A COMPOUND STRATEGY FOR ONTOLOGIES COMBINING

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Abstract: This article reports our work on a strategy for results aggregation coming from a multi agent system. Each set of results is related to a specific ontology. The application is the organisation analysis of Small and Medium Enterprises (SME). In this context, different Knowledge Bases (KB) are used. Depending on their origin, the different KB may be close, complementary and sometimes contradictory. The proposed approach uses a strategy based on two key ideas. The first one is general and aims at selecting a combining method of ontologies and the second one is focused on the selection and combining of sub-parts of ontologies. The combination of these two strategies should improve the understanding of the results produced by the multi agent system.

1 INTRODUCTION

In recent years, software agents (MAS) have become a well studied and frequently applied technical implementation for distributed systems. In this work, a MAS is used as a multi-experts eco-system for analysis and diagnostic of Small and Medium Enterprises (SME) organization. The targeted system analyzes the management activities of an enterprise and provides suggestions to help address those areas in which it is less successful. To introduce the notion of multiple point of views, each agent is associated to a particular knowledge base (KB) and ontology. This situation implies the production of many pieces of results related to a limited topic. To be well understood by an external user, all the produced results must be aggregated by topic. The aggregation of results raises some issues about combining multiple ontologies.

Section 2 describes the context of these works and the following sections present the problem of aggregation of results associated with related ontologies (section 3). A first draft solution is proposed in the form of an assembled ontology in section 4. Finally, section 5 presents our conclusions and perspectives of future work.

2 CONTEXT

MAEOS is a project on the modelling of the support to the organizational and strategic development of SMEs.

The main objective of MAEOS is to improve the efficiency and performance of business advice to SMEs. To do this, the main part of this work is devoted to the modelling of knowledge coming from management sciences.

Unlike the current trends, which are to create a homogeneous KB covering the domain of a problem, our choice is different. It is to keep to a maximum the plurality of each KB with their field of interest, constraints and richness. The interest and the difficulty of this project are to combine a large variety of sources and origins of knowledge around SME topics.

The targeted knowledge is separated into two kinds of expertise. On the one hand, the theoretical knowledge in the area of change in SMEs (organization, strategy,...) are used as core models and on the other hand, expert knowledge accumulated during practice is used as complementary knowledge.

The main outputs of this project are a set of methods and software tools for analysis and diagnosis of SMEs. The software tools must be able to evolve according to the state of the art on SMEs and, in particular, their administrative or legal environments. In addition, they must also be able to reflect the richness and contradictions inherent to the models coming from management sciences.

To achieve these objectives, a multidisciplinary team was created. Three main research areas are represented: artificial intelligence, software engineering and management sciences. This work involves, therefore, two major points consisting of

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the building of KBs related to SMEs and the implementation of an expert system based on software agents. This part of the project uses three technologies: the ontologies are described with OWL-DL (OWL-DL, 2004), OMV is used for meta-data (OMV, 2007) and the MAS is programmed in Java.

Knowledge bases, in progress, are designed to cover a significant portion of aspects relating to organization and managerial behaviours of SMEs.

An ontological study was conducted with the aim of providing the theoretical foundations necessary for the development. Several ontologies have been studied. Our main sources were the ontology MASON (Lemaignan, 2006), TOVE (Fox, 1992, 1998) and ENTERPRISE (Uschold, 1998). Each knowledge base which we are building is divided into three parts: an ontology, a collection of best practices with facts and/or rules, and meta-data. Later in the project, other KBs will be added to the existing ones. All of them will build sets of SMEs modular models.

The expert system is intended to use the different KBs. It will be an ecosystem of reactive agents (Figure 1). At present, the ecosystem is written in Java and is not complete. Indeed, no direct communication exists between agents. All exchanges are made through a common bag. An agent is associated with a particular KB. Therefore, all agents are characterized by a knowledge field through an ontology, a collection of facts and/or rules and a set of meta-data.

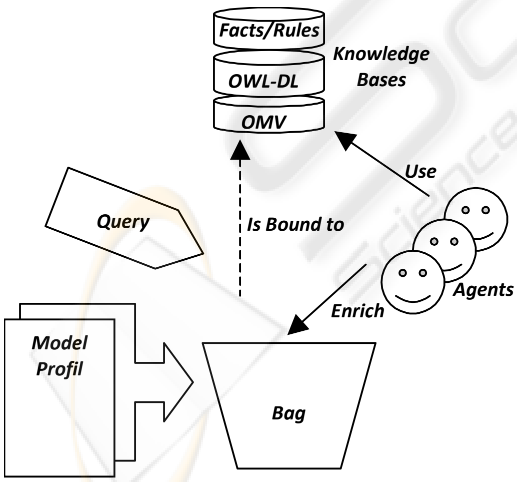

Figure 1: The multi-agents system.

Each agent picks information up in the common bag. It accomplishes its deduction tasks. At the end, it adds the results to the bag. an agent is triggered when there are pieces of information in the common bag matching some of its characteristics. The process is considered as finished when the agents have nothing new to add to the common bag.

3 AGGREGATION OF RESULTS BASED ON ONTOLOGIES

In the context of this ecosystem, our research activities focus on the post-processing of results. The main issue is related to the aggregation of results coming from related domain ontologies. Indeed, the KBs used in this project are limited to SMEs management. Depending on their origin, their contents may be close, complementary and sometimes contradictory.

The current trend is to create a homogeneous ontology covering the domain of a problem. The choice of this project is different. It is to keep to a maximum the plurality and the growth potential of each KB over the process of analysis and diagnosis. The objectives are to address the constraints, on the one hand, related to the expression of the richness and contradictions inherent to the models and, on the other hand, related to the evolution of a MAS and its KB.

Our answer is intended to create local ontologies to the problems. Each set of results from the MAS is supported by an ontology of its own. The main approach is to push the ontology combining as far as possible in the process. This is to keep our goals of multiple point of views.

3.1 Aggregating Results

The aggregation of results based on ontologies requires more than a mere correspondence between terms or parts of models. This is because the production of results is carried out with several facts bases and/or rules and because each of these bases is related to a specific ontology. Each ontology that is used contains its own taxonomy, roles and axioms and is built with an intention and a point of view.

This results aggregation must ensure a coherent semantics. Therefore, it is, at best, the integration of several ontologies into a new one covering all the results. Finally, once aggregated, the results must also be consistent with the facts and rules implemented by the software agents.

3.2 Combining Ontologies

There are many tools and works on ontologies combining (Klein, 2001), (Choi, 2006), (Bruijn, 2006), (Flouris, 2007). Four classes of methods are applicable to the MAEOS problem:

- “Merging” ontologies implies the creation of a new one by linking up existing ones. Each important concept is selected, based on its relevance. There are particular cases, such as the “integration” that is to complement or build an ontology with smaller specific ontologies or the “inheritance” method that uses the notion of a “is_a” relationship to merge several ontologies from the most general to the most specific concept.
- “Mapping” is about building a translation model, via a bijection or not, among ontologies. A special case called “refinement” appears when the atomic concepts of a first ontology have their equivalent in the non-atomic concepts of a second one.
- “Alignment” corresponds to a partial or complete translation of concepts and/or the possible addition of relations in order to create a new ontology from several ones. The operation is called “unification” if the alignment is done on all the concepts of an ontology over another.
- “Mediation” is quite a different class. It uses the idea of negotiation to find the best building compromise for an ontology from several ones.

All these methods cannot always be applied in a systematic and / or automated way. As highlighted by (Noy, 1999), the intervention of an expert may be required.

Some methods, such as the alignment is better suited to a fusion where different ontologies are complementary or have different semantic levels. It is necessary to know the criteria for selecting a combining method as well as the limitations of these methods.

The combining of several ontologies implies, at least, the presence of common or relative conceptual entities in them.

Different criteria can be applied to identify the similarities between two conceptual entities (Maedche, 2002):

- The similarity of terms;
- The similarity of properties;
- The similarity of the entities subsuming or being subsumed.

In real situations, several penalizing cases may appear at different levels. Disparities in the definitions may not only arise at the conceptual, terminological or taxonomy level but also at the syntactic level. Between two close ontologies, it is common to have the same term with different meanings or several terms referencing the same concept. Depending on the ontology author’s viewpoint, several definitions may relate to the same concept. Mismatches among ontologies are numerous. They are summarized in (Klein, 2001), (Visser, 1997) and (Hameed, 2004) with a series of examples (Figure 2).

These differences affect the implementation of the combining methods. The most extreme case happens when disjoint ontologies are considered and makes impossible the application of any combining method. In the case of close ontologies, a choice cannot be made if the degree of similarity among several terms is equivalent (Colomb, 2007).

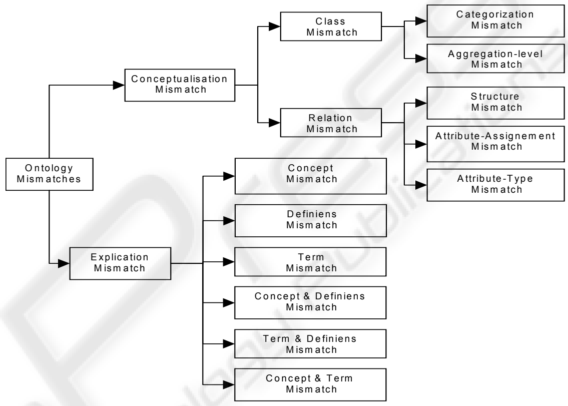

Figure 2: Ontology mismatches taxonomy.

Next, even if connections are established among conceptual entities, there is no guarantee that they will be bijections. Conflicts at semantic level may also appear. Finally, the difference of granularity between ontologies can result in the elimination or aggregation of some entities. It should be noted that the number of mismatches cases increases when ontologies are larger. Different ways should be studied in order to minimise these mismatches.

4 THE AGGREGATION STRATEGY

4.1 A Compound Strategy

For this project, two solutions are combined to reduce the incidence of mismatch in ontologies combining: selecting the combining method and using small size ontologies.

4.2 Method Selection

In general, choosing a combining method for ontologies is a critical issue. It becomes even more problematic if these combinations have to be performed in an automated way. The use of multiple ontologies may be reduced to alignment of parts or a full ontology merging.

A partial alignment may be sufficient in the case of the use of ontologies on complementary knowledge domains or of different semantic levels. Merging is more appropriate if the contents of the ontologies overlap. Finally, in the case where a choice can not be operated in an automated way, there is the mapping solution with a previous work, or the use of mediation. This last method remains complex to implement and is now set aside.

The criteria based on the works of (Flouris, 2007) and (Colomb, 2007) allow the following cases (Figure 3):

- Merging is used when the implemented ontologies are complementary. For two ontologies A and B , merging both of them implies that the two ontologies are treated as sub-parts of a more comprehensive ontology. In other words, ontologies have common parts and distinct ones. The easiest situation is the merging by "inheritance" when the most general concepts of one ontology correspond to more specific concepts of the other.
- Alignment can be achieved when ontologies are close and do not correspond to the merging situation.
- Mapping is used in preparation of merging among multiple ontologies. It is used when the ontologies do not seem to have clear common concepts. Although this technique is very reliable, it requires some previous work.

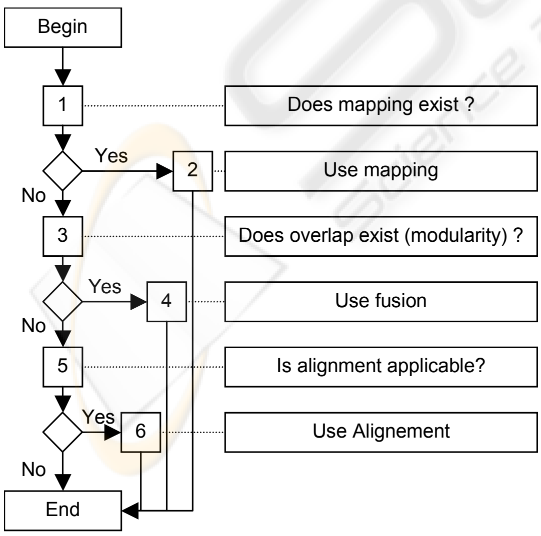

Figure 3: Combining method algorithm.

Finally, in the context of this research work, if no choice can be made, ontologies are not combined.

4.3 The Use of Reduced Ontologies

It is not always possible to be in the best situation for combining ontologies. The size of the ontologies has an important influence on the possibilities of combining: big ontologies are more complex to combine. Indeed, the cases of mismatch are much more frequent if ontologies are important.

Use of small complementary ontologies can facilitate the construction of a more comprehensive one. At best, a solution can be to use modular ontologies or at least, that are possible to be split. The adopted strategy consists in selecting only the necessary concepts for the aggregation of the results.

The objective is to only keep the necessary knowledge for the interpretation of the results supplied by the MAS. This is to facilitate the combining of the ontologies.

The decomposition of ontologies in sub-ontologies seems to be an attractive possibility. However, it supposes several assumptions:

- There are ontologies that are modular or decomposable into partitions
- There exist coherent sub-ontologies
- The number of extracted concepts is sufficient for the combining of the sub-ontologies

And for our system:

- The results produced by the MAS are relative to close concepts
- All the ontologies graphs are single "is-a" trees.

It is evident that these assumptions cannot apply to every combining of ontologies. The context defined by all the produced results is important. This context helps collecting close sub-parts of ontologies around a particular subject.

4.4 Selection of Sub-parts of an Ontology

The basic idea is to extract, from a set of ontologies, the smallest consistent sub-ontologies with a maximum coverage of the concepts used by the results. For that purpose, an algorithm based on the properties of partitioning and modularity of graphs is used.

The algorithm considers an ontology as a semantic network. It treats the network as a directed graph that has nodes as concepts and edges as roles with their properties and their constraints.

It is clear that some characteristics are taken into account in the handling of these graphs. The semantic networks are graphs containing a tree structure related to the taxonomy of the described subject, relationships related to their constraints (transitive, symmetrical…) and to their properties (mandatory, attributes…). Within this framework, the search for a partition in the graph of a semantic network respects certain criteria.

These criteria aim at selecting the concepts intervening in the interpretation of the results and at only preserving a coherent sub-graph. They are expressed as:

- A sub-graph must contain all the necessary concepts to link every part of the result.
- A sub-graph can be extracted if and only if it is connected to the rest of the graph by incident edges.
- A sub-graph must preserve the hierarchy formed by the “is_a” relations.
- Each node must keep its concept definition.

These facts lead to the algorithm in Figure 4.

The first step selects all concepts used by the results. To maintain the consistency, steps two and three extend the selection to sibling concepts.

The second step completes the previous selection with the "is-a" relation tree. The third one adds the shortest mandatory paths between the selected concepts.

The main loop, from step four to step eleven, aims at selecting complementary concepts in relation with the current selection.

Finally, the secondary loop allows enumerating and choosing the necessary relations and neighbour concepts.

The algorithm stops when no concept or no relationship can be selected.

Yet, this strategy has some limitations. On the one hand, the extracted sub-ontology can represent all the ontology in particular cases:

- If the graph is connected or strongly connected. The high number of edges among nodes requires the extraction of a bigger sub-graph.
- If the selected concepts belong to a clique located at the bottom of the “is_a” relations tree.
- If the useful concepts are distributed in a too homogeneous way in the graph. The paths making possible to go from a selected node to another are then more important.

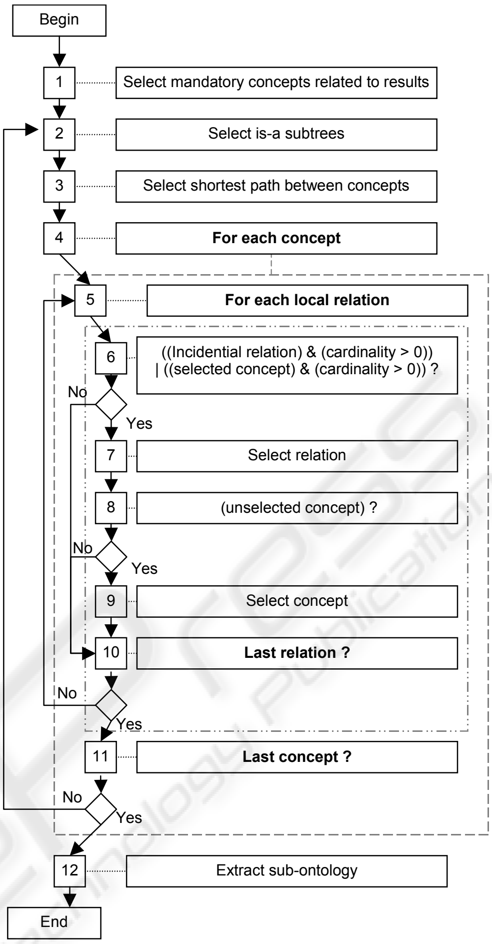

Figure 4: Sub-ontology selection algorithm.

On the other hand, the selected sub-ontology does not necessarily contain all the concepts required to be combined with another ontology. In that case, this sub-ontology must be completed.

This extraction algorithm allows selecting partitions of ontologies. It is integrated in the main aggregation algorithm.

4.5 The Main Algorithm

The strategy of results aggregation aims at producing concise knowledge and at facilitating its interpretation. In the MAS ecosystem of MAEOS, the closeness of the contents of the KBs generates many similar results. For that purpose, it is necessary to be able to combine the whole contents of the bag into groups of homogeneous results.

The proposed algorithm is separated in four steps (Figure 5).

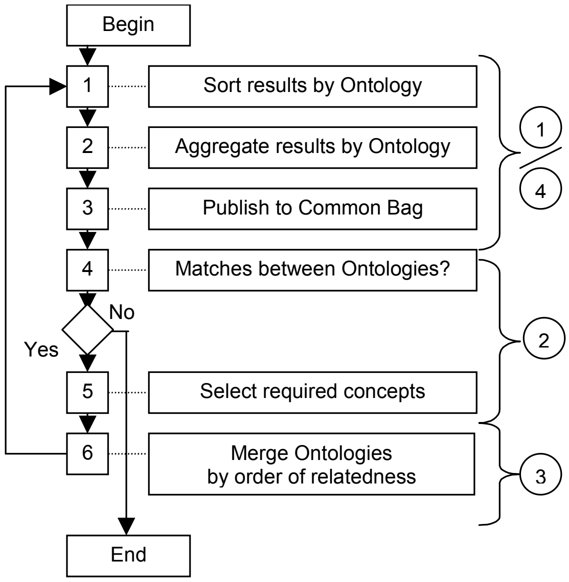

Figure 5: The main algorithm.

The first one aggregates results related to the same ontology. The following one selects the sub-ontology relative to the results. The third one combines sub-ontologies and verifies their validity. And finally, the results are to be aggregated according to the new ontologies.

5 CONCLUSIONS

In this article, we presented an approach for results aggregation coming from multiple ontologies. This approach aims at solving the many limitations resulting from the use of ontologies whose contents are closely related.

The suggested strategy is articulated around two key points: the choice of the combining method and the partitioning of ontologies.

The first tests carried out showed the interest of the approach by sub-ontologies. However, the applied strategies are only efficient on close ontologies with a simple “is_a” relationship tree graph and that are slightly connected or modular.

Our next works will be to improve and expand the selection of sub-ontologies. Indeed, our initial investigations only apply to simple “is_a” hierarchies. To be more robust and versatile, the algorithm must be used on more complex ontologies.

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