AGENT ONTOLOGY INTEROPERABILITY APPROACH FOR MAS NEGOTIATIONS IN VIRTUAL ENTERPRISES

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Abstract: In supply chain management, a Virtual Enterprise (VE) is a dynamic alliance of partner companies. Multi-agent systems (MAS) have been introduced to facilitate negotiations among VE members. From the perspective of knowledge management, heterogeneous VE members utilize different knowledge structures and terminologies in their representative agents. To encourage their collaborative coordination and realize mutual understanding, agent ontology interoperability should be reached. In this paper, an approach for semantic ontology matching is proposed to generate correspondences among heterogeneous ontologies embedded in MAS; additionally, an ontology correspondence generation and negotiation protocol is developed to realize agent ontology interoperability in MAS negotiations.

1 INTRODUCTION

A Virtual Enterprise (VE) is a dynamic alliance of partner companies, aiming at seeking more market opportunities to provide high-quality with low-cost services and products as fast as possible (Camarinha-Matos et al, 1999). Generally, a VE is composed of a VE initiator and several distributed and heterogeneous VE partners. To respond to a market opportunity, the VE initiator relies on its partners to operate, that is, the functioning of a VE relies on the collaboration and interaction of its partners. Therefore, it is important for the VE initiator to select appropriate partners to create the initial VE.

In the VE formation phase, the initiator negotiates with its potential partners to reach agreement on the cooperation issues in order to form the initial VE. In the subsequent VE functioning phase, the initiator negotiates with its partners to contract with each other. With the advance of agent technology, multi-agent systems (MASs) have been introduced to provide an effective and efficient environment for VE formation and operation (Norman et al, 2004). Within the MAS, agents are established to be responsible for various functions of different VE members. However, different VE members may use different structures and terminologies to organize and represent their knowledge; it is important but difficult for agents to reach mutual understanding through heterogeneous knowledge representations. In order to achieve semantic interoperability among agents, many researchers have proposed to adopt the ontology-based approach to support MAS negotiations in the VE (Chen et al, 2008; Lo et al, 2008; Trappey et al, 2009; Garcia-Sanchez et al, 2009). Some are concentrating on developing ontology matching mechanisms to reach semantic interoperability (Chen et al, 2008; Lo et al, 2008); while some are focusing on realizing MAS automated negotiations (Trappey et al, 2009; Garcia-Sanchez et al, 2009). In most of the current applications, there are only a few publications focusing on an entire framework to illustrate how agent ontology interoperability is reached, how semantic matching is conducted, and how ontology based MAS negotiations is realized.

The objective of this paper is to establish an ontology-based framework to achieve agent ontology interoperability and to realize automated MAS negotiations in the VE.

The remainder of this paper is organized as follows: Section 2 presents some related work. Section 3 outlines the MAS framework and semantic matching approach. Section 4presents system implementation and experiment evaluation. Section 5 presents conclusions and future work.

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2 RELATED WORK

2.1 Ontology-based MAS for VE

Many researchers have engaged in providing solutions in this field to reach mutual understanding and automated MAS negotiations in VE.

In Lo et al (2008)'s application, the VE initiator builds up domain ontology with an ontology vocabulary inside its database, which can provide flexible matching with different enterprises. Trappey et al (2009) developed a JADE-based workflow management system, where the workflow ontology is constructed to represent relationships between workflows, resources and actors. Garcia-Sanchez et al (2009) designed and implemented a JADE-based platform for the provision of semantic web services, where ontologies is used to describe application domain knowledge, agent local knowledge, negotiation knowledge and semantic web services knowledge.

The above applications are focused on developing MAS platforms. Detail information about utilizing heterogeneous ontologies is not available. Therefore, a series of semantic ontology matching approaches are proposed to fill the gap.

2.2 Ontology Matching

Ontology is increasingly considered as an essential factor for reaching interoperability across heterogeneous systems. Meanwhile, ontology matching has been introduced to combine distributed and heterogeneous ontologies.

Choi et al (2006) conducted a survey on ontology matching, aiming at providing a comprehensive understanding of ontology matching. Laera et al (2007) proposed an argumentation based ontology matching for MAS. Correspondence matching repository is constructed, where candidate matchings, ontology mismatches, matching preference and candidate threshold are stored in. Bollegala et al (2007) engaged in conducting query-based semantic matching studies, where various types of query ontologies were constructed to enable agents' learning ontology models.

As revealed in the above publications, previous research efforts have been mainly spent on the basic ontology matching approaches. As presented in this paper, a series of ontology-based semantic matching approaches are proposed to reach agent ontology interoperability in VE negotiations.

3 APPROACH

3.1 Ontology-based MAS Framework

An ontology-based MAS framework has been developed to enable distributed and heterogeneous VE members to communicate and negotiate. Figure 1 depicts the architecture of the system framework, which comprises the following elements:

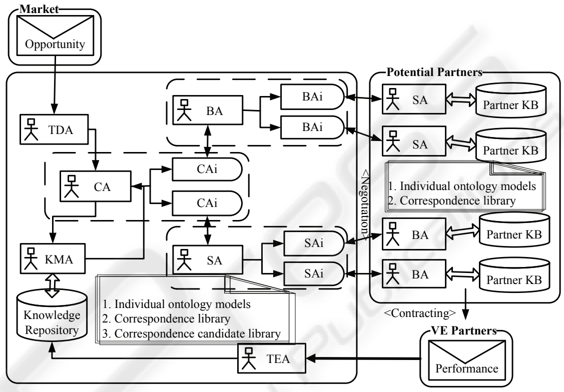


Figure 1: Ontology based MAS system architecture.

- *Buyer Agent* (*BA*): In this study, *BA* is on behalf of the VE initiator, which initiates the preliminary requirements to select its partners.
- *Seller Agent* (*SA*): *SA* is on behalf of VE partners, which responds to *BA*'s requirements and negotiate with it to reach agreements.
- *Task Decomposer Agent* (*TDA*): Receive preliminary requirements from *BA* and decompose them into small sub-tasks.
- *Coordinator Agent* (*CA*): Receive sub-tasks from *TDA*, and sends them to *BA* and initializes the negotiation.
- *Task Evaluator Agent* (*TEA*): Evaluate the partners' performances, and record it into *VE initiator's knowledge repository*.
- *VE Initiator's Knowledge Repository*: Store individual ontology models, correspondence libraries, and correspondence candidate libraries.
- *VE Partner's Knowledge Base*: Store individual ontologies, correspondence libraries with different partners.
- *Correspondence library*: Record historical correspondences used in past negotiations between BA and other agents.
- *Correspondence candidate library*: Record correspondence candidates obtained from semantic matching process, using domain individual ontologies.

3.2 Correspondence Generation and Negotiation Protocol

Figure 2 depicts ontology based correspondence generation and negotiation protocol, which aims at realizing mutual understanding and automated negotiation among VE members. Specification for this protocol is provided in Table 1.

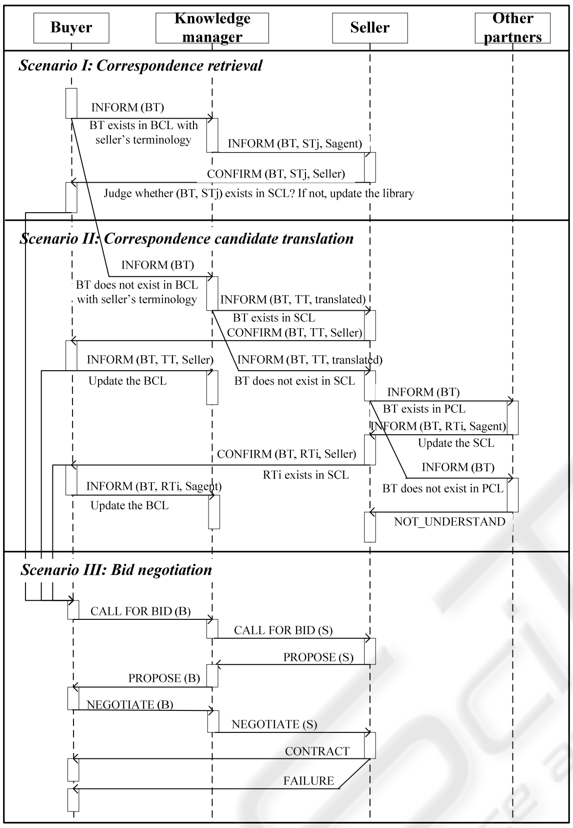


Figure 2: Ontology correspondence generation and negotiation protocol.

Here, BT is a term using buyer's terminology, ST_j is a term using seller's terminology in form of (BT, ST_j) in buyer's *correspondence library*; Sagent is an agent participating in negotiations using (BT, ST_j) as a correspondence; TT is a term translated according to buyer-seller *correspondence candidate library*; translated indicates that (BT, TT) is a correspondence candidate pair, not a correspondence pair; RT_i is a term in form of (BT, RT_i) in other partner's *correspondence libraries*.

Table 1: Interpretation of negotiation messages.

Message Name	Functionality
INFORM	Send a term to the receiver agent; Ask it to check its correspondence library using the received information.
CONFIRM	Confirm the correspondence with the initiator.
NOT_UNDERSTAND	No correspondence is in the partner's library.
CALL FOR BID	Initialize the negotiation with a preliminary bid.
PROPOSE	Respond to CALL FOR BID message.
NEGOTIATE	Negotiate with each other.
CONTRACT	Reach agreement and contract.
FAILURE	No agreement is made.

3.3 Knowledge Representation

Ontology is used to describe domain knowledge of individual VE partners. In this study, two types of individual negotiation ontologies are constructed, i.e. Buyer ontology and Seller ontology, as shown in Figure 3.

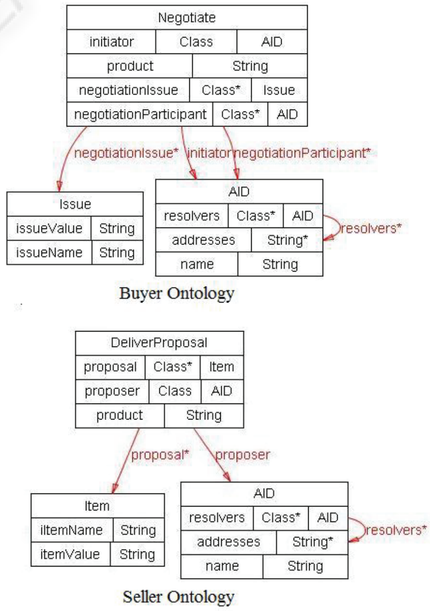


Figure 3: Partial ontologies for buyer and seller 1.

3.4 Semantic Ontology Matching

The purpose of ontology matching is to find out the correspondences between two separate ontologies. By doing so, heterogeneous ontologies can reach mutual understanding among each other.

Definition 1 (Ontology Matching System):

Suppose O and O' are two ontologies, which are defined as O = <C, R, I> and $O' = < C', R', I' >$. Here, C stands for concepts, R stands for relations, while I stands for instances. An ontology matching system MS is defined as a triple (O, O', M). M is the correspondence between two ontologies, which is defined as (e, e', σ). Here, e and e' are concept or attribute in ontologies O and O', respectively; σ is similarity value between e and e'.

The semantic of heterogeneous ontologies is calculated by ontology matching. This study proposes three types of ontology matching methods, which are explained in the following sections.

3.4.1 Name-based Term Matching

In name-based matching process, firstly, names of elements (concept and attribute) should be stemmed and pre-processed into atomic terms. Secondly, WordNet is introduced to find semantically similar terms among heterogeneous ontologies (Cognitive Science Laboratory, Princeton University, 2006).

Algorithm 1: Term similarity calculation
Input: Term T from ontology O, Term T' from ontology O'
Output: < T, T', σ >, correspondence between T and T'

- Initialize similarity value $\sigma(T, T') = 0$;
- Get all the senses and their hypernym of T and T' respectively, i.e., $T(*)$ and $T'(*)$;
- Calculate the lengths of all paths between T and T', and get the shortest path;

Suppose L is the length of the shortest path between T and T', then similarity $\sigma_1(T, T')$ can be calculated by (1):

$$\sigma_1(T, T') = e^{-\alpha L} \tag{1}$$

- Calculate the depths of all terms in set of $T(*) \cap T'(*)$.

Suppose H is the biggest depth between T and T', then similarity $\sigma_2(T, T')$ can be calculated by (2):

$$\sigma_2(T, T') = \frac{e^{\beta H} - e^{-\beta H}}{e^{\beta H} + e^{-\beta H}} \tag{2}$$

- Final term similarity can be calculated by (3):

$$\sigma(T, T') = \omega_1 \sigma_1(T, T') + \omega_2 \sigma_2(T, T') \quad \text{where } \omega_1 + \omega_2 = 1 \tag{3}$$

3.4.2 Structure and Constraint based Attribute Matching

Ontology structure and constraint defined within each element have significant effect on elements' semantics. For concepts, a child concept will inherit the semantics of its father concept; for attributes, different attributes' data types represent different semantics. In this study, attributes are main components which make up of the negotiation messages, a structure and constraint based hybrid matching algorithm for attribute is proposed.

Algorithm 2: Attribute similarity calculation
Input: O = <C, R, I> and $O' = < C', R', I' >$; Attribute r_0' and its related concept c_0' of ontology O'.
Output: < r, r_0', σ_{max} >, the highest similarity between all attributes in O and attribute r_0' from O'.

- Find all attribute r in O of the same data type with r_0', and their related concept names c.
- Calculate similarities between qualified attribute r and r_0' using formula (4):

$$\sigma(r, r_0') = \alpha_1 \sigma_1(c, c_0') + \alpha_2 \sigma_1(c, r_0') + \alpha_3 \sigma_1(c_0', r) + \alpha_4 \sigma_4(r, r_0') \tag{4}$$

- Then the highest similarity can be obtained by formula (5):

$$\sigma_{max} = \max(\sigma(r, r_0')) \tag{5}$$

3.4.3 Distance between Data Patterns based Instance Matching

The contents of instances reveal some correlations among different ontologies. Therefore, an instance matching is proposed based on auxiliary information, such as data pattern, value distribution, average, etc.

Algorithm 3: Instance similarity calculation
Input: Instance strings SB and SS
Output: Distance between input strings, d (SB, SS)

- Pre-process the attribute data according to the following rules: Turn all numerals into symbol "0"; Turn all alphabets into symbol "1"; Turn

Table 2: Similarity results for correspondence candidate generation using three different methods (Buyer and Seller 1).

Correspondence pair		Attribute method		Instance method		Combined method	
Buyer	**Seller 1**	**Similarity**	**Rank1**	**Distance**	**Rank2**	**Average (Rank1, Rank2)**	**Rank3**
resolver	resolver	0.4901	1	0	1	1	1
initiator	proposer	0.3469	3	0	2	2.5	2
issue name	item name	0.6073	2	1	1	1.5	1
issue value	item value	0.5944	2	0	1	1.5	1
product	product	0.4414	3	0	1	2	1
name	name	0.5606	4	0	1	2.5	1
address	address	0.5204	2	0	1	1.5	1
issue name	item name	0.5947	1	1	1	1	1
status	status	0.7506	1	0	1	1	1
payment pattern	payment pattern	1	1	8	4	2.5	4
due date value	time value	0.6503	2	0	1	1.5	1
warranty value	service time	0.3994	4	0	3	3.5	3
quantity value	order size	0.6025	3	1	2	2.5	2
price value	price value	1	1	0	1	1	1
adjustment	adjustment	0.6237	1	0	1	1	1

all " ," into symbol "X"; Turn all white space into symbol "Y"; Turn all "http://" into "*******"; Turn all "@-:/." into symbol "#". Afterwards, the contents of different instances are transformed into a series of similar strings.

- Introduce Edit Distance to calculate similarity of strings (Navarro, G., 2001).

Definition 2:

- *SB* stands for a string from buyer; |*SB*| stands for the length of *SB*; SB_i stands for the i^{th} character of *SB*, for an integer $i \in \{1\ldots|SB|\}$; $SB_{i\ldots j} = SB_i\, SB_{i+1} \ldots SB_j$ stands for a partial string from SB_i, where $i > j$;
- Strings for sellers are defined in the same way.

Definition 3: *d*(*SB*, *SS*) indicates the distance between two strings *SB* and *SS*, which is the minimal cost of a sequence of *operations* that transform *SB* into *SS*. Here, the *operation* refers to *delete*, *insert* or *substitute* a character.

Definition 4: Define a matrix $C_{|SB|,\,|SS|}$, where $C_{i,\,j}$ represents the minimum number of operations needed to match $SB_{1..i}$ to $SS_{1..j}$. *d*(*SB*, *SS*) is computed as follows:

- $C_{i,0} = i$; $C_{0,j} = j$;
- $C_{i,j}$ = if ($SB_i = SS_j$) then $C_{i-1,j-1}$
  else 1 + min ($C_{i-1,j}$, $C_{i,j-1}$, $C_{i-1,j-1}$)
- $d\,(SB, SS) = C_{|SB|,\,|SS|}$.

4 IMPLEMENTATION AND EVALUATION

In this study, the MAS is implemented using JADE. As a simple example in supply chain management, a company has to purchase a product from two potential suppliers. The case is therefore to establish a VE with two of its suppliers. Accordingly, the MAS comprises three VE members, here the VE initiator acts as the buyer part.

Since different VE members are independent companies, it is usual for them to adopt different terminologies, even though they are describing the same semantics. It is easy for human experts to identify the representations, but difficult for agents to recognize automatically. Therefore, semantic ontology matching approaches are developed to reach agent interoperability. As detailed in Section 3.4, the word method is a basic method to calculate term similarities; the attribute and instance methods are based on hybrid criterions and data patterns of instances, respectively.

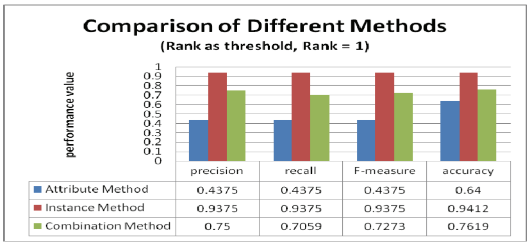
In this study, suppose that two sellers share a same ontology structure. Two separate ontologies are shown in Figure 3. Correspondences are generated, and performances of different methods are compared, which are as shown in Table 2.

To evaluate the performance of different matching methods, four typical evaluators in Information Retrieval (IR) are adopted (Islam, A., 2008). In the following, TP stands for True Positive (how many correspondences were selected with right meanings); FP stands for False Positive (how many correspondences were not selected, which are actually with right meanings); FN stands for False Negative (how many correspondences were selected with wrong meanings).

The evaluators are listed as below:

- Precision (P): P = TP / (TP + FP)
- Recall (R): R = TP / (TP + FN)
- F-Measure (F): F = 2PR / (P+R)
- Accuracy (A): A = (TP + FP) / (TP + FP + FN)

Figure 4 shows the experiment evaluation results.



	precision	recall	F-measure	accuracy
Attribute Method	0.4375	0.4375	0.4375	0.64
Instance Method	0.9375	0.9375	0.9375	0.9412
Combination Method	0.75	0.7059	0.7273	0.7619

Figure 4: Performance of attribute & instance & combination methods (Rank 1 as threshold).

Figure 4 illustrates the comparison of the attribute, instance and combination methods, where rank No. 1 correspondence candidate is adopted as the threshold. It indicates that with the threshold set, performance of the attribute method is the worst and that of the instance method is the best.

However, in reality, the instance method is less restrained since contents of instances can be readily modified manually, the performance cannot be very stable. For this reason, the combination method is adopted to balance the attribute method and the instance method in a stable and well-performed way.

5 CONCLUSIONS

This paper presents an ontology-based approach to achieve agent ontology interoperability in MAS negotiations in the VE formation process. First of all, an ontology-based correspondence generation and negotiation protocol is proposed to provide a way for agents to interact with each other. Secondly, three semantic ontology matching methods are proposed, where the combination method with Rank No.1 correspondence candidate as threshold is adopted as the most appropriate method to realize agent ontology interoperability.

The research is still in progress. Future enhancements will be developed from two aspects: Firstly, new knowledge is created in every contract round. It is required to consider how to update the current knowledge libraries and to manage VE knowledge evolution in an effective and efficient way. Secondly, for different roles of agents, i.e. buyer agents and seller agents, in order to ensure the security of the negotiation platform, different members should be assigned different levels of authority to access the system. Therefore, a knowledge access control mechanism is to be developed in the future.

REFERENCES

Bollegala, D., Matsuo, Y., Ishizuka, M., 2007. Measuring semantic similarity between words using web search engines. WWW2007, May 8-12, 2007, Banff, Alberta, Canada, 757-766.

Camarinha-Matos, L.M., Afsarmanesh, H., (1999). The virtual enterprises concept: Infrastructures for virtual enterprises. Kluwer Academic Publishers: Boston, MA, 3-14.

Chen, Y.J., Chen, Y.M., 2008. Development of a mechanism for ontology-based product lifecycle knowledge integration, Expert Systems with Applications, doi:10.1016/j.eswa.2008.01.049.

Choi, N., Song, I.Y., Han, H., 2006. A survey on ontology matching. ACM SIGMOD record, 35(3), pp. 34-41.

Cognitive Science Laboratory, Princeton University, 2006. *WordNet a lexical database for the English language*, viewed 10 May 2009. <http://wordnet.princeton.edu/>

Garcia-Sanchez, F., Valencia-Garcia, R., Martinez-Bejar, R., Fernandez-Breis, J.T., 2009. An ontology, intelligent agent-based framework for the provision of semantic web services. Expert Systems with Applications, 36: 3167-3187.

Islam, A., Inkpen, D., 2008. Semantic text similarity using corpus-based word similarity and string similarity. ACM Transactions on Knowledge Discovery from Data, 2(2): Article 10.

Laera, L., Blacoe, L., Tamma, V., 2007. Argumentation over ontology correspondences in MAS. In *Proceedings of the Sixth International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS 2007), Honolulu, Hawaii, USA*. International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS), Hawaii, USA. Honolulu:acm, pp. 1293-1300.

Norman, T.J., Preece, A., Chalmers, S., etc., 2004. Agent-based formation of virtual organisations. Knowledge-Based Systems, 17: 103-111.

Lo, W.S., Hong, T.P., Jeng, R., 2008. A framework of E-SCM multi-agent systems in the fashion industry, International Journal of Production Economics, doi:10.1016/j.ijpe.2007.09.010.

Navarro, G., 2001. A guided tour to approximate string matching. ACM Computing Surveys, 33(1): 31-88.

Trappey, C.V., Trappey, A.J.C., Huang, C.J., Ku, C.C., 2009. The design of a JADE-based autonomous workflow management system for collaborative SoC design. Expert Systems with Applications, 36, 2659-2669.