OWL-BASED SEMANTIC MODEL FOR SPATIO-TEMPORAL GEOGRAPHIC ONTOLOGY

Zhaoqiang Huang

Institute of Mineral Resources, China Metallurgic Geology Bureau, 105 Yaojiayuan Road, Beijing, P.R. China, 100025

1. INTRODUCTION

Semantic models are very important in many applications for describing relationships between concepts or entities. From the view of information representation, semantic seems the meanings or comment of data and is to facilitate the comprehension and share of information. Semantic data model is proposed initially to facilitate the design of database pattern and provides a higher layer abstract of data. And it would ultimately make mappings to logic layer model, such as relation model or object-relation model. So the structure of semantic model naturally supports the viewpoint of up-to-down and modularization. In the geospatial domain, geospatial semantic is the mapping relationship between the description of geospatial data and entities of reality world. The formal description of ontology is fundamental to data exchange standards. Ontology, which is a conceptual and explicit and formal shared canonical description, provides the necessary theory base and technology support for geospatial concept creating and semantic formalizing. Geographical ontology defines the important geographical concepts in the geospatial domain. And the characteristics of geographical concepts describe the geometric features, attribute features and various interrelated restrictions or relationships of concepts. Ontology semantic modeling is more similar with geographical cognitive modeling. This paper focuses on the semantic representation of spatio-temporal geographic ontology.

2. SEMANTICS

Semantics is about understanding contents of domain, and capturing this understanding in formal theories. The only sensible use of the term “semantics” refers to the meaning of expressions in a language, which can be single symbols (the “words” of a language) or symbol combinations [1]. And meaning of language expressions is a conceptualization issue. Conceptualization is a description of (a piece of) reality as perceived and organized by an agent, independent of the vocabulary used and the actual occurrence of a specific situation [2]. Symbols or expressions in a natural language evoke the concepts in human minds and are used to express those concepts. And the concepts are defined by human agreement and experience with some real world phenomena (e.g. entities, relationships and processes). Hereby, expressions come to refer to phenomena in real world. Semantics is also a cognitive phenomenon: it refers to the meaning that symbols have for human beings and is determined by individual and cultural factors, involving human minds anchored in a spatio-temporal world and constrained by the conventions of a language or information community [3]. All information is eventually for and from human beings, so that its semantics must relate to meanings in human minds. Cognitive phenomenon is a process that human minds construct meanings in the social and natural environment. Meaning of language expressions also is a conceptualization in a cognitive model. Semantics in a language is a mapping from the expressions of the language to some cognitive or mental phenomena.

3. ONTOLOGY SEMANTIC MODEL

3.1. Spatial temporal geographical phenomena

The geographic phenomena being in the world have the spatio-temporal features. Or we can say that there are spatio-temporal locations: portions of space-time for geographic phenomena. Objects/fields and events/processes represent the spatial and temporal respectively, and they interact with each other. We can consider the general phenomena of the process that Tom gets up and goes to work. One day, Tom gets up at 6:30 a.m., and at 7:00 has breakfast, at 7:30 goes to company, and at 8:00 works on some documents. From object view, we can say there are several status of Tom in different space and time. From event view, we can say there are several events happening on Tom. So the geographical phenomena is a spatio-temporal entity of which the object- and event-view are both partial in. Many geographical phenomena resemble this example to some extent. Thus Spatial and temporal features are the inherent characteristic of the general geographical phenomena. The integrity of geographical phenomena is considered to explicitly represent dynamic spatio-temporal semantic.

In the domain of knowledge representation, ontology facilitates the information shared and interoperation and ensures the consistency of concepts of knowledge system from conception analysis to system construction. And ontology can preserve the semantic consistency of data and knowledge. Ontologies could develop through usage and context with evolving concepts such as events, processes [4]. And in the information retrieval areas, ontologies can be used for interoperability of heterogeneous information sources, in which each information source needs to be provided with a packet that maps the data-scheme of the source to the ontology. Ontologies provide the terms, their meanings, their relations and constraints, etc. and in the communication process all participants should commit to these definitions. An ontology is a logical theory accounting for the intended meaning of a formal vocabulary [5]. Through model theory, formal semantics introduces the notion of possible models, formally defining the semantics of expressions which are formulated in information system ontologies. So that it is the ontologies that can construct the semantics of expressions and evolve along with context.

3.2. Ontology semantic model based on OWL

To describe the details of the ontology semantic model, it is important that an ontology language is presented to describe concepts, properties of concepts, relationships between concepts and constraints. The ontology language Web Ontology Language (OWL) [6] is a Description Logics (DLs) [7] based language and widely used, which makes this work comparable with others [8]. A DL system not only stores terminologies and assertions, but also offers services that reason about them [7]. The language $\mathcal{AL}$ (Attributive Language) is a minimal DL that is of practical interest [9]. For representing and reasoning about spatio-temporal objects, ALCRP extends ALC by adding new role-forming predicate operators of spatial domain S and temporal domain T. Using ALCRP($S \oplus T$), we can define spatio-temporal domain ontology.

Well-defined ontology models are needed to successfully provide efficient reasoning and service and semantic interoperability. For example, in domain of emergency response, emergency ontology is an event-driven ontology. The ontologies include names for important concepts and concepts hierarchy. These concepts have been represented by class names or unary predicates in DLs. For example, earthquake is a natural event (Earthquake$\subseteq$NaturalEvent). Ontologies also include relationships between concepts and properties of concepts. For example, in the domain, "Resultin" relationship is the relationship between concepts of events "Earthquake" and "BuildingCollapsed", e.g., earthquake results in the building collapsed (Resultin(Earthquake,BuildingCollapsed)). And ontologies have a set of axioms and constraints which describe the meaning of a concept in terms of a logical combination of other concepts. For instance, "Dangerzone" concept has been described as follows: Dangerzone$\subseteq$Destination$\cap\exists\leq$1hasDangerSource. This means that a danger zone is a destination with at least one danger source. And the axiom "Events$\equiv$ManmadeEvents$\cup$NaturalEvents" states a definition for concept, i.e., any individual that satisfies this definition will belong to the "Events" concept. Moreover, the following statements also show the reasoning process that the event earthquake with a magnitude of more than 8 has effect to the building and causes the building having high possible to collapse and finally the building collapses:

hasEffect(Earthquake$\cap$hasMagnitudeScale(Earthquake,EightM),Building),

hasHappeningPosible(BuildingCollapsed, PosibleHigh),

hasHappened(BuildingCollapsed).

Based on Protégé [10], which is an open source ontology editor for OWL-based ontology development and inference, the ontology semantic model is constructed. Moreover, there is a visualization tool OntoViz plug-in that presents the emergency ontology concepts classification and its inspection and visualization. Figure 1 represents the ontology construction which has defined the key and main concepts of domain and relationships between concepts. The dashed lines represent role assertions, e.g. hasEventRank(Events, OneRank) represents that this event has a rank as OneRank.

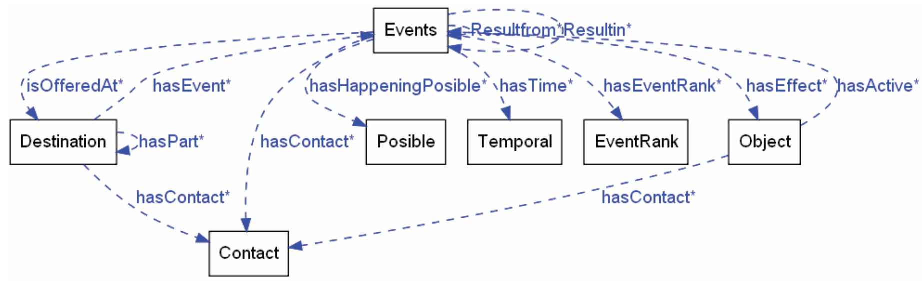

Fig. 1 Construction of Domain Ontology

And through DL system RACER (Reasoner for A-Boxes and Concept Expressions Renamed) RacerPro1.9.0 [11] reasoning machine, the task of automatically mapping between concepts of different application ontologies within the same domain is performed, i.e. allowing the classification of data into another context through subsumption reasoning. So the subsumption checking and consistency maintenance of the model can be reasoned and the model can be optimized gradually.

4. CONCLUSION

In this paper, we have examined the issues on OWL-based ontology semantic model. As a model for information exchange and implicit semantic reasoning, the model can solve the communication among the sub-system and the query for multi-source information. In the future, the important work is to extract the common elements in the aspect of granularities and evaluate and optimize the performance of the model through several typical examples.

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