Software Agents Mediated Interoperability among Heterogeneous Semantic Services

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Abstract

Bringing Interoperability among heterogeneous semantic information services developed for open environments is a great challenge. Software agents have been realized as pivotal technology to drive semantic web and grid services ultimately leading to automation of e-Science, e-Health and e-Commerce applications. Ontologies play a vital role as source of semantic representation of web services, grid services and agent services. Different ontology languages have been proposed for semantic representation of these technologies. OWL is W3C standard for description of services on web and grid while FIPA SL is used as semantic language in agents. Both semantic languages differ in terms, syntax and semantics. We proposed software agent driven system architecture i.e. middleware ontology service (MOS) which provide translation of ontologies between these two languages. At the end, we provide comparative study of MOS with previous developed system i.e. Ontology Gateway and describe its implementation and results.

1. Introduction

An agent “is an encapsulated computer system that is situated in some environment and that is capable of flexible and autonomous action in environment in order to meet its design objectives” [1]. Research in agent technology is broadly divided into two categories. One of them is individual agents which focus on autonomous, proactive and cooperativeness of agents. Second is the multiagent system which is a loosely coupled network of problem-solver entities that work together to find answers to problems that are beyond the individual capabilities or knowledge of each entity. Foundation for Intelligent Agent (FIPA) [2] is standardization body which governs and promotes agent technology. Web services are contemporary technology to software agents which are loosely coupled software components that lack autonomy and pro-activeness but they use internet protocols to describe, publish, discover, and invoke each other dynamically to build complex machine-to-machine programmable services. Both software agents and web services follow Service Oriented Architecture (SOA) principles having Service Provider, Service Consumer, Service Registry and Service Contract as important components. With introduction of semantic web [3], which is extension of current web, the web services are enhanced to semantic web services by introduction of richer metadata i.e. Ontologies, in order to make them programmable by software agents. Another contemporary technology is Grid computing which aim at providing robust infrastructure for resource sharing and coordinated problem solving in dynamic, multi institutional virtual organizations [4]. Semantic Grid movement was started to address the issues of autonomy and dynamic service provisioning in Grid. It envisions autonomy in Grid through the inclusion of semantics, better enabling machines to understand the data and generate knowledge on its basis. The semantic grid can be described as an extension of the current grid in which information and services are given well defined meaning, better enabling computers and people to work in cooperation. Ontologies [5] are pivotal part of semantic web, semantic grid, semantic web services and multiagent system, which are specification of a conceptualization of certain domain and make the data to be processed by machines in autonomous way. Ontologies automated interoperation and cooperation among participating entities. Web Ontology language is W3C standard semantic markup language for publishing and sharing ontologies on the web and grid whereas FIPA SL is semantic language used in agent communities for description of ontologies. The key idea behind introduction of semantic in these technologies is to enable software agents to dynamically discover, invoke
and monitor the heterogeneous semantic services on web and grid

All these technologies described above are distinct technologies arose independent of each other having their own standards and specifications. Web, grid and agent communities have realized the importance of synergies of these technologies for future applications [4,6]. IEEE FIPA agent and web services integration working group and Open Grid Forum Semantic grid research group are outcome of such realization.

We aim at providing agents mediated semantic interoperability in heterogeneous distributed environment where technologies like agents can automatically and transparently access semantic web and grid services and vice versa without changing standards and specifications.

2. Related work

Three types of integration approaches or patterns have been reported [8] for establishing the communication between agents and web services. Those are

- Adapting one technology to other. This requires changes in specifications and standards of integrating technologies.
- Middleware based integration. A successful solution for integrating technologies by creating mappings between protocols.
- Minimal changes integration. This involves adopting one technology to other with minimal changes in standards and specifications.

Web Services Integration Gateway Service (WSIGS) [10] is example of minimal changes integration architecture and is related to Gateway model produced by AgentCities.Net web services working group. AgentWeb Gateway [9] is example of middleware based integration which attempts to abridge the communication gap between two technologies by providing translation between communication protocols and service descriptions. Ontology gateway [7] is also middleware based integration which provides interoperability between OWL and FIPA Ontologies by establishing limited translation/mappings between FIPA semantic language and OWL.

3. Proposed system architecture

This section describe in detail the proposed architecture comprises of middleware ontology service. MOS ontology agent enables interoperability among heterogeneous semantic services. It integrates software agents, web services and grid technologies through providing interoperability between OWL [11] and FIPA SL [2] ontologies. FIPA SL ontology and OWL ontology have different underlying support for the terms, syntax, semantics and implementation constraints. The two languages are based on different standards, one by FIPA and the other by W3C. Devising mappings/translations for such a system is quite demanding and challenging, as both languages vary tremendously.

Main features of Middleware ontology service (MOS) are (1) Translation of OWL ontologies to FIPA ontology and vice versa. (2) Storage / registration of translated ontologies at middleware. (3) Querying of translated ontology by agents and grid clients. Middleware based integration approach is adopted for middleware ontology service because it does not require any changes in standards and specifications used for construction of ontologies in FIPA SL [2] and OWL language. As OWL [11] is W3C standard language for ontology descriptions on web, the communication infrastructure provided by FIPA permit agents to communicate with any mutually comprehensible language as long as it fulfills a few minimal criteria as FIPA compliant content language. Figure 1 shows an abstract architecture of proposed system. The key idea is to show how agents, web and grid service can communicate with each other in bringing semantic interoperability.

MOS comprises of following components:
(1) Ontology Agent is responsible for communicating with FIPA agents and grid client to provide ontology services to them. From agents it will receive queries regarding searching and querying ontologies in ACL format. MOS ontology agent executes those queries on registered ontologies and sends reply in ACL message. From grid client it will receive queries regarding searching and querying ontologies in SOAP format. MOS ontology agent translate SOAP message into ACL format and then execute translated queries on registered ontologies and send reply in SOAP format. SPARQL is used by ontology agent to translate OWL ontology to equivalent FIPA SL ontology. Jena model is used to load the OWL ontology and SPARQL queries are executed on loaded ontology to get the desired information. To query OWL ontology with SPARQL we have explicitly mentioned the rdf:type defining OWL types e.g ?class rdf:type owl:Class. Following SPARQL query is used to get classes and subclass from OWL ontology.
SELECT ?class ?subclass WHERE {
  ?class rdf:type owl:Class .
  ?subclass rdfs:subClassOf ?class
};
Following SPARQL query is used to get OWL properties, domain and range from OWL ontology.
SELECT DISTINCT ?property ?domain ?range WHERE {
  ?property rdf:type owl:ObjectProperty OPTIONAL {?property rdfs:domain ?domain} OPTIONAL {?property rdfs:range ?range}
}

(2) OWL to FIPA SL component is used by ontology agent to translate OWL ontology to equivalent FIPA ontology. (3) FIPA SL to OWL component is used by ontology agent to translate FIPA ontology to equivalent OWL ontology. (4) SOAP to ACL component is responsible for conversion of SOAP message to equivalent FIPA ACL message. (5) ACL to SOAP component is responsible for conversion of ACL message to equivalent SOAP message. (6) Ontology management component is responsible for versioning and alignment of translated ontologies. Ontology web server stores translated ontologies after registration with MOS ontology agent. The detail communication mechanism between agents and semantic web services has been described in [12].

4. Implementation

This section describes the implementation details of MOS. A prototype implementation of proposed architecture has been developed at NUST-Comtec lab on Scalable Fault Tolerance Agent Grooming Environment (SAGE). The test bed information is shown in Figure 4. Jena is Java based framework for building Semantic web applications and it provides a programmatic support for RDF, RDFS and OWL, SPARQL. According to FIPA, the agent ontology is composed on four types of schemas. Those are concept schema, predicate schema, aggregate schema and agentaction schema. Concept schema represents user defined objects. Predicate schema defines list of outcomes/response of the agent.

![Figure 1: Proposed System Architecture](image1)

![Figure 2: Test bed configuration](image2)

Agentaction Schema defines lists of action an agent can perform. Aggregate schema represents the outcome concept of agent action. We implemented the proposed system which translates the FIPA ontology ConceptSchema, PredicateSchema, AggregateSchema and AgentactionSchema into equivalent OWL representations. Following is translation of FIPA ontology concept schema to OWL schema:

```
<owl:Ontology rdf:about=""/>
<owl:Class rdf:ID="university"/>
<owl:Class rdf:ID="courses">
<dfs:subClassOf rdf:resource="#university"/>

<owl:Class rdf:ID="courses">
```

We also carried out comparative study of MOS with Ontology gateway. Table 1 shows the comparative study of MOS with ontology gateway. The MOS provide much more enhanced functionality then ontology gateway

5. Evaluation and future directions

This section provides the evaluation details of proposed system in which we have resolved technical hindrances to make semantic translation between agents and OWL based web services keeping in view standards and specifications of W3C OWL and FIPA SL. We compared two approaches for carrying out evaluation of the system as shown in Figure 5. One approach is FIPA SL to OWL translation and second is OWL to FIPA SL translation.
### Table 1: Comparison of Ontology gateway with Middleware ontology service (MOS)

<table>
<thead>
<tr>
<th></th>
<th>Ontology Gateway</th>
<th>MOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AgentAction and Aggregate Schema</td>
<td>Not captured</td>
<td>Captured</td>
</tr>
<tr>
<td>Discovery and Communication of services</td>
<td>Works with AgentWeb Gateway</td>
<td>Works independently with its own mechanism</td>
</tr>
<tr>
<td>Ontology Translation</td>
<td>Based on Parsing of ontology file.</td>
<td>SPARQL used to query OWL ontology for translation to FIPA SL ontology. Enhanced OWL to FIPA SL parser functionality</td>
</tr>
<tr>
<td>Registration &amp; Querying of translated ontologies</td>
<td>Not provided</td>
<td>Provided</td>
</tr>
<tr>
<td>FIPA Ontology Services specification</td>
<td>Not follows</td>
<td>Follows</td>
</tr>
</tbody>
</table>

Time taken during translation is measured against the number of tags translated. We consider FIPA SL ConceptSchema as one tag and its OWL representation also as one tag. Same rule is considered for AgentActionSchema, PredicateSchema and AggregateSchema. FIPA SL to OWL translation takes less time as compared to OWL to FIPA SL translation. OWL to FIPA SL translation takes more time to load ontology in Jena and executed SPARQL queries on it. The graph shows that increasing no of tags does not affect linear behavior of the system. The graph shows that increasing no of tags does not affect linear behavior of the system.

Many Content languages are being used for description of Ontologies in Agents like XML, KIF etc but only FIPA SL translation to OWL and vice versa provided. Also changes in standards and specifications will lead to changes in MOS. The MOS can be further enhanced to provide following functionalities:

1. Translate the FIPA ACL message to equivalent SPARQL query to search on semantic web.
2. Translate expressions between different translated ontologies.
3. Respond to query for relationships between terms or between translated ontologies.

### 6. References


