Towards Multi-Agent Based Solution for Ontology Alignment

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***Abstract* – Ontology alignment is an ontology mapping technique, which is used for sharing and reusing the content of disparate source of ontologies. Aligning dynamic and distributed ontologies turn out to be a research challenge for many decades. This paper discusses the complexity of the ontology alignment process and presents some major tools that have been developed to support knowledge engineers. Then, we discuss how the agent technology can be used to align dynamic ontologies in distributed environments. Our solution is inspired by how group of people communicate, negotiate, and coordinate to reach common agreements.**

Index Terms - Autonomous Agents, Multi Agent Systems, Ontology Alignment

1. Introduction

Ontology is defined as an explicit specification of concepts, objects, and other entities that exist in a particular domain, and the relationships among them [1]. It can be any source of knowledge in any format such as databases, web sites, xml files, text files, images, computer programs etc. Ontologies are becoming popular as a way of representing structured knowledge. They provide a shared understanding of domain knowledge between heterogeneous applications. This formalization makes ontologies machine-processable and hence, they have been the key element in emerging semantic web technology [2].

Ontologies are used extensively to model any information system and they are developed in a de-centralized and collaborative approach. As a result, ontologies could contain similar and overlapping content. Thus, there is a high demand for sharing and reusing the knowledge in these distributed ontologies. The most difficult part of the sharing process is the mapping between different ontologies. The term ontology mapping is used in a broad meaning that consists of integration, merging and alignment [3].

The idea of ontology integration is to generate a single ontology from different ontologies covering different subjects. However, these subjects may be inter-related. After integration, only the integrated ontology is continued. Ontology merging generates a single, coherent ontology from different ontologies related to the same subjects. Original ontologies cover similar or overlapping domains and after merging, original ontologies are discontinued. The ontology alignment is used to establish links between existing ontologies. Usually, alignment is performed when original ontologies cover domains that are complementary to each other. After alignment, original ontologies continue with newly established links.

For most of the applications, it is important them to maintain their own ontology locally, even when its content is shared with other applications. Thus, ontology alignment becomes beneficial for sharing contents of such ontologies. Automating the ontology alignment process is a challenge, as when the original ontologies are evolving, we should also update the established links between them.

We believe that, this challenge could be overcome by enabling communication, negotiation, and coordination between ontologies. The multi agent system technology is the best known problem solving approach in de-centralized and dynamic environments. Communication, negotiation, and coordination are the core features of a multi agent system [4]. Our proposed solution uses the multi agent technology to automate the ontology alignment process.

The rest of this paper is organized as follows. Section 2 discusses the existing solutions for ontology alignment. Section 3 illustrates the key problems we have identified in ontology alignment process. Section 4 presents our proposed solution and finally, the last section shows the summary of our work.

2. Existing Solutions for Ontology Alignment

Various ontology alignment systems have been developed to support knowledge engineers. These systems are classified ino categories such as frameworks, methods and tools, translators, mediators, techniques etc… [5]. These systems use combination of similarity measures of string based, linguistic based, and structural based matchers to compare the overall similarity between entities in different ontologies. Some systems are automated, while others need some input from knowledge engineers occasionally. Although it was common to find literature with ontology alignment systems, not much attention has been given to the integration of ontologies.

Noy and Musen have developed a series of ontology alignment tools, including PROMPT [6] and PROMPTDIFF [7]. All these tools are available as plugins to the protégé ontology development environment. Sadaqat and colleagues have developed a system that uses rough sets for ontology alignment [8]. IF-Map system is developed by Kalfoglou and Schorlemmer to automate the ontology alignment using the information flow theory [9]. Detailed explanations of these systems can be found as follows:

PROMPT

Some ontology alignment systems try to semi-automate the alignment process by considering the similar class names and suggesting users to manually link them. But, PROMPT is a semi-automated tool that goes beyond the class name matching as it also considers linguistic similarities of the class names. It creates initial list of linguistic similarities by determining different parameters such as synonymy, shared substring, common prefixes, common suffixes etc. Once an action is performed, it updates the initial list by considering the structure of relationships of merged concepts as well.

An interesting feature of the PROMPT is that its custom tailoring behaviour. It allows users to select a preferred policy to handle conflicts in advance. Users could choose their own preference and then, the system operates based on their choice. PROMPT allows users to select an ontology as the stable ontology and other ontologies are aligned around the stable ontology. The system makes sure that it applies minimum modifications to the stable ontology. We believe that this approach is close to the real world scenarios, where the person with highest domain knowledge gets more attention.

PROMPT is one of the earliest systems that was developed to ontology alignment automation and it is one of the milestones in ontology alignment research. It is based on the frame-based knowledge model and designed to be compatible with Open Knowledge Base Connectivity (OKBC) [10]. Thus, it could only operate on OKBC frameworks. In Fig. 1, we present the flow of the PROMPT algorithm.

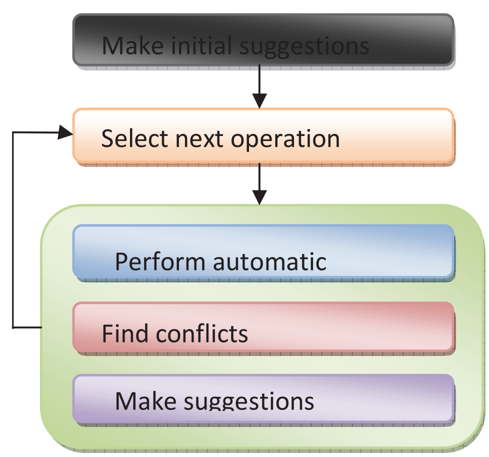


Fig. 1: The flow of PROMPT algorithm. (Source: [6])

The main steps of the PROMPT approach are making the initial suggestions, selecting the next operation, performing the automatic updates, finding the conflicts and making suggestions. Users have to select the next operation manually. System suggests set of possible actions and then based on the users input, the system performs them autonomously.

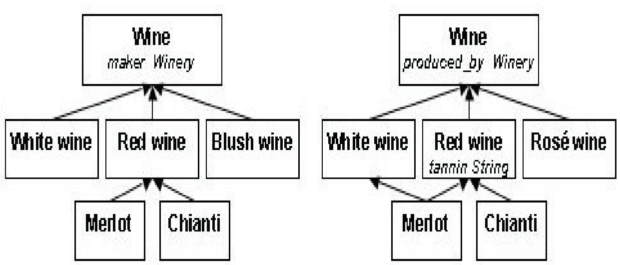
PROMPTDIFF

PROMPDIFF is an ontology versioning system to address the issues in large scale ontology development projects. As ontology development is a distributed and collaborative approach, the authors argue that there should be a versioning mechanism to monitor the ontology development. PROMPTDIFF is similar to the tools that are available for managing versions of software codes such as CVS or SVN.

The PROMPTDIFF algorithm consists of two parts: an extensible set of heuristic matchers and a fixed-point algorithm to combine the results of the matchers to produce a structural difference between two versions. Each matcher employs a small number of structural properties of the ontologies to produce matches. The fixed-point step invokes the matchers repeatedly by feeding the results of one matcher into the others until they produce no more changes.

Similar to the PROMPT tool, the PROMPTDIFF is also based on the frame-based knowledge model and it is designed to be compatible with Open Knowledge Base Connectivity (OKBC) [10].

In Fig. 2, we include an example of using PROMPTDIFF. There are two versions of wine ontology. The first one, at the left-hand side of Fig. 2(a), has a class Wine with three subclasses namely; Red wine, White wine, and Blush wine. The class Wine has a slot maker whose values are instances of class Winery. The class Red wine has two subclasses; Chianti and Merlot. The second version, at the middle of Fig. 2(b) has changed the name of the maker slot to "produced_ by" and the name of the Blush wine class to "Rose wine". There is also a tannin level slot to the Red wine class and Merlot is also a subclass of White wine. At the right-hand side of Fig. 2(c), PROMPTDIFF has found automatically the differences in these two versions of ontology wine. The map level rightmost column in that table indicates whether the matching frames are different enough from each other to warrant the user's attention. There are three types of mapping level defined; unchanged (nothing has changed), isomorphic (images of each other), and changed (they are not images of each other). For example, the Red wine class has changed; it has a new slot (tannin level).



(a) (b)

f1	f2	renamed	operation	map level
	S tannin level	No	Add	
C Blush wine	C Rosé wine	Yes	Map	Isomorphic
S maker	S produced_by	Yes	Map	Isomorphic
C Chianti	C Chianti	No	Map	Isomorphic
C Merlot	C Merlot	No	Map	Changed
C Red wine	C Red wine	No	Map	Changed
C White wine	C White wine	No	Map	Changed
C Wine	C Wine	No	Map	Isomorphic
C Winery	C Winery	No	Map	Unchanged

(c)

Figure 2 An Example of PROMPTDIF Algorithm (source [7])

The PROMPTDIFF algorithm works on two versions of the same ontology and is based on the empirical evidence that a large fraction of frames remains unchanged and that, if two frames have the same type and the same or very similar name then, one is almost certainly an image of the other.

Ontology Alignment Using Rough Sets

This system automates the ontology alignment process using rough sets. The authors argue that the main challenge in ontology alignment is that the uncertain entities are neither completely similar nor dissimilar. An automated solution is presented to overcome this challenge by the authors.

It uses combination of similarity measures of string based, linguistic based, and structural based matchers to compare the overall similarity between entities in different ontologies. String based matchers consider the string similarity between two entities. They use Smoa algorithm to measure the string similarity [11]. Linguistic based matcher users WordNet [12] to compute the linguistic similarity. Structural based matcher performs by analyzing super-class, sub-class relationships. Authors believe two entities that have similar super-class or sub-class relationships are most likely to represent the same concept.

If the similarity measures give exact match, those entities are selected as alignment candidates. But if the matchers are inexact, the results are normalized into the nearest decimal values and stored with corresponding entities. Then, the system uses rough sets to classify the similar entities by defining their matching results as attributes of the rough set. Fig. 3 shows the overall ontology alignment process.

The authors have evaluated their system by comparing it with some of the existing ontology alignment systems. The results show that this approach has achieved a better recall value, while the precision is also comparable with other systems.

IF-Map

IF-Map algorithm is based on the Barwise-Seligman theory of information flow. The algorithm provides a systematic and mechanized way of deploying the proven information flow theory on a distributed environment to perform ontology alignment. Authors assume that local ontologies are used by different communities and they are populated with instance data. Their algorithm generates a reference ontology "on the fly" with the agreed understanding of sharing the local knowledge. This reference ontology is not supposed to use to create instance data. This approach is inspired by the Kent's virtual ontology of community connections.

Fig. 4 illustrates the process of IF-Map. It consists of four major steps; (a) ontology harvesting, (b) translation, (c) information generation, and (d) display of results. During the harvesting step, the system acquires different ontologies by using existing ontologies, downloading from ontology libraries, downloading from the web etc. This step results in a variety of ontology formats. The examples are RDF, OWL, and Prolog etc… The

next step is to translate these formats into a common format. IF-Map executes its logic in prolog engine, and hence, it translates all above formats to Prolog clauses. The next step is the main alignment process.

The system provides a web interface to access the results from the web. They also provide an API to other systems to access their algorithm. Finally, the system presents its output in RDF format.

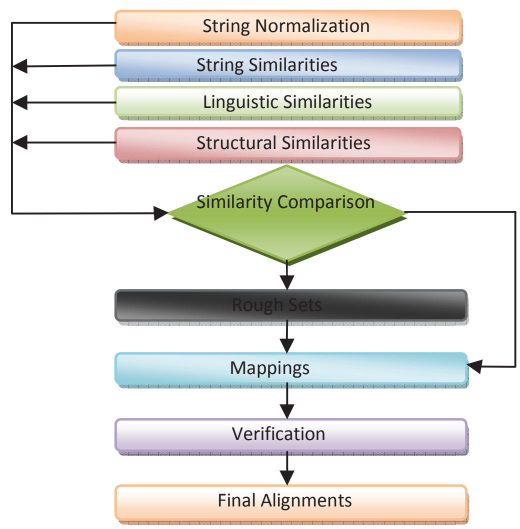


Fig. 3: Ontology Alignment Process (Source: [8])

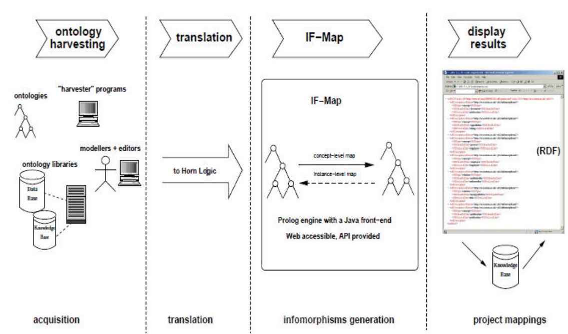


Fig. 4: The IF-Map architecture (Source: [9])

3. Key Challenges in Ontology Alignment

The systems we discussed in the previous section are inspired by different theories such as information flow, rough sets etc. The empirical evidence shows that these systems are successful to some extent. But, one important aspect of ontology alignment is to facilitate the evolvability of the different ontologies during and after the alignment process. Most of the systems that are available today, could not handle such complexity as they perform the alignment in one step process. We believe this approach was correct during early days, when the focus of the ontology alignment research was to simply automate the ontology alignment process.

But in future, our challenge is to develop new approaches and mechanisms to maintain the links between evolvable ontologies. These systems should be able to frequently update the links between ontologies to reflect the changes in original ontologies. Thus, the new approach should be a continuous process.

4. Multi-Agent based Approach

We believe automating the process of ontology alignment can be inspired by how group of people reach common agreements in a group discussion. Typically, different people have different point of views about the same concept, but they communicate, negotiate and coordinate to reach in common agreements. The person with highest domain knowledge will get more attention in the discussion. This may result in some people changing their beliefs, adjusting their ideas etc. However, with time, group member's knowledge about that particular subject may evolve. This could cause the group to reassess their original decisions and sometime to completely change them.

Our primary hypothesis is that, ontology alignment can be solved using multi agent technology in the manner of communication, negotiation and coordination in a group discussion.

Our inputs are set of dynamic ontologies and as the output we generate links between these ontologies. The process of establishing these links is continuous process, which will be based on multi agent system approach.

The Multi agent system is a group of agents that operates by passing messages among them to achieve a certain goal. This is a model of team work. More importantly, the intelligence appears to be an emergent feature of a multi agent system.

Our multi agent system will be developed based on Request-Resource-Message Space-Ontology architecture. Fig. 5 is a top level view of our proposed system architecture.

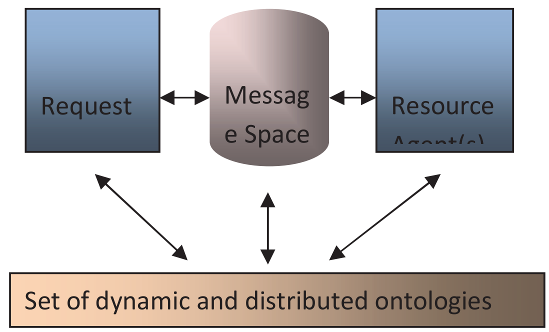


Fig. 5: Proposed System Architecture

5. Summary

In this paper, we discuss different ontology mapping techniques with more emphasis in ontology alignment. Then, we present some major ontology alignment tools and discuss each approach in detail. In our discussion, we discovered that the current systems are able to automate the alignment process at a considerable level. But, these systems are not much useful when the original ontologies are evolving. Therefore, we have presented a multi agent based novel approach to establish and maintain links between evolvable ontologies.

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