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Semantic Mapping of Component Framework Interface Ontologies for Interoperability of Vehicle Applications

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Abstract

Over the past few years, ontology merging, and ontology semantic alignment has gained significant interest as research topics in automotive application domain for finding solutions to semantic data heterogeneity. To accomplish the complex and novel vehicle service requirements such as autonomous driving, V2X (Vehicle-to-Vehicle communication), etc. the automotive applications involve collaborations of several platform-specific data from heterogeneous enterprises component frameworks and consequently there has been increase in data interoperability issues. At the application component level, data interoperability relies on the semantic alignment or mapping between the various component framework interfaces data models represented as XML schemas (XSD). With the XML schemas being the preferred standard for the interface description exchange between most of the automotive application domain components, however, the data interoperability between the semantically equivalent but structurally different data constructs of multiple heterogeneous XSDs stands as a challenge in the absence of an ontology-based approach. To confront this crucial requirement for data interoperability and to increase in effect the reuse of existing components through their interfaces, we propose an approach to semantically map the various component framework interface data models when expressed as ontology schemas, based on the exploration of semantic synergies. The transformation between XSD and RDF (Resource Description Framework) schema representations and the use of queries over the ontology schemas for semantic mapping are demonstrated including a real-world case study.

Keywords: ontology, xml, xsd, rdf, model, mapping, semantic, component, interface;

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1. Introduction

The semantic heterogeneity has been identified as the most important and the toughest problem when interoperating with various component framework interface data models within a domain [1][10]. In context of semantic mapping of component interface data models, Model Driven architecture (MDA) based approaches and ontology-based approaches can be viewed as two complementary approaches to offer solutions to address semantic interoperability within a domain. Model transformation is considered as the main key of MDA and addresses semantic mapping needs by using model transformation methodologies such as business models (CIM) to Platform Specific models (PSM), Platform Independent Model to Model (PIM2PIM), etc.[13]. On the other hand, ontology-based approaches within a domain organizes system knowledge in conceptual sub-domains according to its meaning. It addresses the semantic mapping needs by identifying, abstracting commonalities and checking for inconsistencies with reference to a domain ontology using a unified vocabulary of domain specific terminologies[14][15].

To ease the issue of semantic data heterogeneity due to the heterogeneous artifacts produced by various enterprise platform specific interface modelling languages in automotive domain, a unified and platform independent domain-specific entities vocabulary representation for various interface data models of automotive domain platform-specific components using ontology is the need of the hour [14]. Even in order to define a domain metamodel using an MDA approach for cross-platform interface data model interoperability, it is essential to have a platform independent reference domain model and the domain-specific entities as keywords or vocabulary associated with the domain.

XML is a standard for structuring and exchanging data between heterogeneous applications which can be carried out with or without a schema. XML that conform to different schemas may represent data with equivalence semantic, but the data cannot be semantically mapped in the absence of an ontology-based reasoner [1]. For the semantic mapping between the semantically equivalence data of XML schemas (XSD) representing such as component framework interface data models, it is therefore, essential to translate XSDs to ontology-based schemas.

2. Motivation and Contribution

The automotive industry can be regarded as a complex yet connected network or ecosystem as seen in Fig. 1. Component frameworks with heterogeneous architectures and semantics must be integrated into collaborative systems of the future ECU (Electronic Control Units) high performance computing software platforms to support automotive complex services. At an application level, interoperability is one of the major challenges to be addressed in achieving efficient software application cooperation among enterprises within this new ecosystem [14][15]. One of the key elements in heterogeneous enterprises component framework's collaboration is the mutual agreement between the interfaces of their software components at application level where interoperability is crucial.

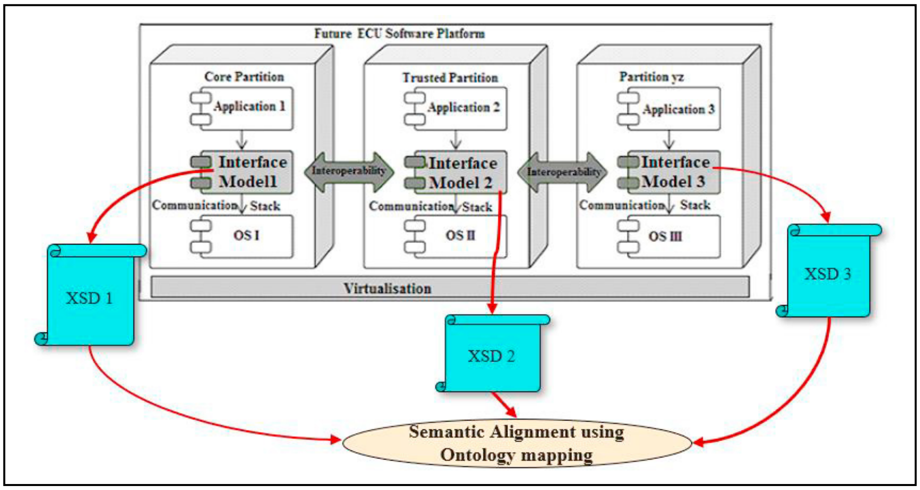

Fig. 1. Overview of Interoperability scenario between Application Interfaces in future Vehicle ECU Software Platforms.

In the automotive domain, XML schemas are the preferred standard for interface description exchange between various enterprise application component framework templates, e.g. AUTOSAR Classic, AUTOSAR Adaptive, Franca, ROS, etc. To confront the issue of interoperability by exploring the possibilities of semantic alignments between the interface descriptions of various component framework templates, we try to schematically translate the XML schemas representing the various component interface data models to RDFS (Resource Description Framework Schema). RDFS are ontology-based schemas that can be represented as an object model or a kind of constrained relational model and can provide semantic enrichment to XML schema data constructs [8]. Exploring semantic synergies between component interface data models increases possibilities of reusing of few of the existing vehicle components through their interfaces for the semantic integration to a domain specific interface ontology in the future.

3. Background and Related Work

Ontology-driven software development is widely pursued in domain-specific application development. A major benefit of using ontologies is their capacity to be extended using new knowledge whenever it is obtained [14]. S-Match is one of the primary used tools for semantic ontology matching. They distinguish between equivalence, subset (is-a), overlap and mismatch correspondences and try to provide a relationship for any pair of concepts of two ontologies by utilizing standard match techniques [11]. Incorporating the XML and RDF paradigms approach was also proposed by Yin-Yang Web [9] but it did not consider any heterogeneous sources with different syntax or data models. They developed an integrated model for XML and RDF by integrating the semantics and inferencing rules of RDF into XML, so that XML querying can benefit from their RDF reasoner.

In context of domain specific global ontology, the author of [6] has proposed an ontology for automobile industry named as VCO (Vehicle Corporate Ontology) that would address the problems of platform and syntactic heterogeneity by mapping between individual schemas and XSLT transformations. The authors of [1] proposes an ontology-based framework for interoperating of two XML documents at semantic level and proposes integration of local RDF ontologies to a hypothetical global ontology. A fully automated mapping of ontology into a relational Database schema with a complete mapping approach was also proposed by authors of [5].

4. Methodology

With the proposed approach we have tried to customize and contribute to an existing semantic ontology mapping technique [2] to schematically translate the XML schema representing component framework interface data models to RDF schema and semantic mapping of the interface models through their RDFS representation. The intention to map and translate the XSD nested structure into the relation-based structure such as RDFS expressed by ontologies is to enable semantic enrichment [1][2] and semantic alignment between the semantically equivalent data constructs conforming to different XSDs by hiding their structural heterogeneity in the native nested structure and exploring areas of possible semantic synergies [9]. Semantic mapping between the constructs of the RDFS can be achieved using SPARQL (SPARQL Protocol and RDF Query Language) query engine and reasoner [6] [4]. The proposed approach considered XSD to RDFS translation and semantically mapping between the RDFS-based local interface ontologies in two stages as seen in Fig.2 [3]. The approach uses an ontology-based tool for the two stages [2][4].

4.1. Stage 1: Schematic Translation from XSD to RDFS

In the first step, the proposed approach relies on the availability of the various existing platform-specific component framework XML schemas describing the interface description data models with the basic information required for peer-to-peer interoperability of application components. The heterogeneous XSDs are then schematically translated to RDFS-based local ontologies represented as "*O*" using an ontology-based tool as seen in Fig.2 [1][4]. The tool uses an automated technology to internally map each entity or construct in the local RDFS to the corresponding construct in the XSDs [4] as also seen in Table 1.

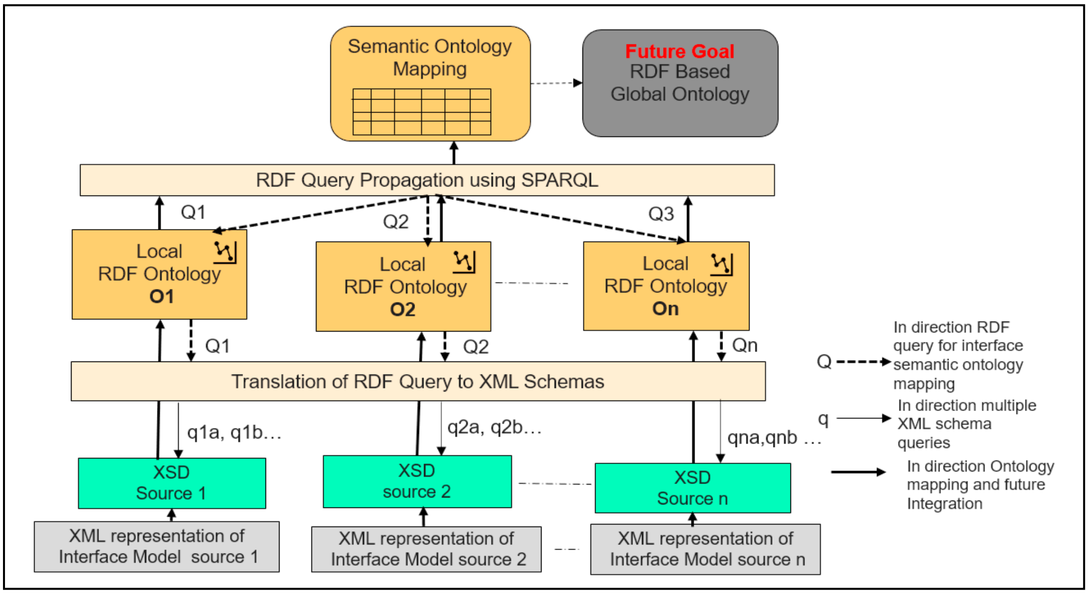

Fig.2. Work-flow Model for Approach to Schematic Translation and Semantic Ontology Mapping.

The schematic translation from nested to relational databases considers the constraints and structure of the target schema [1]. Some of the mappings between XSD and RDF Schema constructs are summarized in the Table 1.

Table 1. Mapping between XSD and RDF Schema Constructs

Input Schema: XSD Construct	Target Schema: RDF Schema Construct
Attribute	Property
Simple type	Property
Complex type	Class
Element	Class
Cardinality Qualifier	Cardinality qualifiers
Extension	subClass Of axiom
Sequence	Unnamed Class

4.2. Stage 2: Semantic Mapping between RDFS-based Local Interface Ontologies

The ontology mapping describes a set of correspondences between concepts or traits of two (or more) ontologies in the areas of semantic matches [9]. These matches are called "Semantic Mappings". In the second step of the proposed approach, the semantic mapping of the RDFS-based local interface ontologies is achieved by propagation and translation of RDF queries using a query engine such as SPARQL and RDF reasoner configuration. For example, an RDF query to local ontology "$Q \longrightarrow O$" say is translated into multiple XSD sub-queries "q" by the ontology tool as illustrated in Fig.2. The semantic matches described by the mappings can denote relations like *equivalence (is-a)*, *specialization* and/or *generalization (part of)* [14]. The SPARQL queries are constructed to apply semantic analysis of interface properties or traits that are represented as local RDFS based ontology entities in order to scale out the similar ones [4]. SPARQL queries and RDF reasoner identifies the areas of semantic overlapping between the equivalent interface traits of different local RDFS-based ontologies [3]. Semantic mapping, alignment and exploration of semantic synergies between local RDFS-based interface ontologies can further be semantically integrated to a domain specific global interface ontology in the future [3].

5. Case Study and Results Achieved

For the demonstration of the proposed methodology, a commonly used type of Client-Server interface method named as *Fire and Forget* was selected as a case study for semantic analysis of two different automotive component frameworks interfaces data models [4][7]. For the case study we have considered XSD representation of two component framework interface data models and have schematically translated the XSD to RDFS in the first stage. Source 1 represents RDFS for AUTOSAR component framework interface data model and Source 2 represents RDFS for an automotive infotainment component framework (Franca+) interface data model as seen in Fig.3 [4][7]. Both the sources component frameworks are part of automotive application domain. RDFS related to Source 1 and 2 were graphically represented as local ontologies O1 and O2 using an ontology-based editor in Fig.3 [2].

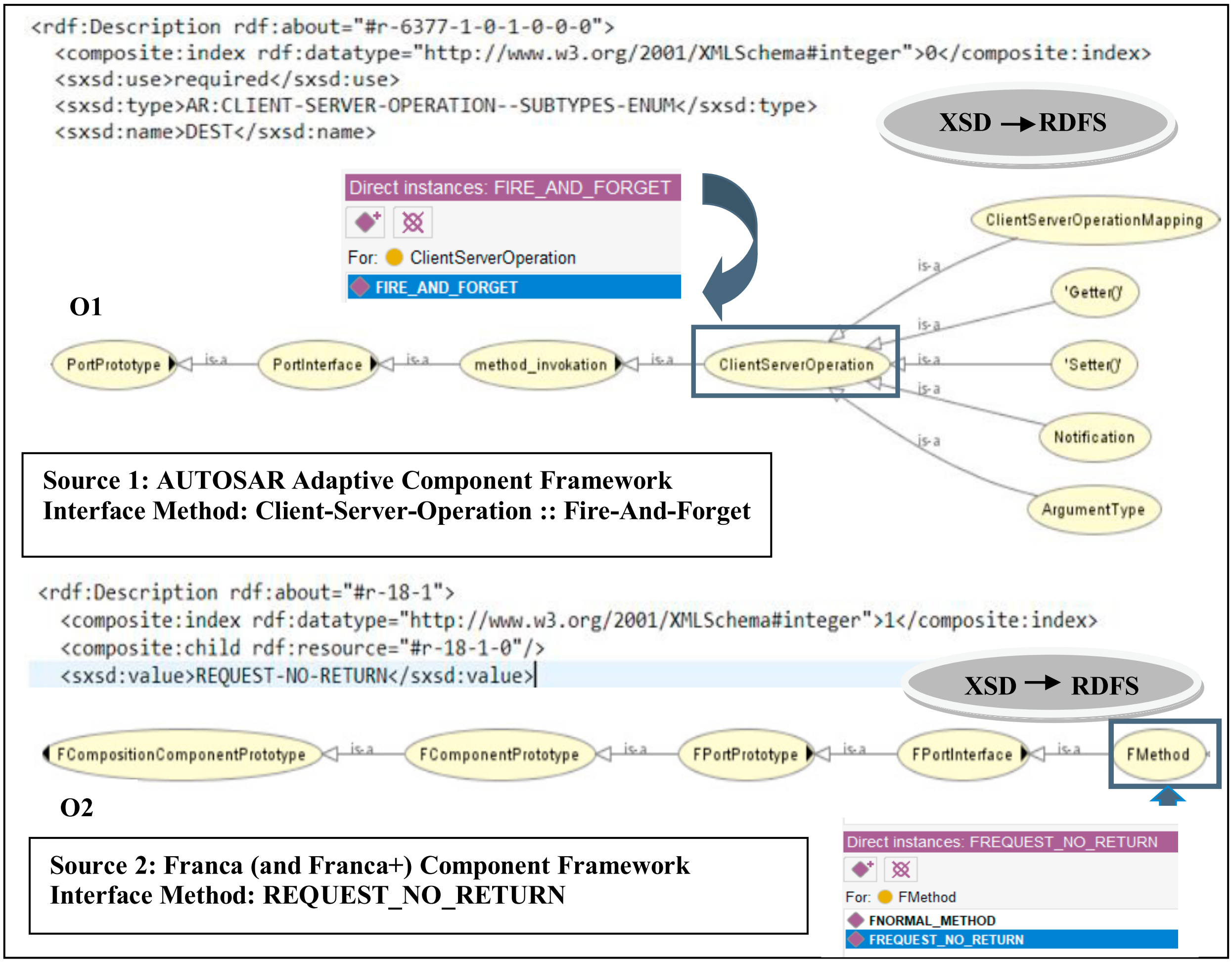

Fig. 3. Illustration of Methodology using a case study.

As a next step, an appropriate RDF query for *FIRE_AND_FORGET* (or *REQUEST_NO_RETURN*) interface method was constructed using SPARQL and RDF reasoner was configured to identify the semantically aligned traits for the given interface method between the local ontologies *O1* and *O2*. As a result of the RDF query (using SPARQL) the ontology entities of *O1* and *O2* representing component interface data model traits for the *FIRE_AND_FORGET* and *REQUEST_NO_RETURN* interface methods were identified to be semantically equivalent and these entities were semantically aligned using *equivalence(is-a)* mapping using the ontology-based editor and tools as seen in Fig.3[5][11]. Due to semantic *equivalence*, the *REQUEST_NO_RETURN* interface method of local ontology *O2* has further chances to be reused as *FIRE_AND_FORGET* interface method and could be merged as *generalization(a part of)* of *Client-Server-Operation* of local ontology *O1*, when integrating to an automotive domain-specific global interface ontology in the future [11][3].

6. Conclusion

In automotive domain cross-enterprise interoperability is very crucial at an application level. Model-based and ontology-based approaches offers alternative solutions to semantic data heterogeneity. In this paper we proposed an approach to semantically map various automotive platform-specific component interface data models by using an ontology-based approach. The approach contributes to ease interoperability between component frameworks interface data models. Semantic synergies were explored between identical traits of component interface data models represented as RDF schemas using RDF query engines and reasoning. Exploring semantic synergies between interface data models increases possibilities of reusing of few of the existing vehicle components through their interfaces for semantic integration to a domain-specific global ontology. The approach also paves the path to future possibilities to combine both MDA and ontology-based technologies in a more effective and value-added way to offer promising solution to semantic data interoperability[12]. In context of designing a domain specific software solution for interoperability of automotive component interface models, semantic alignment of interface models is crucial for semantic integration. In the future, our investigations will address the question on how to extend the existing semantic ontology mapping approach to include instance-based matchers and structure-based matchers to provide more extensive support to the evolution of an automotive domain specific global interface ontology.

7. Acknowledgement

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