A Negotiation Model for Ontology Mapping

Cássia Trojahn
Universidade de Évora, UEVORA
Rua Romão Ramalho, 59, Évora, Portugal
cassia@di.uevora.pt

Márcia Moraes
Pontifícia Universidade Católica, PUCRS
Av. Ipiranga, 6681, Porto Alegre, Brazil
mmoraes@pucrs.br

Paulo Quaresma
Universidade de Évora, UEVORA
Rua Romão Ramalho, 59, Évora, Portugal
pq@di.uevora.pt

Renata Vieira
Universidade do Vale do Rio dos Sinos, UNISINOS
Av. Unisinos, 950, São Leopoldo, Brazil
renata@unisinos.br

Abstract

This paper presents an agent negotiation model for ontology mapping. We consider that different agents working on the basis of particular approaches arrive to distinct mapping results that must be shared, compared, chosen and agreed. Then, the final mapping result must reflect a better solution than individual approaches.

1 Introduction

Ontology mapping is the process of linking corresponding terms from different ontologies. Well-known approaches to the problem can be grouped into lexical [9][6] and semantic and structural ones [1][8], as terms may be mapped by a measure of lexical similarity or they can be evaluated semantically, usually on the basis of one lexical database, thesaurus or similar semantic oriented linguistic resources. However even in the same group of approaches, different approaches are abundant in the literature.

Given the nature of the problem and the variety of proposed solutions, we present here an agent negotiation model for ontology mapping. We consider that different agents working on the basis of particular approaches arrive to distinct mapping results that must be shared, compared, chosen and agreed. Then, the final mapping result must reflect a better solution than individual approaches.

This paper is structured as follows. The section 2 comments on cooperative negotiation. Section 3 introduces the ontology mapping approaches. Section 4 presents our agent negotiation model and comments our initial experiments. Finally, section 6 presents the final remarks and the future works.

2 Cooperative Negotiation

Negotiation is a process by which two or more parties make a joint decision [11]. The basic is reaching a consensus. Negotiation usually proceeds in a series of rounds, with every agent making a proposal at each round [10]. The process can be described as follow [4]. One agent generates a proposal and others agents review it. If some other agent does not like the proposal, it rejects the proposal and might generate a counter-proposal. If so, the others agents (including the agent that generated the first proposal) then review the counter-proposal and the process repeats. It is assumed that a proposal becomes a solution when it is accepted by all agents.

Cooperative negotiation is a particular kind of negotiation where agents cooperate and collaborate to obtain a common objective. This kind of negotiation has been currently adopted in resource and task allocation fields [7][11]. In these approaches, the agents try to reach the maximum global utility that takes into account the worth of all their activities. Differently from what is found in literature, in our approach the cooperative negotiation is a way to agents negotiate on a final mapping that is the result of different ontology mapping approaches.

3 Ontology Mapping Approaches

The approaches for ontology mapping varies from lexical (see [9][6]) to semantic and structural levels (see[1]). In the lexical level, metrics to compare string similarity are adopted. One well-known measure is the Levenstein distance or edit distance [5], which is given by the minimum number of operations (insertion, deletion, or substitution of a character) needed to transform one string into another.

The semantic level considers the semantic relations between concepts to measure the similarity between them, usually on the basis of one lexical database (e.g, WordNet[1]), thesaurus or similar semantic oriented linguistic resources. This kind of mapping is complementary to the pure string similarity metrics. There are cases where string metrics fail, identifying high similarity between strings that represent completely different concepts (e.g., the words "score" and "store", represent different concepts, but the Levenstein metrics is 0.68). Moreover, it is not uncommon works exploring the semantic-structural levels[1]. In the structural level, the positions of the terms in the ontology hierarchy are considered, i.e, terms more generals and terms more specifics are also considered as input to the mapping process.

Given the nature of the problem and the variety of mapping approaches, we propose an agent negotiation model for ontology mapping, where agents use lexical and semantic approaches to mapping terms of two different ontologies and they negotiate on a final mapping result. We understand that this result should reflect a better solution when compared to the solutions of individual agents.

4 Our Negotiation Model

4.1 Organization of the Agents Society

We describe our model according to an agents society (Figure 1), using the Moise+ model[3]. This model proposes three dimensions for organizations of agents society: structural, functional and deontic. This paper focuses on the first dimension, presenting the structure specification for the organization of the proposed agents society. According to [3] and [2], structural specification has three main concepts, roles, role relations and groups that are used to build, respectively, the individual, social and collective structural levels of an organization. The individual level is composed by the roles of the organization. A role means a set of constraints that an agent ought to follow when it accepts to play that role in a group. The following roles are identified in the proposed organization: (a) mediator, responsible for mediating the negotiation process, sending and receiving messages to and from the mapping agents; (b) mapper, responsible for giving an output between two ontology mappings (i.e, one mapper could assume the role lexical or semantic).

In the social level are defined the kinds of relations among roles that directly constrain the agents. Some of the possible relations are: (a) acquaintance (acq), where agents playing a source role are allowed to have a representation of the agents playing the destination role (i.e, source role mediator and the destination role mapper); (b) communication

[1]http://www.wordnet.princeton.edu

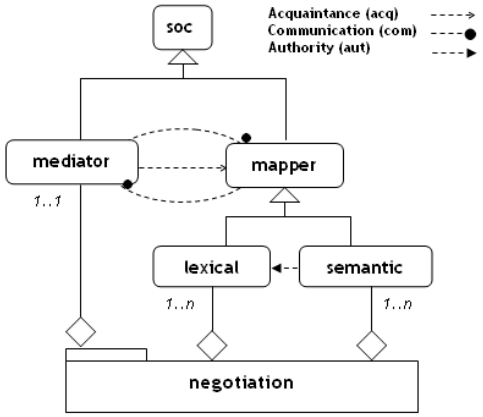

Figure 1. Organizational model.

(com), where agents playing a source role are allowed to communicate with agents that playing the destination role (i.e, source role mediator and the destination role mapper); (c) authority (aut), where agent playing a source role has authority upon agent playing destination role (i.e, source role semantic and the destination role lexical).

The collective level specifies the group formation inside the organization. A group is composed by the roles that the system could assume. A group can have intra-groups links and inter-groups links. The intra-group links state that an agent playing the link source role in a group is linked to all agents playing the destination role in the same group. The inter-group links state that an agent playing the source role is linked to all agents playing the destination role despite the groups these agents belongs to [3]. Links intra-group are represented by a hatched line and links inter-groups are represented by a continue line. This specification defines only a group called negotiation and all links are intra-group.

4.2 Negotiation Process

The negotiation process involves two phases. First, the agents work in an independent manner, applying a specific mapping approach and generating a set of negotiation objects. A negotiation object is a triple O = (T1,T2,C), where T1 corresponds to a term in the ontology 1, T2 corresponds to a term in the ontology 2, and C is the mapping category resulting from the mapping for these two terms. Second, the set of negotiation objects, that compose the mapping is negotiated among the agents. The negotiation process involves one mediator and several mapping agents.

In order to facilitate the negotiation process (i.e, reduce the number of negotiation rules), we define four mapping categories according to the output of the mapping agents. Table 1 shows the categories and the corresponding mapping results. The output of lexical agents is a value from

the interval [0,1], where 1 indicates high similarity between two terms (i.e, the strings are identical). This way, if the output is 1, "a mapping with certainty" is obtained. If the output is 0, the agent has a "not mapping with certainty". A threshold is used to classify the output in uncertain categories. The threshold value can be specified by the user.

The semantic agents consider semantic relations between terms. Considering the WordNet database, relations such as synonymous, antonymous, holonym, meronym, hyponym, and hypernym can be returned. According to the mapping categories, synonymous terms are mapped with certainty; terms related by holonym, meronym, hyponym, or hypernym are considered mapped, but with uncertainty; when the terms can not be related by the WordNet (the terms are unknown for the WordNet database), the terms are not mapped, but with uncertainty. We do not consider the antonym relations because terms such as "hot" and "cold" can be related by ancestor terms, such as temperature, and we are not still considering the ontology structure.

Table 1. Mapping categories.

Category	Lexical	Semantic
Mapping (certainty)	1	synonym
Mapping (uncertainty)	$1 > r > t$	related
Not mapping (uncertainty)	$0 < r <= t$	unknown
Not mapping (certainty)	0	

The negotiation process starts with the mediator agent asking to the mapping agents for its number of "mappings with certainty". The first mapping agent to generate a proposal is one that has the greatest number of "mappings with certainty". The proposal contains the first negotiation object that still wasn't evaluated by the agent. This proposal is then sent to the mediator agent, which sends it to others agents. Each agent then evaluates the proposal, searching for an equivalent negotiation object. One negotiation object is equivalent to another when both refers to equals terms which are being compared in the two ontologies.

If an equivalent negotiation object has the same category, the agent accepts the proposal. Otherwise, if the agent has a different category for the compared terms in the negotiation object, its object negotiation is sent as a counter-proposal to the mediator agent, which evaluates the several counter-proposals received (several agents can send a counter-proposal). The mediator selects one counter-proposal that has the greater number of vote. If two categories receive the same number of votes, the category indicated by the semantic agent is considered a consensus.

When a proposal is accepted by all agents or a counter-proposal consensus is obtained (through voting), the mediator adds the corresponding negotiation object in a consensus negotiation set and the mapping agents mark its equivalent one as evaluated. The negotiation ends when all negotiation objects were evaluated.

Figure 2. Onto 1.

Figure 3. Onto 2.

4.3 Experiments

We applied our model to defined mappings that link corresponding class names in two ontologies related to bibliography domain (Figure 2 and Figure 3).

The lexical agents were implemented using two string distance measures: edit distance (Levenstein measure) and substring distance. The substring distance is a variation of the former, considering the substring distance between two strings. We used the algorithms available in the API for ontology mapping (INRIA)[2] (EditDistNameAlignment and SubsDistNameAlignment, respectively).

The semantic agent uses the JWordNet API[3], which is a interface to the WordNet database. For each WordNet synset, we retrieved the synonymous terms and considered the hypernym, hyponym, member-holonym, member-meronym, part-holonym, and part-meronym as related terms.

The threshold used to classify the output of the mapping agents was 0.6. For the evaluation purpose, we considered for each individual agent the number of "mappings with certainty" and the number of "not mappings with certainty", considered as corrects and not corrects, when evaluated by a human specialist. We compared these results with the negotiation output (see Table 2).

The substring distance agent obtained better performance that edit distance agent, having as output only one incorrect mapping. Only using lexical agent is not sufficient to obtain all corrects mappings – these agents are not able to identify the reference- citation and dissertation-thesis mappings, considered as corrects in our ontology. The negotiation result is better than the results obtained by individual lexical agents applying string metrics similarity.

The semantic agent had better performance that lexical agents, identifying all correct mappings considered as corrects in our ontology. However, this agent does not identify "not mappings with certainty" because we consider that when this agent does not have corresponding entries for the searched terms (or the terms are antonymous) it return "unknown" (see Table 1).

[2]http://alignapi.gforce.inria.fr

[3]http://jwn.sourceforge.net (using the WordNet 2.1)

Table 2. Comparative results.

	Category	Total	Correct	Incorrect
Edit distance	Mapping	4	4	0
	Not mapping	30	28	2
Substring distance	Mapping	4	4	0
	Not mapping	30	29	1
WordNet	Mapping	6	6	0
	Not mapping	0	0	0
Consensus	Mapping	5	5	0
	Not mapping	28	27	1

The consensus had similar result when compared with the semantic agent in number of correct mappings. Then, other kinds of semantic agents must be explored. However, the consensus identified "not mappings with certainty", differently from semantic agent, which did not identify this kind of mapping. In the voting process, the lexical agents obtain consensus in the mapping category "not mapping with certainty".

The results are detailed in the following. The edit distance agent identified incorrectly two "not mapping with certainty" (reference-citation and thesis-dissertation) and two "mappings with uncertainty" (reference-dissertation and thesis-citation). For the substring distance agent, one "mapping with uncertainty" (reference-conference) and one "not mapping with uncertainty" (thesis-dissertation) were identified. Differently from the former agent, only one "not mapping with certainty" was identified incorrectly (reference-citation). The WordNet agent identified the two correct mappings, not identified by the lexical agents (reference-citation, thesis-dissertation mappings).

Finally, in the negotiation consensus, differently from semantic agent, the correct mapping between reference and citation terms did not identify. This occurs because the two lexical agents vote in the "not mapping with certainty" category for these terms. Moreover, two "not mappings with uncertainty" were obtained (thesis-citation and reference-dissertation, i.e., as lexical agents vote in distinct categories, the semantic agent decides the final category).

5 Final Remarks

This paper presented an approach on ontology mapping negotiation, in which agents are able to achieve consensus about their individual mapping results. As our ontology is very simple, the negotiation process resulted in a consensus similar to the semantic agent output. However, the negotiation result is still better than the results obtained by individual lexical agents applying string similarity metric. We believe that this improvements in the results will show for larger ontologies. Moreover, some aspects must be considered. First, we used very simple string similarity metrics. Second, others domains needed to be evaluated to confirm our initial results. Third, structural agents can be explored to obtain a better mapping.

In the future, we intend to apply others string similarity metrics; compare the initial results with that obtained from others ontologies; and add to our model semantic agents based on ontology structure. We intend also to consider the ontology's application context in our mapping approach.

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