ONTOLOGY MAPPING NEGOTIATION BASED ON CATEGORIZATION OF SEMANTIC BRIDGES

Paulo Maio, Nuno Bettencourt, Nuno Silva, and João Rocha
Research Group on Knowledge Engineering and Decision Support
School of Engineering - Polytechnic Institute of Porto
Rua Dr. António Bernardino de Almeida, 431
4200–072 Porto – Portugal
{paom,nmgb,nps,jsr}@dei.isep.ipp.pt

Abstract. Ontology mapping negotiation aims to achieve consensus among real-world entities about the process of transforming information between different ontologies. This paper describes a novel ontology mapping negotiation approach, based on the categorization of semantic bridges according to their confidence and relevance to the interoperability. The semantic bridges are then proposed between two agents in order to derive an ontology mapping agreement. Agents representing the real-world entities are able to achieve consensus based on the re-categorization of semantic bridges. The negotiation process, the intervenients and flow of execution is further described, thus presenting an integrated perspective of the envisaged system.

Keywords: Ontology, Mapping Negotiation, Categorization, Semantic Bridges

I. Introduction

Ontology mapping is a key technology for the development and deployment of the semantic web. Ontology mapping provides the mechanisms to access data from different repositories represented according to different ontologies, in a way the systems can process it as if data was represented according to their internal model (ontology).

The ontology mapping process aims to define a mapping between a source and target ontology ($\mathcal{M}: O^s \to O^t$). This ontology mapping ($\mathcal{M}$) is composed of a set of semantic bridges and their interrelations. Semantic bridges are further applied in transforming instances of the entities of the source ontology into instances of the entities of the target ontology.

The ontology mapping process is therefore a two phase process: (i) the specification of the semantic bridges and (ii) the execution of the semantic bridges to transform data between both systems.

However, because the specification of the mapping is a very knowledge demanding task, two different mappings will easily result from the specification process of two different organizations. Moreover, the resulting mappings are often divergent and even contradictory, preventing two such organizations interoperating.

Ontology mapping negotiation aims to overcome such divergences and contradictions, promoting the convergence of consensus about the mappings defined by two interoperability's partners. Two distinct approaches exist depending on the user's role in the process. The user-based process is naturally applied in offline semantic bridging scenarios, i.e. when the semantic bridging phase is carried out and proofed by human domain experts, prior to any data exchange phase. Alternatively, in scenarios where online semantic bridging is required, an automatic consensus building mechanism is necessary in order to supply the necessary consensus and speed up the interoperability process. Application scenarios such as information retrieval, e-business, e-commerce, web services orchestration and database integration, will directly benefit from the development of better and more accurate automatic ontology mapping negotiation systems.

This paper addresses the problem of the automatic consensus building among two agents about an ontology mapping, based on the agents relaxation of constraints associated with the semantic bridges using confidence categories of semantic bridges.

Long running research exists in the general topic of negotiation concerned with electronic commerce and resource allocation [1,14], but limited research exists concerning the specific case of ontology mapping negotiation. Supporting this premise, it has been noticed that in two of the most specific and relevant research events in this topic, MCN'2004@ISWC'04 and MeaN'2002@AAAI-02, while many research papers on ontology coordination (mapping) have been presented, none has been presented about ontology negotiation.

While the resource allocation and e-commerce research fields may contribute generally to the negotiation of ontology mappings, no research exists about the specific characteristics of this field. The definition and characterization of the negotiation context is the subject of the next section.

Database Integration, E-Commerce, Information Retrieval and Knowledge Management are some of the most prominent applications of ontology mapping negotiation. In particular information retrieval and knowledge management typically requires the capability to map between different domain models with less precision than in database integration. E-commerce and B2B are application scenarios in which precision and speed are both fundamental.

The rest of this paper runs as follows: the next section defines and constraints the ontology mapping negotiation problem and characterises the different types of negotiation and their dimensions. The third section describes some of the basic notions behind the ontology mapping process and specially those corresponding to our perspective of the process. Fourth section introduces the proposed conceptual approach to the problem. The fifth section describes the negotiation process, namely the envisaged phases necessary to achieve and improve the quality of the agreement. Finally, the conclusions section gives an overview of the proposed solution and emphasizes the major contributions of the paper.

II. Definition of the Problem

Any negotiation process aims to achieve a consensus that corresponds to a commonly agreed contract between two entities.

In the context of this project, the real-world organizations requiring interoperability are represented by artificial agents that act on behalf of the real-word organizations during the negotiation. Considering that the real world organizations (and therefore the artificial agents too) most probably have different perspectives on the ontology mapping scenario, one of the major questions is how to supply the agents with the capability to converge on a consensus.

Beforehand though, it is necessary to determine and characterize the variables of the negotiation [6,11], in particular:

- Object of the negotiation (single/multi-object, uniqueness, granularity).
- Type and number of negotiation entities.
- Value of the negotiation (single/multi-attribute).
- Negotiation strategies and convergence mechanisms.

A. Object of the Negotiation

As in any negotiation process, the ontology mapping negotiation problem is mainly characterized by the type of object being negotiated. According to the developed semantic bridging phase [12,13], several types of objects might be considered:

- The mapping ($\mathcal{M}$), when the whole specification is subject of the negotiation.
- The semantic bridges, when each of the semantic bridges are the subject of the negotiation.
- Parameters of the semantic bridges (e.g. the set of related entities).

However, the more elements are included in the negotiation, the longer and more difficult it is to achieve a consensus among agents. Notice that a coarse grained negotiation (i.e. negotiation about the whole mapping) is very fast, but is unlikely to achieve a consensus due to the lack of relaxation parameters. On the other hand, a fine grained negotiation (i.e. about the semantic bridges' parameters) is easier to achieve, but may take too long to achieve and therefore be unfeasible.

According to this, in the scope of this work, and in order to achieve a balance beteen accuracy and speed, it has been decided to consider the semantic bridge as the object of the negotiation.

B. Type and Number of Negotiation Entities

At least two parties must participate in the negotiation, but it is possible for multiple to map the same two ontologies. However, even if agents have the same understanding of the ontology mapping, the more agents participate in the negotiation process the more difficult would be to achieve a consensus. Yet, this scenario is not that uncommon, namely in e-market places [4].

Additionally, it is sometimes advisable to include third party entities in the negotiation. In fact, each agent is free to request such entities without any prior knowledge or agreement from the other agent, when the role to play is only related to its own tasks. For example, deriving the correct semantic bridges or getting better domain knowledge. Instead, when the role of third party entities affects both negotiating agents (e.g. exchanging arguments for making decision), it might be necessary to agree about their participation role, communication mechanisms, etc.

For the moment however, the negotiation will proceed with the participation of the two parties only, who are considered honest and co-operating. Moreover, both agents must be capable of devising a valid ontology mapping between the two ontologies.

C. Value of the Negotiation

Another important dimension to consider is the value associated with the object of negotiation. This value is typically one of the main dimensions of the process that is modified in order to reach a consensus. While in e-commerce, B2B and other real-object negotiation scenarios there are well-known features to evaluate the object (e.g. price, brand, warranty), with respecting to ontology mapping, it is not clear how the agent can evaluate a specific semantic bridge and additionally, how can an agent relax the value of the semantic bridge such that the other agent can accept it.

In order to answer these questions, it is useful to analyse the semantic bridging phase. When a party defines a semantic bridge, it (implicitly or explicitly) states its confidence value in that the semantic bridge is necessary to map between the two ontologies. In fact, the value of a semantic bridge is a function relating to the:

- Semantic correctness of the relation holding between source and target entities.
- Pertinence (importance) of the semantic bridge in respect to the interoperability.
- Relation between other semantic bridges (some semantic bridge may imply others).

Therefore, the value associated with a semantic bridge is stated according to the importance the agent attributes to it. It is our conviction that this confidence value may be further applied in the negotiation process, representing the value of the object.

D. Negotiation Strategies and Convergence Mechanisms

While the agreement is the goal of the negotiation, its content is subject to change during the negotiation and, in the end, it might not be the best possible agreement for any of the agents. Besides, it is good enough and advantageous to both agents so that it can be accepted by each of them. In fact, the best agreement is a function that might not be explicitly or implicit defined by any of the agents, especially due to: (i) the differences between both ontologies, (ii) the subjective nature of both ontologies and (iii) the goal and requirements of the interoperability.

Moreover, because it is most probable that each agent devises semantic bridges that are not devised by the other, it will happen that some of the semantic bridges are simply not considered in the agreement.

Nevertheless, it is the goal of the negotiation to drive both agents into an optimal agreement. Therefore, the goal may be understood as an optimization function that:

- Maximizes each agent's benefit.
- Maximizes the sum of the benefits from both agents.

III. CONTEXT

Despite the fact that ontology mapping can be represented in any model or language, the work presented in this paper is based on the MAFRA Toolkit and therefore the ontology mappings are represented in SBO - Semantic Bridging Ontology [7]. Each SBO semantic bridge describes the semantic relation between a set of entities (concepts or properties) of the source ontology and a set of entities of the target ontology. The definition of ontology mapping in scope of the SBO differs from other approaches [5], specially concerning the type of relation holding between source and target entities. In fact, while equality is the only relation typically considered in those approaches, the SBO models allows and promotes the specification of any kind of relation (e.g. concatenation, split, currency converter, table-based translation).

In its simplest form, an SBO semantic bridge is a tuple in the form of $\langle \mathcal{E}^s, \mathcal{E}^t, S, \phi^s, \phi^t \rangle$ where $\mathcal{E}^s$ and $\mathcal{E}^t$ are the set of source and target ontologies entities, S is the transformation function, and ϕ^s and ϕ^t are the relations (e.g. concatenation) between source and target entities and the arguments of S.

During the specification phase, external entities (matchers) provide similarity measures (matches) between one source entity and one target entity. A match corresponds therefore to the following tuple:

$$match := \left(e^s, e^t, Matcher, SimValue\right) : e^s \in O^s, e^t \in O^t$$

Matches are used by the system to devise the semantic bridges and then propose them to the user [13]. In order to devise the set of semantic bridges, the system exploits the so called service-oriented architecture, in which every service (S) has the ability to reason upon the provided matches and decide about its own capability to transform the instances of $\mathcal{E}^s$ into instances of $\mathcal{E}^t$.

Services are then perceived as the decision makers of the semantic bridging phase. In order to carry out this task, every service defines a set of important information (Table I):

- The types of matches required (e.g. h-match [3], resnik [10], Momis [2], Levenshtein string distance), which are provided by the respective matcher.
- For every match type, the acceptance threshold (t_{match}), i.e. the value below which the matches are not considered.
- The confidence evaluation function (u) that evaluates the Service confidence in the semantic bridge (c_{sb}) according to the set of required matches.
- The Service confidence threshold (t_r), below which the semantic bridge is rejected and therefore not suggested to the user.

Table I- Example of transformation services parameterization.

Service	Matches	t_{match}	u	t_r
CopyInstance	Resnik-like	0.7	u_{ci}	0,6
	H-Match	0.7		
CopyRelations	Resnik-like	0.5	u_{cr}	0,67
	H-Match	0.7		
CopyAttribute	Resnik-like	0.8	u_{ca}	0,85
	MOMIS-like	0.8		

IV. HYPOTHESIS

One of the major problems faced in negotiation scenarios relates to the difficulty in determining and supplying convergence mechanisms to the agents. In that respect, it is important to analyse the notion of negotiation.

Negotiation suggests the need for relaxation of the goals to be achieved by one (or both) of the intervenients in the negotiation, so that both can achieve an acceptable agreement, and both as good as possible.

This introduces two distinct concepts:

- The goals of the negotiation (the features of the agreement to achieve).
- The possibilities of relaxing the goals.

Mathematically, these concepts might be represented respectively as:

- A utility function (u), responsible for the evaluation of the confidence value of the semantic bridge, in which each parameter of the function is a subgoal of the negotiation:

$$u(p_1, p_2, ..., p_n)$$

- A meta-utility function (U) of the parameters of the utility function, defining the conditions in which the parameters may vary:

$$U(p_1, p_2, ..., p_n)$$

Since the parameters of the utility function are the basic concept of this approach, it is fundamental to identify the possible elements that might play this role in the ontology mapping negotiation process.

It is our conviction that this role might be played by the same function and parameters that contribute to determine the correctness and completeness of the semantic bridges in the semantic bridging phase. Reusing the utility function reduces the efforts of Services parameterization and customization, two very human intensive tasks.

The proposed process distinguishes the semantic bridging from the negotiation phase, i.e. both phases occur consecutively. First, each agent performs its own semantic bridging process, generating a valid and meaningful mapping. Afterwards, the set of semantic bridges composing the mapping are subject to negotiation between both agents.

The confidence value evaluated for each semantic bridge in the semantic bridging phase (c_{sb}) is then used as the negotiation value of the semantic bridge, corresponding to the agent confidence in proposing the semantic bridge to the other agent.

Since the goal of the process is to reach consensus, it is important to provide the mechanisms so that both agents are able to propose, reject and revise their understanding of the semantic bridges. In fact, throughout the negotiation, it is important that agents relax their sub-goals in favour of a larger and wider goal. In this sense, the agent should not decide on *a priori* values on the acceptance/rejection of the semantic bridge. Instead, it should admit that certain semantic bridges are neither accepted nor rejected: they are negotiable. Consequently, it is necessary to define confidence categories, so that the agent can judge the semantic bridge pertinence to the mapping and to the interoperability. As a consequence, the rejection threshold borderline (t_r) represented in Table I is insufficient and should be replaced by a multi-threshold approach:

- Mandatory threshold (t_m), which determines the utility function value above which it is fundamental that the semantic bridge is accepted by the other agent.
- Proposition threshold (t_p), above which the semantic bridge is proposed to the other agent.
- Negotiation threshold (t_n), above which the semantic bridge is negotiable.

Therefore, five distinct categories of semantic bridges are defined according to the confidence value and the previously identified thresholds (Figure 1):

- Eliminated semantic bridges (SB^e set) are those that $c_{sb} < t_r$. Eliminated semantic bridges are not even proposed to the user.
- Rejected (not-negotiable) semantic bridges (SB^r) are those that $t_r \le c_{sb} < t_n$. These semantic bridges are proposed to the user but unless he/she changes explicitly its category, they are not negotiated.
- Negotiable semantic bridges (SB^n) are those that $t_n \le c_{sb} < t_p$. It means that the agent confidence in the semantic bridge is sufficient to consider relaxing c_{sb}, but not enough to propose it to the other entity. In successful relaxing cases, the semantic bridge might be accepted. These semantic bridges are further classified as positive and negative gain semantic bridges (see below).
- Proposed semantic bridges (SB^p) are those that $t_p \le c_{sb} < t_m$. It means the agent is confident enough upon the semantic bridge so that it proposes it to the other agent.
- Mandatory semantic bridges (SB^m) are those that $c_{sb} \ge t_m$. The agent is so confident of the pertinence and correctness of this semantic bridge, that the semantic bridge should not be rejected by the other agent.

It is now necessary to provide the mechanisms to the system so that each agent is able to revise its perception of the negotiable semantic bridges. These mechanisms should be embodied in the meta-utility function. This meta-utility function is not yet contemplated in the service-oriented architecture though. The meta-utility function (U) is responsible for the definition of:

- The parameters variation possibilities.
- The priorities over parameters variation.
- The conditions under which the variation may take place.

Through these elements, an updated confidence value is evaluated (c_{sb}^u) for the negotiable semantic bridges that were proposed by the other agent. If $c_{sb}^u \ge t_a$, the negotiable semantic bridge is categorized as tentatively agreed (SB^t). Tentatively agreed semantic bridges are subject of a definitive decision phase.

Since the meta-utility function determines priorities and conditions for the variation of the parameters, it is possible that, for some variations, $c_{sb}^u < t_a$. It is therefore necessary to iterate across the different variation possibilities, following the defined priorities and conditions. In case it is impossible to evaluate $c_{sb}^u \ge t_a$, the semantic bridge is not re-categorized and is therefore rejected.

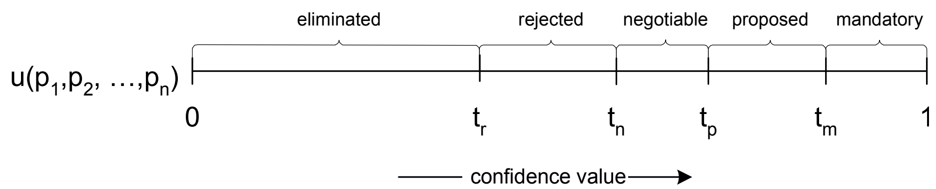

Figure 1- Categorization of semantic bridges according to the utility function and thresholds.

The effort made by the agent to re-categorize a semantic bridge to SB^t varies according to the priorities conditions and values of the parameters. The meta-utility function is also responsible for the evaluation of this effort, named convergence effort (e_{sb}). Two distinct situations may occur:

- Negative gain negotiable semantic bridges, when $e_{sb} > c_{sb}^u$. The convergence effort to accept the semantic bridge is greater than the value of the semantic bridge itself, which reduces the negotiation gain of the agent.
- Positive gain negotiable semantic bridges, when $e_{sb} < c_{sb}^u$. The convergence effort is less than the value of the semantic bridge itself. Therefore, the acceptance of the semantic bridge represents a negotiation gain. These semantic bridges can therefore be interpreted and processed as proposed semantic bridges (SB^p) when the user defines such operating strategy. In case they are redefined as SB^p, they are also proposed to the other agent, which might lead to loss of confidence in the overall agreement.

This convergence effort value is further applied in the definitive agreement phase, as described in the next section.

V. NEGOTIATION PROCESS

The ontology mapping negotiation process is described in this section. It exploits the hypothesis elements introduced in previous sections. This process is composed by five different phases (Figure 2):

- Mandatory semantic bridges processing phase.
- Proposed semantic bridges processing phase.
- Definitive agreement phase.
- Mapping consolidation phase.
- User decision phase.

The set of conversations between the intervenient agents that lead to an/the agreement about an ontology mapping is summarized in Table II, where.

- Failed means that the semantic bridge is rejected and the overall mapping negotiation fails.
- Rejected means that if the semantic bridge is rejected, only the semantic bridge is rejected.
- User means that the decision about an agreement about the semantic bridge is forwarded to the user when the negotiation between the agents finishes.
- Accepted means the semantic bridge is definitely accepted.
- Negotiation means that the semantic bridge is negotiated and in case of success it is conditionally accepted. In case the semantic bridge is rejected by one of the agents, the semantic bridge is conditionally rejected.

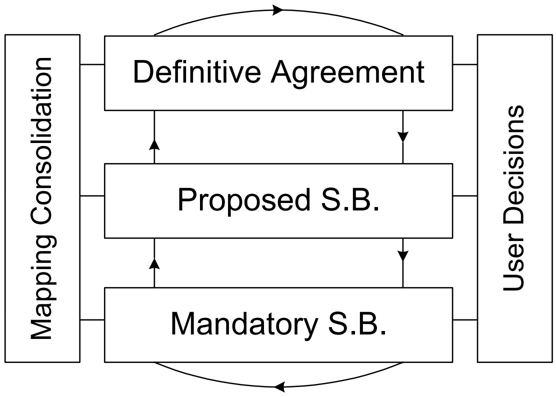

Figure 2- Negotiation Process Phases

A. Mandatory Semantic Bridges Processing Phase

This phase processes every mandatory semantic bridge (SB^m) of both agents. As the name suggests, an agreement should be produced, otherwise the negotiation fails.

Each agent proposes each $sb^m \in SB^m$ to the other agent. Two situations may occur:

- If one sb^m is not accepted by the other agent, the negotiation fails, invalidating any further process.
- If all mandatory semantic bridges from both agents have been accepted (sb^a), it proceeds to the next phase (sb_8 and sb_9 semantic bridges in Figure 3).

B. Proposed Semantic Bridges Processing Phase

In this phase, each agent proposes every $sb^p \in SB^p$ to the other agent. Three situations may occur:

- The semantic bridge is also proposed by the other agent, thus categorized as agreed semantic bridge (SB^a). This situation is represented in Figure 3 by the sb_2 semantic bridge.
- The semantic bridge is rejected by the other agent, and is therefore rejected (sb_6).
- The semantic bridge is proposed to the other agent, which in turn accepts it through the constraint relaxation provided by the meta-utility function. These semantic bridges are then re-categorized as

Table II- Negotiation according to the type of semantic bridges suggested by the two agents.

Agent 1 \ Agent 2	Mandatory	Proposed	Negotiable	Non-negotiable
Mandatory	accepted	accepted	accepted/failed	failed
Proposed	accepted	accepted	negotiation	rejected
Negotiable	accepted/failed	negotiation	user	-
Non-negotiable	failed	rejected	-	-

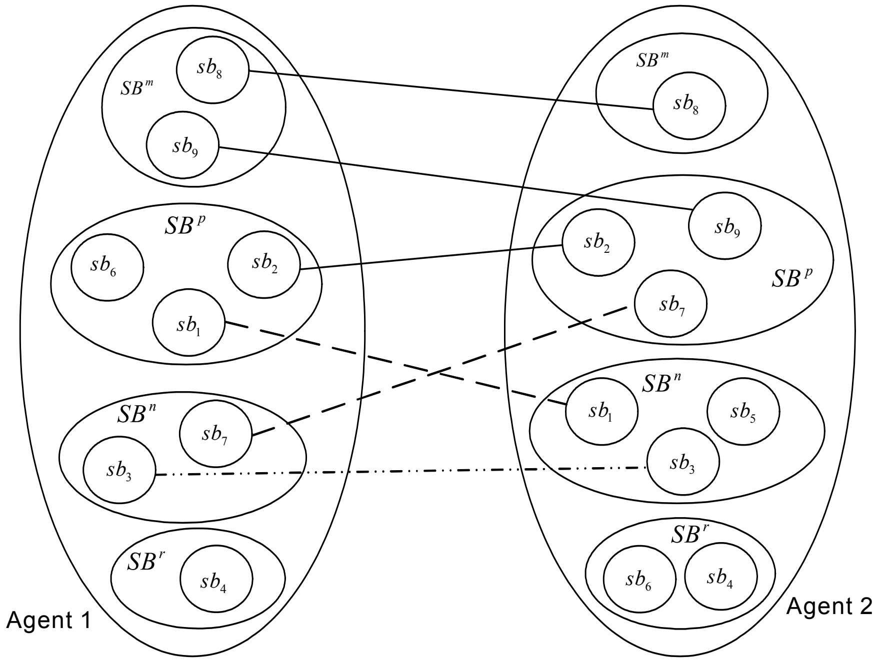

Figure 3- Metaphor of the semantic bridges negotiation process between two agents.

tentatively agreed (SB^t) (e.g. sb_1 and sb_7).

Semantic bridges in SB^t will be further processed in the definitive agreement phase.

C. Mapping Consolidation Phase

This phase is responsible for the correction and improvement of the ontology mapping according to the dependencies between semantic bridges. In fact, in order to make sense, some semantic bridges require other semantic bridges to exist. For example, it does not make sense to specify a semantic bridge between source and target ontology attributes “name”, if no semantic bridge has been stated between the domain concept of those attributes (e.g. person). In that sense, the semantic bridge relating the domain concepts acquires an extra confidence value that might contribute for its negotiation agreement. An opposite situation might occur if the semantic bridges related to a specific semantic bridge have been rejected. In such circumstances, the semantic bridge is affected negatively.

The types of inter-relations between semantic bridges are very dependent on the ontology mapping model used. In the particular case of SBO, besides the inter-relation already defined it includes the relation between semantic bridges relating hierarchical concepts.

D. User Decision Phase

Despite this stage being optional, the hints and decisions given by the user can be very useful for the rest of the process. This stage represents the features and mechanisms of the negotiation process providing the user with the ability to drive the negotiation process according to unspecified requirements. This stage has considerable benefits in the early development stage of the ontology mapping negotiation system, as shown in other approaches [8,9].

Because this stage is orthogonal to the other stages, user decisions directly influence the inputs and outputs of the previous stages. Some examples of user’s tasks are:

- to create, define and customize the negotiation strategy to adopt;
- to re-classify any existing semantic bridge (e.g. $sb_i \in SB^n$ is re-classified in order that $sb_i \in SB^p$);
- to examine the facts that are leading to an imminent negotiation failure, in order to avoid it. The imminent negotiation failure is predicted by the agent which in turn alerts the user;
- to review the facts that have lead to a negotiation failure situation, in order to attempt to recover from it;
- to insert or update a semantic bridge in the initial ontology mapping document, in order to improve the quality, extension or simply correct a semantically erroneous mapping specification;
- to provide additional domain knowledge, supplying complementing reasoning elements to the other stages.

E. Definitive Agreement Phase

The semantic bridges in SB^t are subject to a definitive agreement phase in order to ensure that the proposed agreement is advantageous for both agents.

The process consists in deciding if the achieved agreement is globally advantageous (mapping granularity) and not only locally advantageous (semantic bridge granularity).

It is therefore necessary to combine semantic bridges such that the benefit of both agent and the overall benefits are maximized. Because the combination process might be to long, a heuristic approach is suggested. The alternation heuristic used in the system is very simple but effective:

- One of the agents includes into the agreement its most valuable semantic bridge from SB^t that effectively benefices the agent.
- If the agent overall benefit is positive it passes the control to the other agent, which in turn repeats first step. In case the benefit is less than zero, it repeats first step.
- The process ends when no more tentative semantic bridges exist for any of the agents.

VI. Conclusions

The Service-Oriented Architecture advocates that ontology mapping system capabilities and its supported semantic relations are ultimately dependent on the type of transformations allowed/available in the system. Services represent the transformation capabilities in SBO, in semantic bridging and in the execution system, but the proposed architecture suggests that their capabilities should be expanded to support the requirements of other phases of the process. The hypothesis and the negotiation process introduced in this paper exploit such architecture.

Services are empowered with competencies to negotiate the agreement on semantic bridges previously generated by the same Services. Services are able to revise their perspectives on the previously categorized semantic bridges, providing therefore the ability to relax their constraints in order to agree on a semantic bridge.

Consequently, it is our conviction that this paper will contribute with a set of novelties to the ontology engineering research area:

- The conceptualization of the ontology mapping negotiation problem based on the utility and meta-utility functions.
- The identification of matches as parameters of these functions.
- The service-oriented negotiation process based on the categorization of semantic bridges.

While the negotiation process is relatively simple and the utility functions have already been developed from the semantic bridging process, the major effort consists in configuring and customizing the meta-utility function. Nevertheless, tests are being carried out in parallel with customization, so that effective results are expected in the near future.

Another important open issue is the optimization function, in particular the mechanism to generate the optimal solution that maximizes the agents and the overall negotiation profits. While the alternate heuristic is being used with effective results, it is advisable to experiment other heuristics or approaches.

VII. Acknowledgements

This work is partially supported by the Portuguese MCT-FCT project EDGAR (POSI/EIA/61307/2004).

Many thanks to Ana Moura for the fruitful discussions we had about optimization and heuristics. Thanks to Owen Gilson for his revisions and suggestions to the paper.

VIII. References

[1] Bailin, S. C. and Truszkowski, W.; Ontology Negotiation between Agents Supporting Intelligent Information Management; Workshop on Ontologies in Agent Systems at the 5th International Conference on Autonomous Agents, 13-20; Montreal, Canada; 2001.

[2] Beneventano, D. et al.; The MOMIS Approach to Information Integration; Proceedings of the International Conference on Enterprise Information Systems, 194-198; Setúbal, Portugal; 2001.

[3] Castano, S., Ferrara, A., and Montanelli, S.; h-match: an Algorithm for Dynamically Matching Ontologies in Peer-based Systems; 1st VLDB Int. Workshop on Semantic Web and Databases; SWDB 2003; 2006.

[4] Debenham, J. K.; Managing e-Market Negotiation in Context with a Multiagent System; Twenty First International Conference on Knowledge Based Systems and Applied Artificial Intelligence; Cambridge, UK; 2002.

[5] Ehrig, M., Staab, S., and Sure, Y.; Qom - quick ontology mapping; Third International Semantic Web Conference 3298, 683-697; Hiroshima, Japan; 2005.

[6] Lomuscio, A., Wooldridge, M., and Jennings, N.; A Classification Scheme for Negotiation in Electronic Commerce; Lecture Notes In Computer Science, 19-33; 2001.

[7] Maedche, A. et al.; MAFRA - A MApping FRAmework for Distributed Ontologies; 13th International Conference on Knowledge Engineering and Knowledge Management 2473, 235-250; Sigüenza, Spain; 2002.

[8] McGuinness, D. L. et al.; An Environment for Merging and Testing Large Ontologies; Seventh International Conference on Principles of Knowledge Representation and Reasoning, 12-15; Breckenridge (CO), USA; 2000.

[9] Noy, N. F. and Musen, M. A.; Anchor-PROMPT: Using Non-Local Context for Semantic Matching; Workshop on Ontologies and Information Sharing at IJCAI '01, 63-70; Seattle (WA), USA; 2001.

[10] Resnik, P.; Semantic Similarity in a Taxonomy: An Information-Based Measure and its Application to Problems of Ambiguity in Natural Language; Journal of Artificial Intelligence Research, AI Access Foundation/Morgan Kaufman; 11, 95-130; 1999.

[11] Rosenschein, J. S. and Zlotkin, G.; Rules of encounter - designing conventions for automated negotiation among computers; 1994.

[12] Silva, N. and Rocha, J.; Semantic Web Complex Ontology Mapping; Web Intelligence and Agent Systems Journal, IOS Press; 1, 235-248; 2004.

[13] Silva, N. and Rocha, J.; Multi-Dimensional Service-Oriented Ontology Mapping; International Journal of Web Engineering and Technology, Inderscience Publishers; 2, 50-80; 2005.

[14] Tamma, V., Wooldridge, M., and Dickinson, I.; An Ontology-based Approach to Automated Negotiation; AAMAS 2002 Fourth International Workshop on Agent-Mediated Electronic Commerce, 219-237; Bologna, Italy; 2002.