Efficient Argumentation over Ontology Correspondences (Extended Abstract)

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1. INTRODUCTION

The ability to communicate is one of the key capabilities of an agent within a Multi-Agent System. In open environments, where agents are likely to use heterogeneous ontologies, it is necessary to use formally defined ontologies [1] to support communication. However, this requires either a shared ontology, or a *set of correspondences* (alignment) that map semantically related entities from one ontology to another. The open nature of such environments results in this being unlikely due to few *a priori* assumptions being made about the agents present; thus requiring techniques for dynamic alignment and reconciliation. To dynamically reconcile heterogeneous ontologies, agents need to be able to agree on an acceptable alignment between their ontologies. Various approaches attempt to resolve ontological mismatches in open environments [8, 4], using negotiation approaches that search the space of alignments to find a mutually acceptable set of correspondences. However, this search can become prohibitively costly when negotiation mechanisms such as argumentation are involved, reaching $\Pi_2^{(p)}$-complete [5]. Hence, it is important to reduce the search space *before* the argumentation process takes place. The *Meaning-based Argumentation* approach [8] allows two agents to dynamically and automatically reach consensus by arguing over a set of candidate *mappings* (or correspondences) obtained from a mapping repository. We have explored the use of *Ontology Modularization* as a filtering mechanism for reducing the number of candidate mappings, by isolating only those mappings that are relevant to the communication, and hence reducing the size of the search space for the argumentation process.

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Mechanisms supporting the storage and provision of mappings have already been devised, such as the *Ontology Alignment Server* (OAS)[7] which can supply alignments between two agents' ontologies. However there are various mechanisms for alignment generation [6], thus agents are likely to encounter a number of different alignments that are mutually acceptable for both.

The *Meaning-based Argumentation* approach describes a *mapping* as a tuple: $m = \langle e, e', n, R\rangle$, where e and e' are the entities between which the mapping is asserted, n is a degree of confidence in this mapping and R is the relation, such as equivalence, holding between e and e' [6]. The approach assumes that many *candidate mappings* between two agent ontologies are available from an *OAS*. Agents have private preferences over these candidate mappings which are used by the agent to decide whether to argue for or against a mapping. However, the argumentation process is costly and can easily result in agents arguing over mappings that are not relevant to the task at hand. Therefore, ontology modularization can be used to reduce the size of the search space by identifying those mappings that are relevant.

An **ontology module extraction** technique extracts a consistent module M from an ontology O that covers a specified signature $Sig(M)$, such that $Sig(M) \subseteq Sig(O)$. M is the part of O that is said to cover the elements defined by $Sig(M)$. An ontology, O, is defined as a pair, $O = (Ax(O), Sig(O))$, where $Ax(O)$ is a set of axioms describing the entities (classes, properties, and instances) in O and $Sig(O)$ is the signature of O, that is the set of entity names used by O, i.e., its vocabulary. Several ontology modularization techniques have been proposed, which can be classified as *traversal approaches* [3, 9], which conditionally traverse the ontology represented as a graph, and *logical approaches*, [2] which identify modules that preserve certain logical properties, such as coverage. Doran *et al*'s traversal approach [3] was adopted as it allows an agent to specify a $Sig(M)$ such that the resulting module contains the entities believed to be relevant for its task, by including the relevant subclasses and properties of the concepts in $Sig(M)$.

To combine modularization and argumentation the steps in Figure 1 must be followed. When two agents communicate (Steps 1-2), only the initiating agent (Ag_1) is aware of its task, and, consequently, what concepts are relevant to this task. These concepts will be included in $Sig(M)$, the signature of the resulting ontology module (Step 3).

1 Ag_1 asks a query, $query(A \in Sig(O))$, to Ag_2.
2 Ag_2 does not understand the query, $A \notin Sig(O')$, and informs Ag_1 they need to use an OAS
3 Ag_1 produces, $om(O, Sig(A))$, an ontology module, M, to cover the concepts required for its task.
4 Ag_1 and Ag_2 invoke the OAS. Ag_1 sends its ontology, O and the signature of M, $Sig(M)$.
5 The OAS aligns the two ontologies and filters the correspondences according to M. Only those featuring an entity from M are returned to both agents.
6 The agents begin the Meaning-Based Argumentation process, with each agent generating arguments and counter-arguments.
7 The iteration terminates when the agents agree on a set of correspondences.
8 Ag_1 asks again Ag_2, using the agreed correspondences, query($A \in Sig(O) \wedge B \in Sig(O')$) where A and B are aligned.
9 Ag_2 answers the query using the agreed correspondences.

Figure 1: Combining argumentation and modularization.

Name	# Cl.	# Prop.	DL expressivity	% Reduction
Cmt	36	59	$\mathcal{ALCIF(D)}$	43
ConfTool	38	36	$\mathcal{SIF(D)}$	28
Crs	14	17	$\mathcal{SHIN}$	39
Edas	104	50	$\mathcal{ALCIF(D)}$	28
Ekaw	77	33	$\mathcal{SHIN(D)}$	34
Sofsem	60	64	$\mathcal{ALCHIF(D)}$	28
Micro	32	26	$\mathcal{ALCIOF(D)}$	14
Pcs	23	38	$\mathcal{ELUIF(D)}$	28
OpenConf	62	35	$\mathcal{ALCIO(D)}$	37
Paperdyne	47	82	$\mathcal{ALCHIOF(D)}$	0
Sigkdd	49	28	$\mathcal{ELI(D)}$	13

Table 1: Average % reduction in module size.

The set of candidate mappings, gathered from the OAS (Step 4), are filtered prior to argumentation (Step 5) according to the **filtering function** $filter()$, which filters the set of mappings Z into a subset $Z' \subseteq Z$ such that $filter(Z, Sig(M)) : Z \rightarrow Z' \mid \forall m \in Z'\ ,\ m = \langle e, e', n, R \rangle$ and $e \in Sig(M)$. The agents now make use of the Meaning-based Argumentation (Steps 6-7) to reach an acceptable alignment. Modularization is therefore used to filter the correspondences that are passed to the argumentation process. The combination of argumentation and modularization reduces the cost of reaching an agreement over an alignment, by reducing the size of the set of correspondences argued over, and hence the number of arguments required.

2. EVALUATION

Several ontologies have been take from the OAEI07 Conference track[1] (listed in Table 1). To explore the effectiveness of modularization two sets of alignments were used: **Builtin**, where the possible mappings were determined by using simple textual and structural similarity between concepts and properties; **Falcon-AO**, where the possible mappings were those obtained by the Falcon-AO system[2] which was the best performing system on this track. For each technique, each ontology was compared to the other ontologies (excluding itself) giving 110 distinct pairs for a total of 220 tests. Two agents are created to start the argumentation procedure. The result of the argumentation process between the ontologies when no modularization occurred was used as a baseline result for each pair. Table 1 presents the average reduction in size for each ontology due to the modularization process, where the overall average was 26.5%.

The results (Figure 2) indicate that ontology modularization has a considerable impact on the number of mappings that are argued over. On average, this number is reduced by 75% (69% for the built-in and for Falcon-AO 79%). The experiments identify three cases: those where modularization has no effect (11.5%), where it reduces the number of mappings (47.1%), and where argumentation is redundant (41.4%), i.e., y is zero. This last result is interesting, as it implies that the agents are able to identify the cases where there is no alignment relevant to the current task, thus avoiding a potentially costly process that would not help the communication. The results therefore confirm the hypothesis that *modularization* is effective in reducing the search space for *argumentation*.

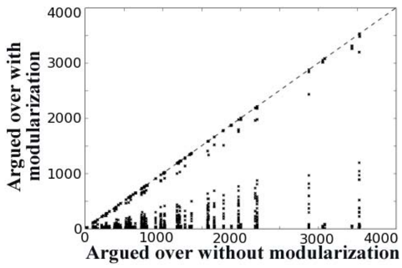

Figure 2: Number of correspondences accepted.

[1] http://oaei.ontologymatching.org/2007/conference/
[2] http://iws.seu.edu.cn/projects/matching/

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