Connecting ISO and OGC Models to the Semantic Web

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Motivation

OGC and ISO have developed extensive standards for geospatial applications, providing well-founded definitions of concepts related to the geospatial domain.

Currently these standards are available in textual descriptions supported by UML static structure diagrams, giving guidance to developers to implement applications. However, in an open and distributed environment, the possibility to assess the interoperability of applications and data sources without human intervention is becoming increasingly important. The current forms of representations hinder this attempt since UML is designed for model building and sharing by human experts.

We propose to enforce the efforts to include such standards in the framework of the semantic web. This would leverage investment into these standardization efforts by opening sophisticated domain models to a wide range of potential users. The paper shows a first attempt at capturing the contents of some key ISO and OGC standards in a standard web ontology environment. We propose OWL as a candidate representation language since it is designed to provide guidance for intelligent processing methods (Falkovych, Sabou *et al.* 2003).

Ontologies for the Geo-Domain

In the context of the ACE-GIS project (http://www.acegis.net), semantic descriptions of web services on the bases of WSDL descriptions are being developed. The project need for well-founded concept specifications to provide definitions for the terms used in the WSDL descriptions led to the creation of domain ontologies based on the ISO 19111 Spatial Referencing by Coordinates, ISO 19112 Spatial Referencing by Geographic Identifiers, ISO 19107 Spatial Schema and OGC Observation and Measurement. These ontologies represent the proof of concept for the approach described here. They are accessible at http://musil.uni-muenster.de/onto/ACE.

Refined semantics

The UML representation of the standards is optimized to guide efficient implementation. Thus, a goal is to use as few classes as possible. Ontology design, on the contrary, aims to provide extensive semantic definitions of concepts. In order to increase the accessibility of domain knowledge, we encountered the need for additional concepts. For example the UML diagram for *units of measure*, implemented in the ISO_N1309 (Metadata Implementation Specification), does not cover all needed relations. The diagram provides only one level of inheritance. We introduced an intermediate set of sub-concepts for measure. This set is based on the categorization introduced by (Stevens 1946), and organizes the measures in nominal, ordinal, interval and ratio. The proposed structure of the new ontology is strongly connected and based in a classification proposed by (Chrisman 2001) that provides an interconnected process between the concept of *representation* and the concept of *measurements*. This process of increasing the explanatory power of the existing standards is possible in various other parts of TC 211 Geographic Information/Geomatics standards.

Mapping UML to OWL

Before starting to develop OWL ontologies we refined the UML models in order to improve the expressiveness of the concept definitions. Mapping rules for transforming a UML model into a DAML ontology are described in (Baclawski, Kokar *et al.* 2001) and can easily be transferred to OWL. Although their purposes are different, UML and OWL share many characteristics. For example, attributes in UML classes with simple data types are mapped to OWL as a DatatypeProperty, linking with the data types defined in the XML Schema. Attributes related to complex data types or relationships between classes are mapped in the ontology as an ObjectProperty. Classes containing enumerations are mapped as subconcepts of the concept denoted by the class.
The ISO standards adopt the stereotype «Union» denoting a type consisting of one and only one of several alternatives (listed as member attributes). This is similar to a discriminated union in many programming languages. In OWL this stereotype can be modelled as union of two classes and additionally defining the two united classes as disjoint. E.e. the class GM_Position in ISO 19107 is the discriminated union of GM_DirectPosition and GM_PointRef. This is, a GM_Position is either a GM_DirectPosition or a GM_PointRef but not both at the same time. Note that in ISO

19107 the stereotype «Union» models the "is-a" relation between a class and its alternative subclasses with two or more attributes which are related via a XOR relation. An attempt to model in OWL this stereotype as it is done in the ISO model, would result in formalizing an intended taxonomic relation (GM_DirectPosition "is-a" GM_Position) as a non-taxonomic relation (with the attribute *direct*). This would result in loosing the formal semantics of a taxonomic relation, and thus in loosing reasoning capabilities.
Another encountered modeling difference is that a circular relationship in the UML model need to split into two but inverse ObjectProperties. Moreover, these ObjectProperties are transitive, allowing automated reasoners to infer new knowledge.

Merging Ontologies

The relatively small number of 80 terms employed in the WSDL files of the ACE-GIS web services caused 915 concepts to be included into the domain ontologies. This is due to the fact that the different ISO standards used to build the ontologies need to be transformed completely, since otherwise the definition of concepts would be incomplete. In this case study, the different standards were used as a guidance for how to carve up the different domain ontologies. However, the problem of efficiently and adequately carving up domains remains an important research question.
This question directly refers to the current practice of importing concepts from other ontologies. Currently, OWL offers with the <import> tag a possibility to import all concepts of another ontology. This can easily lead to importing unnecessarily concepts. The domain ontologies developed in this study are partly connected. For example the concept *RS_ReferenceSystem* of ISO 19111 has an attribute *name* which is taken from ISO 19115 Geographic Information - Metadata. Interconnected ontologies form large interwoven networks of concept definitions, where the number of available concepts can become hard to handle for a human user.

Conclusion and Future Work

In this case study, geospatial domain ontologies were developed by transforming the UML models provided in core domain models of ISO and OGC standards. From today's semantic web perspective, this procedure represents a pragmatic approach to share what used to be called "essential models" in the standards communities (Cook and Daniels 1994). It is a contribution to geographic information science by showing how two existing modeling paradigms can be connected for the benefit of the GI community itself and of potential GI users. The remodeling of the standards in a language with an expressivity different to UML may reveal shortcomings or redundancies which otherwise are hardly discovered.
The UML models turned out to cover the domain, but could be improved by introducing additional concepts that refine the semantic definitions. Building on previous work on transforming UML to DAML, producing OWL ontologies was easily achieved. Useful work is being undertaken to provide semi-automatic translation of UML to OWL (Gasevic 2004). Problems with ontology management can be foreseen when the developed domain ontologies are merged and the number of available domain concepts reach unmanageable complexity.

We consider it most promising to formalize and share the concept definitions available in standards in the form of OWL. This procedure will allow for accessing the extensive domain knowledge encoded in the standard via emerging semantic web technologies, facilitating access to this knowledge for users outside the domain. The main benefit of turning standards into ontologies is that an agreed upon vocabulary of the standards becomes available to describe web services and data sources in a way allowing consistency checking and reasoning.

For the geospatial domain, we consider the construction of a comprehensive ontology representing the complete ISO TC211 Harmonized Model as most promising and pressing.

Acknowledgements

This work has been supported by the European Commission through the ACE-GIS (grant number IST-2001-37724) and ALFA (No. II-0250-A-FI) projects. Serge Margoulies (Ionic Software Inc.) has stimulated some of the work reported here.

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