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Ontology languages for the semantic web: A never completely updated review

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Abstract

This paper gives a never completely account of approaches that have been used for the research community for representing knowledge. After underlining the importance of a layered approach and the use of standards, it starts with early efforts used for artificial intelligence researchers. Then recent approaches, aimed mainly at the semantic web, are described. Coding examples from the literature are presented in both sections. Finally, the semantic web ontology creation process, as we envision it, is introduced.

Keywords: Semantic web; Ontology languages; Knowledge representation; Ontology creation process

1. Introduction

In recent years, several markup languages have been developed for realizing the semantic web. The construction of these languages is evolving according to a layered approach to language development, in particular at the level of the *ontology vocabulary* (Fig. 1 from [1]) as it is in this layer where the basis to carry out reasoning and inferencing are laid. These languages must meet a number of requirements. They[1] must [2]:

- Have a compact syntax.
- Be highly intuitive to humans.
- Have a well-defined formal semantics.
- Be able to represent human knowledge.
- Include reasoning properties.
- Have the potential for building knowledge bases.
- Have a proper link with existing web standards to ensure interoperability.

Unlike some existing markup languages, specifically HTML, a semantic web language must describe meaning in a machine-readable way. Therefore an ontology language needs not only to include the ability to specify vocabulary but also the means to formally define it in such a way that it will work for automated reasoning. Because the web is decentralized, the language must also allow for the definition of diverse vocabularies and let them evolve. Some existing languages let authors create ontologies by defining class taxonomies and relationships between multiple classes. Some other also allow the formation of more complex definitions by using axioms from some form of logic. The idea in this context is to add ontology-based metadata to web pages and improve accessibility providing a means for reasoning about content [45–48].

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[1] See also http://www.w3.org/DesignIssues/Logic.html.

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2. Early approaches

In this section some early languages for representing knowledge are briefly discussed, namely, the Knowledge Interchange Format, F-Logic, the Dublin Core, and The CYC project.

2.1. Knowledge Interchange Format

The Knowledge Interchange Format (KIF) is a formal language for the interchange of knowledge among disparate computer programs. The following are some of its features [3]:

- Declarative semantics. It is possible to understand the meaning of expressions in the language without appealing to an interpreter for manipulating the expressions.
- Logically comprehensive. It provides for the expression of arbitrary sentences in predicate calculus.
- Metaknowledge. This allows us to make all knowledge representation explicit and permit us to introduce new knowledge representation constructs without changing the language.
- Translatability. It enables practical means of translating declarative knowledge bases to and from typical knowledge representation languages.
- Readability. Although KIF is not intended as a language for interaction with humans, it is useful for describing representation language semantics and assisting humans with knowledge base translation problems.

As any declarative representation language, it requires a conceptualization of the world in terms of objects, functions, and relations. KIF is a language that was developed by the interlingua working group under the DARPA knowledge sharing initiative to facilitate knowledge sharing. It was designed to be a *state-of-the-art* interlingua tool. KIF is an extended version of first-order predicate calculus, and essentially an intermediary language for translating different knowledge representation languages. Its specifications are meant to be sharable. The sentence *All writers are misunderstood by some reader* is shown in Table 1 as a KIF sentence [4].

2.2. F-Logic

F-Logic is a full-fledged logic that includes a model-theoretic semantics and a sound and complete proof theory. This makes it computationally attractive and renders it as a suitable basis for developing a theory for object-oriented logic programming. F-Logic is an integration of frame-based languages and first-order predicate calculus. It includes objects, inheritance, polymorphic types, query methods, and encapsulation. Its deductive system works with the theory of predicate calculus and structural and behaviour inheritance [5]. It is capable of representing virtually all aspects of the object-oriented paradigm. Its main achievement is to integrate conceptual modelling constructs into a coherent logical framework. It provides classes, attributes with domain and range definitions, *is–a* hierarchies with set inclusion of subclasses, and logical axioms between elements of an ontology and its instances. Table 2 shows an example of F-Logic declarations [5].

Table 1
KIF example

```
(forall ?w
  (⇒(writer ?w)
    (exists (?r ?d)
      (and (reader ?r) (document d?)
         (writer ?w ?d) (read ?r ?d)
        (not (understands ?r ?d))
      )
    )
  )
)
```

Table 2
F-Logic example

```
bob: manager
1989: year
manager::empl
mary: faculty
10000: int
.
.
.
faculty :: empl
mary[boss→bob]
empl [boss⇒manager; salary @ year⇒integer]
faculty[boss⇒faculty]
```

2.3. Dublin core

The oldest and most widely adopted initiative for global markup is the Dublin[2] Core (DC). Its goal is to facilitate electronic resource discovery on the web. It consists of a set of 15 elements for describing web resources, and it is the *de facto* worldwide standard for information resources across disciplines and languages [6]. It has already been translated into 25 languages. The DC is a metadata element set for describing cataloguing information, such as that needed in digital libraries. This initiative early embraced RDF as the framework on which to build such metadata [7]. Simplicity is both the strength and the weakness of it. The initial aim was to create a single set of metadata elements for untrained people who publish electronic materials for describing their work. Some people continue to hold this minimalist view, a simple set of rules that anyone can apply. Others prefer the benefits that come from more tightly controlled cataloguing rules and would accept the additional labour and cost. Table 3 shows a DC example coded in HTML [8].

2.4. CYC

This[3] knowledge base is a formalized representation of a vast quantity of fundamental human knowledge: facts,

[2] http://dublincore.org.
[3] http://www.cyc.com.