly, i.e. with their intended meaning, even by the members of the community sharing the ontology.

For instance, if we consider the fragment of reality represented by the academic world, we can state that, from a certain perspective, it can be described by the concepts of person, teacher, student, exam, etc. and by the relations linking them, e.g., students take exams. Given this conceptualization, we could introduce the terms *pers*, *teach*, *stud*, *exam*, *taken-by*. However, nothing prevent somebody from incorrectly using such terms, e.g., using *taken-by* to refer to a relation linking teachers to students.

Logical languages support the specification of axioms that constraint the usage of terms, and thus, specify, at least to some extent, their intended meaning. For example, our ontology could be a first-order theory, including – among others – the following axioms:

$$(\forall x,y)(\text{taken-by}(x,y) \rightarrow \text{exam}(x) \wedge \text{stud}(y)) \quad (1)$$

$$(\forall x)(\text{stud}(x) \rightarrow \text{pers}(x)) \quad (2)$$

$$(\forall x)(\text{tech}(x) \rightarrow \text{pers}(x)) \quad (3)$$

$$(\forall x)(\text{pers}(x) \rightarrow \neg \text{exam}(x)) \quad (4)$$

where: (1) specifies that if x is taken by y, then x is an exam and y a student; (2) specifies that every student is a person; (3) specifies that every teacher is a person; (4) specifies that entities which are, at the same time, persons and exams can not exist.

A (human or artificial) agent that follows the first-order predicate calculus rules, given these axioms, will never use the term *taken-by* with the wrong meaning mentioned before, since such a usage would contradict the given axioms. However, axioms (1)-(4) do not exclude the possibility of using, for instance, the terms *teach* and *stud* as synonyms. Such a usage would not correspond to the intended meaning for these terms, but, formally, it would be allowed by an ontology including only axioms (1)-(4). Therefore, such an ontology would exclude only some incorrect uses of these terms and thus it would not represent the exact meaning of these terms, but only an approximation of it. In other words, it is only a *partial* specification of the conceptualization we aim at representing. Since this is a feature characterizing ontological modeling as such, the definition of ontology we adopted takes it into account.

It is important to stress that, although a "good" ontology can allow usages of the language which are not coherent with the conceptualization it specifies, however, it can never exclude coherent usages. For instance, consider an ontology containing, beside axioms (1)-(4), also the following:

$$(\forall x,y,z)(\text{taken-by}(x,z) \wedge \text{taken-by}(y,z) \rightarrow x=y) \quad (5)$$

which states that every student can take at most one exam. Such an ontology excludes the possibility, for a student, to take two or more exams, and this is not coherent with the conceptualization of the academic rules we are trying to capture with the ontology. Such an ontology would not be an acceptable specification for the considered conceptualization.

In this section we mainly referred and will refer to ontologies expressed by means of logical languages,

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