

Issues and Advances in Semantic Web GIS and its Interoperability Using OWL

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Abstract

With the recent advances in the web technology, automatic position sensing and wireless connectivity the utility and development in the field of GIS has been increased very high. Web service has been viewed as one of most significant innovations in business industry, and designed on demand to provide spatial related information for Location Based Service consumption. The idea and vision of the “Semantic Web” catches on and researchers as well as companies have already realized the benefits of this great vision. Ontology is considered the basic building block of the Semantic Web as they allow machine supported data interpretation reducing human involvement in data and process integration. Information systems often require combining datasets available in different formats, and geographical information systems are no exception. The semantic web promises a world where anyone can publish data on the web and intelligent agents can process this data to infer information. OWL is a core component of the Semantic Web, which is a universe of metadata and ontology expressed in machine-readable format along with software tools that allow the understanding of semantic relations among heterogeneous and distributed resources in the Web. This paper analyzes several issues and advances in OWL and its usage in the GIS development and its interoperability in the semantic web.

1.0 INTRODUCTION

Web Service (WS) technology has been proved very helpful in establishing a common, vendor-neutral platform for integrating distributed computing applications, in intranets as well as the Internet at large. Semantic Web Services (SWSs) promise to provide solutions to the challenges associated with automated discovery, dynamic composition, enactment, and other tasks associated with managing and using service-based systems. OWL is an ontology language, or rather a family of three ontology languages, developed by the World Wide Web Consortium (W3C) as part of its Semantic Web activity. The basic idea underlying the vision of the Semantic Web is to make websites machine-processable by structuring and enhancing the information contained in them. This allows for the creation of intelligent applications roaming the Internet and using the Web’s information to offer all sorts of services. Semantic Web services (SWS) pledge the automation of core Web service tasks such as discovery, selection, composition, and execution, thus enabling interoperation between systems, keeping human intervention to a minimum.

2.0 SEMANTIC WEB

One of the main technical differences between the current World Wide Web and the Semantic Web is that while the first relies on syntactic-only protocols such as HTTP and HTML, the latter adds meta-data annotations as a means to convey shared, precisely defined terms. That is, semantic awareness is exploited to improve interoperability among Web resources. Semantic interoperability requires shared

repositories of precisely defined concepts. Such repositories are called ontologies. Semantic Web service technology adds expressivity to existing Web service standards by introducing well-formed semantics that simple Web service descriptions are lacking and envisages the automated and meaningful composition of complex business services through logic-based reasoning upon their semantic annotations. Semantic Web Service is next generation of Web Service. Adding enough and rich semantics to Web Service description will enable the automation of various kinds of tasks, such as discovery, composition, and invocation of Web services .

3.0 ONTOLOGIES

Ontologies are considered the basic building block of the Semantic Web as they allow machine supported data interpretation reducing human involvement in data and process integration. Ontology is used to capture knowledge about some domain of interest and to describe the concepts in the domain and also to express the relationships that hold between those concepts. Ontology consists of finite list of terms (or important concepts) and the relationships among the *terms* (or Classes of Objects).

OWL ontology includes description of classes, properties and their instances. OWL is used to explicitly represent the meaning of terms in vocabularies and the relationships between those terms. Such representation of terms and their interrelationships is called ontology. OWL has facilities for expressing meaning and semantics and the ability to represent machine interpretable content on the Web. OWL is designed for use by applications that need to process the content of information instead of just presenting information to humans. This is used for knowledge representation and also is useful to derive logical consequences from OWL formal semantics.

4.0 OWL

OWL, originally created for the Semantic Web enables us to represent not only the data itself, but also its *interpretation*, i.e. knowledge about its format, its origin, its usage, or its original embedment in specific frameworks. OWL is the latest standard in ontology languages (W3C Recommendation February 2004). It is layered on top of RDF and RDFS, and has a rich set of constructs. There are three categories of OWL: OWL-Lite, OWL-DL and OWLFull. OWL provides three increasingly expressive sub-languages designed for use by specific communities of implementers and users

(i) **OWL Lite** (is least expressive, suitable for simple class hierarchy and simple constraints and useful for quick migration path for thesauri and other taxonomies),

(ii) **OWL DL** (is more expressive, retains *Computational Completeness* that is, all conclusions are guaranteed to be computable and has *Decidability* that is, all computations will finish in finite time, and is based on Description Logic),

(iii) **OWL Full** (is most expressive and has syntactically freedom of RDF and has no computational guarantees but allows an ontology to augment the meaning of the pre-define

OWL Ontology Components

An OWL Ontology consists of the following components:-

(i) **Individuals or Instances or Objects** (No Unique Name Assumption UNA)

(ii) **Properties or Relations** (e.g. Binary relations- *hasChild*)

(iii) **Classes or Concepts** (Subclasses are subsumed by their superclasses. Classes are described *using* formal or mathematical descriptions stating requirements for membership of the class).

Automated reasoning is possible over ontologies that are written in OWL Lite and OWL-DL. OWL brings relationships to RDF. OWL allows individual instances of classes to be included in the ontology. OWL classes and individuals can be stored as RDF triples. RDF extends the XML Model and Syntax to be specified for describing resources. OWL assigns a specific meaning to RDF Triples. OWL is derived from the DAML + OIL Web Ontology Language and builds upon the RDF. OWL ontology language differs from an XML schema in that it is meant for knowledge representation, not for a message formatting. XML and RDF formats are part of the OWL standard. OWL is useful for various applications such as knowledge representation, knowledge management, photo retrieval, access control policies and so on.

5.0 ISSUES IN OWL

The expressivity of RDF and RDF Schema is deliberately very limited: RDF is (roughly) limited to binary ground predicates, and RDF Schema is (again roughly) limited to a subclass hierarchy and a property hierarchy, with domain and range definitions of these properties. However, the Web Ontology Working Group of W3C3 identified a number of characteristic use-cases for Ontologies on the Web which would require much more expressiveness than RDF and RDF Schema.

A number of research groups had already identified the need for a more powerful ontology modeling language. This led to a joint initiative to define a richer language, called DAML+OIL4 (the name is the join of the names of the American proposal DAML-ONT5, and the European language OIL6). DAML+OIL in turn was taken as the starting point for the W3C Web Ontology Working Group in defining OWL, the language that is aimed to be the standardized and broadly accepted ontology language of the Semantic Web.

RDF and RDFS allow the representation of some ontological knowledge. The main modeling primitives of RDF/RDFS concern the organization of vocabularies in typed hierarchies: subclass and subproperty relationships, domain and range restrictions, and instances of classes. However a number of other features are missing like local scope of properties, disjointness of classes, Boolean combinations of classes and cardinality restrictions. These features are given by OWL.

An ontology that has probabilities attached to some of its elements is Probabilistic ontology. A *probabilistic ontology* is an explicit, formal knowledge representation that expresses knowledge about a domain of application. This includes: (i) Types of entities that exist in the domain; (ii) Properties of those entities; (iii) Relationships among entities; (iv) Processes and events that happen with those entities; (v) Statistical regularities that characterize the domain; (vi) Inconclusive, ambiguous, incomplete, unreliable, and dissonant knowledge related to entities of the domain; and (vii) Uncertainty about all the above forms of knowledge. In this definition, the term entity refers to any concept (real or fictitious, concrete or abstract) that can be described and reasoned about within the domain. Probabilistic Ontologies are used for the purpose of comprehensively describing knowledge about a domain and the uncertainty regarding

that knowledge in a principled, structured and sharable way, ideally in a format that can be read and processed by a computer. They also expand the possibilities of standard ontologies by introducing the requirement of a proper representation of the statistical regularities and the uncertain evidence about entities in a domain of application.

PR-OWL is an extension that enables OWL ontologies to represent complex Bayesian probabilistic models in a way that is flexible enough to be used by diverse Bayesian probabilistic tools based on different probabilistic technologies. PR-OWL can only be realized via extending the semantics and abstract syntax of OWL. There is no need for all the concepts in a probabilistic ontology to be probabilistic. The ability to perform probabilistic reasoning with incomplete or uncertain information conveyed through an ontology is a major advantage of PR-OWL. However, it should be noted that in some cases solving a probabilistic query might be intractable or even undecidable. In fact, providing the means to ensure decidability was the reason why the W3C defined three different version of the OWL language. While OWL Full is more expressive, it enables an ontology to represent knowledge that can lead to undecidable queries. OWL-DL imposes some restrictions to OWL in order to eliminate these cases. Similarly, restrictions of PR-OWL could be developed that limit expressivity to avoid undecidable queries or guarantee tractability.

The Web Ontology Language (OWL) is the newly emerging standard proposed and supported by W3C for defining ontologies in semantic web. It is based on DAML+OIL but with simpler primitives. Like DAML+OIL, OWL is also based on description logics, which is a subset of first-order logic that provides sound and decidable reasoning support. As with traditional crisp logic, any sentence in OWL, being asserted facts, domain knowledge, or reasoning results, must be either true or false and nothing in between. However, most real world domains contain uncertainty knowledge and incomplete or imprecise information that is true only to a certain degree. Attempts have been made to apply different formalisms such as Fuzzy logic , Rough set theory and Bayesian probability as well as ad hoc heuristics into ontology definition and reasoning. A probabilistic extension to OWL using Bayesian Networks have also been made. The Bayesian networks works as a underlying probabilistic model and the reasoning mechanism. Bayesian networks (BN) have been established as an effective and principled general framework for knowledge representation and inference under uncertainty. In the BN framework, the interdependence relationships among random variables in a domain are represented by the network structure, and the uncertainty of such relationships by the conditional probability table (CPT) associated with each variable. These local CPT collectively and compactly encode the joint probability distribution of all variables in the system. This extension thus provides OWL additional expressive power, support probabilistic queries, and make more accurate semantic integration possible.

6.0 CONCLUSION

Systems and infrastructures are currently being developed to support Web services. The main idea is to encapsulate an organization's functionality within an appropriate interface and advertise it as Web services. *Semantic Web will enable automatic collection and correlation of various parts of information about an object, available at various different web resources.* The Semantic Web is being built on XML's ability to define customized tagging schemes and on RDF that is a flexible approach to represent data and on ontology

language (OWL). The standardization of OWL has led to the development and adoption of a wide range of tools and services. This paper describes a coherent, comprehensive probabilistic framework for the Semantic Web, that provides a means of representing probabilistic knowledge and providing web services such as plausible inference and Bayesian learning. The process of writing probabilistic ontologies can be greatly improved via automation of most of the steps in the ontology building.

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