A Service Oriented Ontology Management Framework in the Automotive Retail Domain

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Abstract

In the automotive retail industry, many enterprises are transforming their systems to the Service Oriented Architecture (SOA) and mapping data models to achieve seamless information exchange. In this paper, we propose a Service Oriented Ontology Management Framework (SOOMF) that combines ontology with Web Services to improve the semantic interoperability of automotive retail applications. We will also introduce our reference ontology based approach for ontology mapping, STAR ontology, and the prototype system.

Keywords: SOA, Web Services, Reference Ontology, Ontology mapping, STAR

1. Introduction

In Business-to-Business (B2B) applications, the interoperability of heterogeneous data sources is an important issue for academic research and industry practice. To establish effective information exchange among applications, the systems of business participants are not only required to share their functions or service interfaces, but in many cases, they also need to share their models. Therefore, the semantic relations of models need to be identified and characterised. In the automotive retail industry, for example, a Retail Management System (RMS) and a Dealer Management System (DMS) exchange customer data. The traditional message based approach [1] requires developers to retrieve data models through messages and then perform a one-to-one mapping in order to identify and characterize relationships between the models of two applications. However, it is a major challenge to create and maintain thousands of mappings for these models. Furthermore, in order to share their models, each application needs to publish its data in a place where other applications can locate and retrieve the related models for information exchange.

As the core of the semantic web [2][3], ontology [4][5] provides a common shared knowledge in a domain so it can be used for the integration of heterogeneous data sources. Meanwhile, SOA [6][20] is well suited for the processing of domain model interoperability because SOA explicitly addresses domain-aligned functionality. As the implementation of SOA, Web Services can be used to integrate existing applications with different data models. Therefore, the combination of Web Services and Ontologies provides a promising solution for improving the semantic interoperability among automotive retail applications.

In this paper, we propose a Service Oriented Ontology Management Framework (SOOMF) for the automotive retail industry domain. Our approach uses ontologies for defining the semantics of data models, and Web Services enable users to publish, discover and reuse ontology resources on the web. A reference ontology based approach is used for ensuring interoperability among different data sources.

The rest of the paper is organized according to various sections: Section 2 gives a brief overview of the related works that help to influence our approach. In Section 3, we present the methodology of the reference ontology based approach for ontology mapping and the system architecture of SOOMF. The prototype system and its implementation are introduced in Section 4. Finally, Section 5 presents a conclusion, including future work for the SOOMF.

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2. Related Works

A substantial amount of literature has been published about the combination of SOA and ontology improving semantic interoperability [7][8][9]. Three typical approaches, which have influenced our methodology, will be summarized.

First, IBM Web Ontology Manager (WOM) represents a major contribution to ontology management [10]. WOM is a lightweight, web-based tool for managing ontologies that are expressed in OWL. With this technology, the developers can browse, search, and submit ontologies to a repository, which allows the ontologies be shared and reused by other developers.

Another approach to service-oriented ontology mapping is presented in the MAFRA Toolkit [11] [12]. This Toolkit adopts a service-oriented method, maintaining the capabilities of an ontology mapping system dependent on the transformations that are present. It also provides support for other ontology mapping tasks, such as the automatic specification of semantic relations, negotiation and evolution.

The third distinct project, proposed by Korotkiy and Top, is known as Onto-SOA[13]. Onto-SOA is a framework that integrates ontologies and Service-Oriented Architectures to provide a mechanism for representing and exploiting both the conceptual and behavioral domain aspects. It employs an ontology-based domain model as a direct input to a service and enables messages exchange between a service and its consumer.

Although these three solutions possess outstanding features, they are not proposed to meet the major integration needs in terms of business processes perhaps because they are not based on a specific industry background. After analyzing these literature, we created our own ontology management framework in order to provide a service oriented and broadly usable framework that satisfies the data model mapping requirements in the automotive retail industry domain. The major contribution of our work is that we use ontologies for publishing the information of data models and for aligning it with business needs and use web services to reflect further business needs based on standardization.

3. Service Oriented Ontology Management Framework

3.1 Reference ontology based approach

In this paper, our approach relies on the reference ontology based approach [14][15][16] in order to achieve the semantic mappings between different data sources. The basic idea of this method is to first align the concepts of the corresponding data models involved in the business process with the reference domain knowledge. Next, we use the semantic information from this reference knowledge to infer relationships between the models. Lastly, the relationships are utilized to induce an indirect set of mapping pairs, and to generate the required correspondences between data models. In forming our framework, we create a reference ontology and map the individual local ontology to this reference, thereby creating a global view of all data models residing in the automotive retail business domain along with an insight into the location of the models.

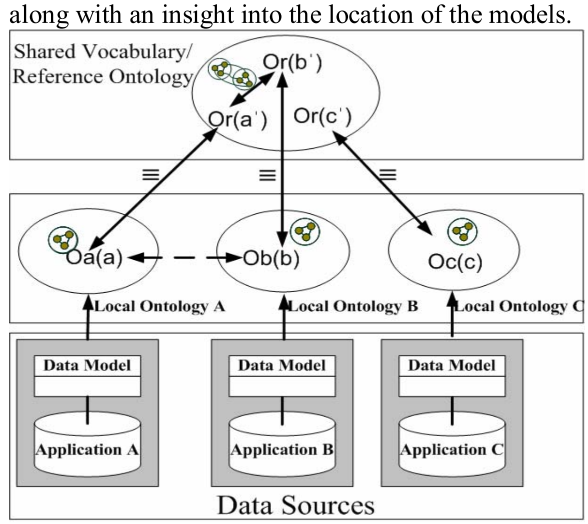

Figure 1: A reference ontology based approach for ontology mapping

In our approach, we develop local ontologies to represent different data models and form a reference ontology as the semantic bridge between local ontologies. The reference ontology is the shared vocabulary of a domain and defines basic terms that can be combined to describe more complex semantics in the local ontologies. For example, in Figure 1, we show a Local Ontology (Oa) for the data model of Application A and a Local Ontology (Ob) for the corresponding data model of Application B. Accordingly, these local ontologies are used for exchanging data between Application A and Application B in certain business processes. The global terminology, represented by a shared vocabulary, the Reference Ontology (Or), represents the set of basic domain terms that provide a semantic link between different data models. In this paper, we develop a reference ontology for the automotive retail business domain to support the mapping between the concepts contained in two local ontologies, Oa and Ob.

3.2 STAR Ontology

Standards for Technology in Automotive Retail (STAR) [17] is a nonprofit, unionized organization whose members include dealers, manufacturers, retail system providers and automotive-related industrial organizations. The goal of the STAR Organization is to use non-proprietary information technology (IT) standards as a catalyst in fulfilling the business information needs of dealers and manufacturers while reducing the time and effort required in supporting related activities. In this research, we have developed the STAR Reference Ontology in order to gain a high level of detailed knowledge from the automotive retail industry domain and therefore to facilitate the interoperability of automotive retail applications.

The STAR reference ontology, which is based on the STAR metadata, is created through a process of manual identification. Because the ontology needs to be continually refined, the missing classes, properties and business rules have to be discovered. In our research, the STAR Ontology is formalized in OWL DL [18][22], and currently, it describes 1396 lexical terms, all of which refer to major concepts in the Automotive Retail Domain. Furthermore, the STAR Ontology is structured in six different categories. These categories, shown in Figure 2, include General, Dealer, Customer, Parts Management, Vehicle Management and Sales, Vehicle Repair and Service. Each category has a domain of possible values, which are organized in a tree-structured taxonomy.

The STAR ontology serves as a source of background knowledge in the automotive retail business domain. Elements from the different data sources, such as the terms of customer information in the RMS and DMS, are first mapped to the intermediate terminology defined in STAR. Subsequently, their mapping is deduced based on the semantic relation of the intermediary terms within the STAR reference ontology. Accordingly, the obtained mappings can describe a larger variety of semantic relations between terms rather than just equivalencies. Therefore, our approach takes advantage of richly axiomatized ontology as background domain knowledge and thus guarantees the semantic nature of the mappings.

3.3 System Architecture

This paper proposes a service oriented framework for ontology management; the framework is known as SOOMF. By using the SOOMF, participants of business processes in the automotive retail industry can register and publish their local ontologies/data models through defined Web Services. Moreover, they can also discover other published ontologies and execute mappings using Web Services. The reference ontology and the local ontologies, along with the correspondences generated by mappings, are published to the Web. A centralized repository used as the service registry facilitates the discovery and reuse of the Web Services.

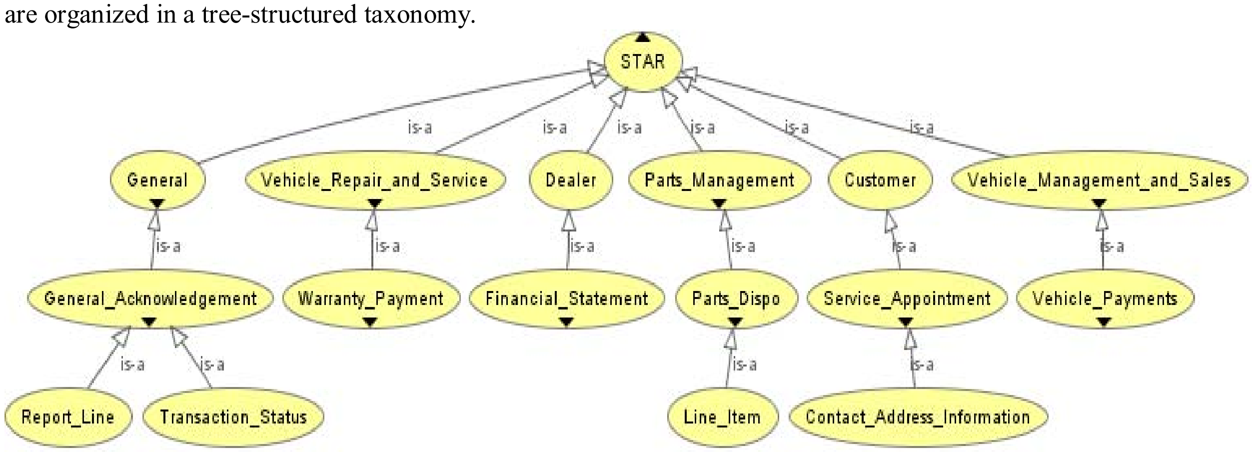

Figure 2. STAR reference ontology taxonomy (Generated by OWLViz[21])

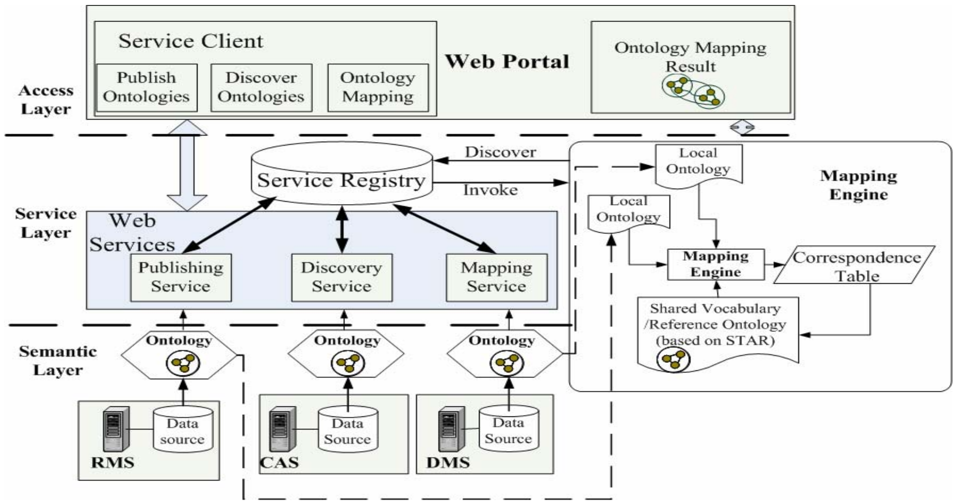

Figure 3. System Architecture of SOOMF

SOOMF can be divided into three architectural layers, as depicted in Figure 3. These layers include the semantic layer, the service layer and the access layer. At the semantic layer, the semantic and expressive descriptions are used to describe the data models. Data model ontology sources, also known as local ontologies, are developed to represent different data models. Subsequently, the information corresponding to the ontologies is published using Web Services.

At service layer, the regular Web Service technologies are utilized. We are using SOAP for messaging, WSDL for service description, and service registry for publishing, discovering, and retrieving semantic information. Finally, a mapping engine is used to execute ontology mapping.

For implementing the service registry, we have also developed three key Web Services:

- The publishing service - the ontoPublish Web Service, allows web users to submit their ontologies and other related information on the web. The information includes the provider of the ontologies and business process that the ontologies are applied.
- The discovery service - the ontoSearch Web Service, executes a search based on the information given by business processes or ontology providers. When a user submits a request for acquiring certain ontology, the service returns the available ontologies list as well as the corresponding URL of ontologies as the searching results.
- The mapping service - the ontoMapping Web Service, which provides the functionality of ontology mappings. Similar to the ontologies themselves, the mapping engines are developed externally and imported into the SOOMF.

The final architectural layer of the SOOMF, the access layer, contains the Web Portal, which is the entrance to the SOOMF. The Web Portal enables users to access available Web Services of SOOMF on the web. Users can also execute specific functions, such as publishing ontology to the web by the publishing services, searching and retrieving ontologies by the discovery service, and performing ontology mapping by the mapping service.

4. Implementation and Prototype

Our research is based on an actual business case in the automotive retail domain. In this case, we use a typical customer data exchange process, where a Retail Management System (RMS) receives customer information updates from the dealers via a Dealer Management System (DMS). When customer data from the DMS is inserted, updated or deleted, an outbound customer transaction will be sent to the RMS. In this scenario, the RMS acquires the ontology of updated customer information from the DMS. First, the RMS needs to access the service registry and discover which DMS published its data model for customer information. Subsequently, the RMS utilizes a corresponding service to retrieve the ontological data from the DMS. Finally, the user of the RMS invokes the ontology mapping service to call the mapping engine. The mapping engine executes a reference ontology based ontology mapping between the retrieved ontology of the DMS and the local ontology of the RMS; this procedure generates correspondences based on the mapping result. In order to build the reference and local ontologies, we use Protégé [19]. Figure 4 provides a sample snippet of the local ontologies that are used to match customer information with the data models of DMS and of RMS.

```
<owl:Class
rdf:ID="CuUpdate"/>
 <owl:Class rdf:ID="Email">
   <rdfs:subClassOf
rdf:resource="#ContactInfo"/
> </owl:Class>
<owl:Class
rdf:ID="ContactInfo">
   <rdfs:subClassOf
rdf:resource="#CustRec"/>
</owl:Class>
<owl:Class
rdf:ID="CustRec">
   <rdfs:subClassOf
rdf:resource="#CuUpdate"/>
</owl:Class>
<owl:Class
rdf:ID="Address">
  <rdfs:subClassOf
rdf:resource="#ContactInfo"/
>
</owl:Class>
...
<owl:DatatypeProperty
rdf:ID="City">
   <rdfs:domain
rdf:resource="#Address"/>
     <rdfs:range
rdf:resource="&xsd;string"/>
 </owl:DatatypeProperty>
 ...
 <owl:ObjectProperty
rdf:ID="hasAddress">
   <rdfs:domain
rdf:resource="#ContactInfo"/
>
 <rdfs:range
rdf:resource="#Address"/>
<rdfs:subPropertyOf
rdf:resource="#hasContactIn
fo"/>
 </owl:ObjectProperty>
  ...
RMS
```

```
<owl:Class
rdf:ID="ProcessSaleslead"/>
<owl:Class rdf:ID="Customer">
      <rdfs:subClassOf
rdf:resource="#ProcessSaleslea
d"/>
</owl:Class>
<owl:Class rdf:ID="Individual">
   <rdfs:subClassOf
rdf:resource="#Customer"/>
</owl:Class>
<owl:Class rdf:ID="Address">
   <rdfs:subClassOf
rdf:resource="#Individual"/>
</owl:Class>
…
<owl:DatatypeProperty
rdf:ID="City">
   <rdfs:domain
rdf:resource="#Address"/>
      <rdfs:range
rdf:resource="&xsd;string"/>
…
<owl:ObjectProperty
rdf:ID="hasAddress">
      <rdfs:domain
rdf:resource="#Individual"/>
      <rdfs:range
rdf:resource="#Address"/>
      <rdfs:subPropertyOf
rdf:resource="#hasIndividual"/>
 </owl:ObjectProperty>
   <owl:ObjectProperty
rdf:ID="hasContact">
      <rdfs:domain
rdf:resource="#Individual"/>
      <rdfs:range
rdf:resource="#Contact"/>
      <rdfs:subPropertyOf
rdf:resource="#hasIndividual"/>
   </owl:ObjectProperty>
   …
DMS
```

Figure 4. The sample of ontology of DMS and RMS (Built by Protégé [19])

A web based prototype of the SOOMF is implemented in order for the end user to publish, discover and map ontologies on the web. Hence the prototype system consists primarily of the three Web Services that are presented in Section 3, the publishing service, the discovery service and the mapping service. Moreover, the prototype also contains a web based user client that facilitates publishing, searching and retrieving ontologies along with producing a reference based ontology mapping. In order to access the prototype system, the user manipulates the web client.

Through the web client, users can access the Web Services and then execute the corresponding operations, including publishing their own ontologies, discovering the ontologies of other users, invoking the ontology mapping engine to perform mapping and reviewing the mapping results. Figure 5 demonstrates that in order to execute an ontology mapping, users can invoke the Web Services via the service registry to search and retrieve the corresponding ontologies. After targeting and loading the ontologies, the web user then summons the ontology mapping engine by invoking the mapping service. Finally, the mapping result, the semantic correspondence of the two ontologies, will be displayed on the web portal for the user to review.

5. Conclusion and Future Work

In the automotive retail industry, the efficiency of data model mapping is a critical issue for information exchange. In order to solve this issue, we propose a service oriented ontology management framework (SOOMF) that supports the semantic interoperability of heterogeneous data sources among automotive retail applications. Specifically, we have developed the STAR reference ontology and implemented a prototype of this framework for ontology mapping. The next stage of our research involves completing the development of the framework and creating a number of services to fully implement the features of the SOOMF.

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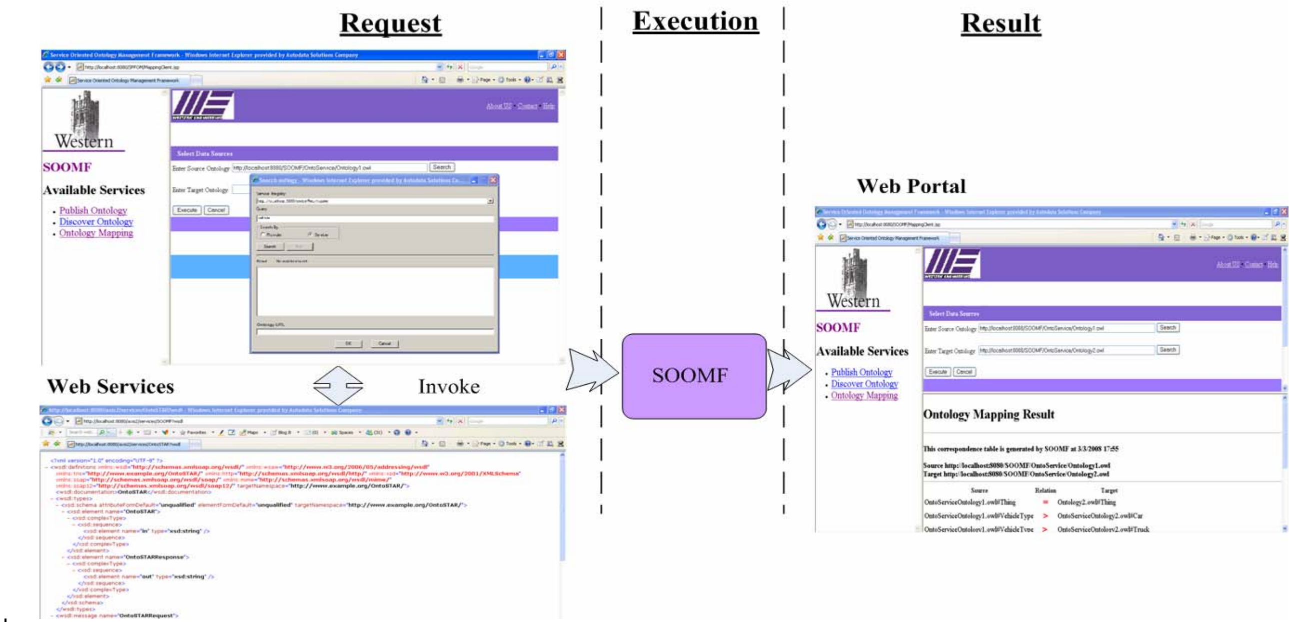

Figure 5. Search ontologies and perform ontology mapping through SOOMF

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