Alloy를 이용한 SQL-DB 온톨로지의 일관성 검증 프레임워크

이스마파라시디키, 이욱진
한양대학교 컴퓨터공학과
isma2012@hanyang.ac.kr, scottlee@hanyang.ac.kr

A Framework for Verifying Consistency of SQL-DB Ontology using Alloy

Isma Farah Siddiqui, Scott Uk-Jin Lee
Department of Computer Science and Engineering, Hanyang University

ABSTRACT

Semantic Web is an extended form of World Wide Web in which efforts of Knowledge Engineers and Web Developers are combined to provide a semantic-rich web environment. Semantic Web application processes knowledge based on metadata of shared data sources available on Linked Open Data cloud. The ontology language plays vital role to provide metadata semantics in Semantic Web applications. The complexity of ontology varies with the use of concepts, relationships and constraints. Hierarchical related ontologies can counter with defined constraints at any level. Hence, verifying consistency and correctness of ontology relationships and constraints is necessary. The accessibility of data sources from RDBMS on Semantic Web applications requires verification of extracted OWL ontology. In this paper, we propose a framework with Alloy and Alloy Analyzer to verify OWL ontology of RDBMS data.

1. INTRODUCTION

Tim Berners-Lee's [1] vision of Semantic Web was that software agents should be able to understand and process the information available on internet. The aim is to automate information accessibility using semantics. In order to achieve such aim, software agents should have common understanding of semantics which is provided by ontology. Role of ontology is to give conceptual meaning to data. Theoretically, ontology [2] acts as common conceptualization model that is shared among multiple semantic web agents. The Web Ontology Language (OWL) provides powerful logical meanings and identifies resources and their relationships. The constraints are applied over relationships and their cardinality increases complexity of an ontology.

Consistency verification of constraints within ontology is trivial for its optimal utilization by semantic web agents, as it can result irregular RDF models. Moreover, an ontology must be powerful enough to express the complex semantics of web resources and not considered absurd by web agents. It is important to check and verify constraint's consistency of ontology as it is also used later on by web agents for reasoning and drawing conclusions on the information associated with that ontology. Nevertheless, existing tools for consistency verification of ontology such as Fast Classification of Terminologies (FaCT), Renamed ABox and Concept Expression Reasoner (RaCER) [3] are still primitive. Alternatively, a lightweight approach of using formal methods provides better verification of ontology.

Currently, ontology documents are dependent on semantic web application developers and knowledge engineers. The semantic of web resource is manually provided by considering application domain. A number of ontology documents shared on web are utilized by new resources on semantic web applications. However, nowadays semantic web is becoming enriched by information from SQL Database (SQL-DB), resulting the need for consistency verification of the extracted ontologies. This paper introduces a framework for verifying consistency of OWL constructs and their constraints in SQL-DB's ontology.

The rest of this paper is organized as follows. Section 2 gives a brief introduction of Semantic Web, OWL and Alloy. Section 3 gives an overview of related work. Section 4 demonstrates the proposed framework. Finally, Section 5 concludes the paper.

2. BACKGROUND

2.1. Semantic Web

Semantic Web is a vision to enhance performance of web agent with respect to interpreting, processing and reasoning of information. The W3C proposed a series of technologies to achieve this vision. Resource Description Framework (RDF) is standardized data model for providing interoperability among semantic web applications and exchanging semantically rich information. RDF Schema (RDFS) is an earliest way to provide simple vocabulary for RDF models.

2.2. Web Ontology Language (OWL)

Semantic Web Ontology Languages are enhanced gradually where earlier versions came as Ontology Interference Layer (OIL), DARPA Agent Markup Language (DAML), DAML+OIL [4] and Web Ontology Language (OWL). Currently OWL2 [5] is standardized by W3C. These languages enable knowledge engineers to express semantics, logics and inference patterns. OWL document provides better understanding than RDFS. OWL gives default syntax constructors for class, properties and constraints with formal semantics. OWL class represents set of objects that connects with instances in RDF document. OWL properties are interpreted as binary relations among instances.

2.2.1. Existing Reasoning Tools for OWL

There exists a number of Semantic Web Ontology reasoning tools such as RaCER, FaCT, FaCT++ and Pellet [6]. These all are based on Description Logic and better suited for obtaining satisfactory OWL document. However, these tools have limitations such as: 1) inability to provide proper explanation while pointing out an inconsistency within OWL class; 2) lack of explanation for occurred errors; and 3) lack of instance generations that otherwise can enable better hands-on verification over OWL document.

2.3. Alloy and Alloy Analyzer

Alloy [7] is a lightweight formal software modeling language based on First-Order-Logic. It works with logics as relations and uses relational compositions to express various entities. The essential constructs of Alloy are:

Signature: [*sig*] introduces entities used in model.

Functions: [*fun*] captures behavior constraint that is applied with signature entities.

Fact: [*fact*] imposes global constraint over all the existing entities and relations. It is self-invoked with instance generation of system model.

Assertion: [*assert*] specifies desired property whose validity needs to be checked or verified. If not satisfied, a counterexample is provided.

Alloy Analyzer [8] is an analysis tool for Alloy models that provides simulation and assertion checking. With finite scope of logic relations, it generates instances while satisfying the facts and properties defined in an Alloy model. It uses SAT solver to translate Alloy model into propositional formulas.

3. RELATED WORKS

Verification of Semantic Web Ontology is to ensure its correct utilization by web agent. The initial work done by Dong et al. [3] was based on formal tool Z/EVES for checking errors in DAML+OIL document. This work has also used RaCER tool to identify inconsistent ontologies where the source of an inconsistency was identified by Alloy Analyzer. This work was to ensure the correctness of Z/Alloy semantics for DAML+OIL, and to prove the soundness of ontologies.

Song et al.'s approach [9] was motivated by previously mentioned work. It was developed for interpreting DAML+OIL document into Alloy model for verification. This work was supported by Semantic Web tool Jena. Jena is used to parse ontology document into individual components of classes, subclasses, properties and statements. The components then modeled with Alloy and Alloy Analyzer is used for constraint consistency checking and reasoning.

Wang et al.'s work [10] was on automatic reasoning on OWL. Their research focused on development of reasoning environment using Alloy and its Analyzer. It compliments RaCER tool and also supports other ontology languages such as SWRL and SWRL-FOL [9]. Alloy Analyzer is used to identify errors with counterexamples. This work motivates another research conducted by Song et al. [11], which is based on conversion of complex-properties of OWL ontology into Alloy. It uses Alloy model to convert properties into relations.

In all these researches, the main focus was on reasoning and checking consistencies of properties and constraints in predefined or user-defined ontologies (DAML+OIL, OWL, and OWL2). However, the absence of verifying ontology extracted from SQL-DB still exist.

4. FRAMEWORK FOR VERIFYING SQL-DB ONTOLOGY

An ontology extracted from SQL-DB may hold inconsistencies among its classes, subclasses, properties and constraints. A sound verification and correctness of ontology is required before its supported RDF data is generated. Figure 1 below shows the proposed solution for formal verification as an intermediate process during the translation of SQL-DB into RDF model.

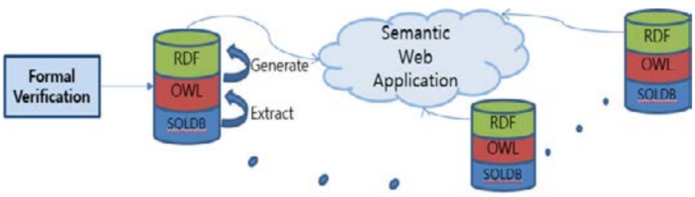

Figure 1 Proposed Solution

As shown in Figure 1, OWL ontology extracted from SQL-DB will be modeled in Alloy and verified further. Figure 2 below shows proposed framework to work over this approach.

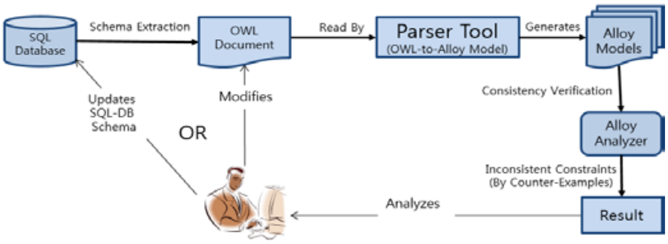

Figure 2 Framework for Analyzing SQL-DB Ontology

Figure 2 highlights stages of OWL-to-Alloy modelling and its verification in a process flow. It starts with schema extraction from SQL-DB, which is used to generate OWL document. The approach is based on an OWL-to-Alloy parser for extracting OWL constructs (such as classes, subclasses and their properties along with constraints) and generating Alloy models. The generated Alloy models are analyzed by Alloy Analyzer for verification. The analyzer will first translate Alloy model into FOL formulas and then uses its built-in SAT solver to generate instances. If there is no inconsistency in Alloy model then Alloy Analyzer will generate instances otherwise counterexample would be provided to track inconsistency within Alloy model. The instance results would be available to developer for further analysis and verification of logics in Alloy model. By using these result, inconsistencies in OWL document can be modified manually or SQL-DB schema can be updated for better ontology development. This framework can be used for sound verification and consistency checking of OWL documents. It is essential for ontology extracted from SQL-DBs to be verified before its corresponding RDF is generated and used by semantic web agents.

5. CONCLUSION

The logic of Semantic Web lies at the OWL ontology based on RDF. The OWL ontology may hold inconsistencies among classes, properties and constraints. As, Semantic Web agents utilizes OWL ontology for automatic reasoning, all inconsistencies need to be resolved. Reasoning and verification of OWL ontology using Alloy models and Alloy Analyzer can interactively identify inconsistencies by simulation. Currently, researchers have considered pre-defined ontologies for reasoning and verification and did not included OWL ontology that is extracted from SQL-DB. Such Ontology may also be inconsistent and need to be checked and verified. This paper proposes a novel approach where its implication can provide sound verification of SQL-DB based OWL ontology.

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