Reasoning with Multiple Points of View: A Case Study*

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Abstract. This article presents our approach to reasoning with diversified and voluminous knowledge sources that can eventually be, contradictory. In fact, knowledge sources coming from management sciences are inherently rich and, sometimes, conflicting. We choose to exploit the entire range of this diversity to improve business advice to small and medium enterprises (SMEs).

Keywords: multi-agents system, ontologies, rule-based reasoning.

1 Introduction

One of the major difficulties encountered by the smallest companies, especially today, in a crisis context, is how to manage their evolution. To do so, they need the capacity to perform a global analysis of all their aspects (economic, production, organization, human resources, sales, etc.). They also need to keep the sufficient distance to put this analysis in the perspective of their evolution. Change management becomes a key success factor for many firms facing strong competition.

Very often, the SMEs getting involved in this approach look for the help of consultancy services. In this context, there is a recurrent question that arises: how to access existing knowledge to diagnose the SME while thinking about its evolution.

Here, there are several important aspects regarding knowledge management. The main problem is that the volume of, both theoretical and "expert", knowledge is huge and sometimes, much more detailed than needed. We face a triple issue about knowledge capitalization: structuring to manage large quantities of knowledge, organizing it to permit different access levels, and linking different sources to develop valuable knowledge.

This knowledge management may lead to two different types of results. Firstly, it may allow the consultant and the company to more easily put typical solutions into practice. These solutions may already be known, but they might not have been implemented in the company yet. This fact will allow the company to go further in its evolution, integrating innovation in this way, even if this innovation is minor because it only concerns the company itself. Secondly, efficient knowledge management with the help of reasoning tools might allow the consultant to propose original solutions, thus generating high level innovations, because they are radically new.

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This article is structured as follows: Section 2 presents the project itself along with the ontological framework and the architecture of our development. Section 3 describes an example to show our results in a real industrial case study and, finally, Section 4 presents our conclusions.

2 The Project

MAEOS is a project dealing with the modelling of the organizational and strategic development support of SMEs. The main objective of MAEOS is to improve the efficiency and performance of business advice to SMEs. The whole description of the project can be found at [9].

To achieve this objective, a multidisciplinary team was created. Three main research areas are represented: artificial intelligence, software engineering and management sciences. This work aims at establishing a set of methods and software tools for analysis and diagnosis of SMEs. The software tools will have to evolve according to the state of the art of SMEs and, in particular, their administrative or legal environments. In addition, they must also be able to reflect the richness and contradictions that are inherent to the models coming from management sciences. Finally, they must permit the consultants to access knowledge coming from diverse sources in an efficient and pertinent way.

As presented in the introduction, one of the major difficulties is the manipulation of huge quantities of knowledge. The implementation choices were, therefore, directed by these issues: a multi-agent system[1] or MAS [12] is at the heart of the development, where each agent reasons (following a rule-based approach) with a specific modular ontology.

2.1 Ontological Framework of Our Development

An ontology is a formal explicit description of concepts in a domain of discourse [7]. Associated to an ontology, we may also define a set of rules that will permit reasoning about facts. Rules are expressed as implications.

An ontological study was conducted to provide the theoretical foundations necessary for the development. Several ontologies have been studied.

Our main sources were the MASON [5], TOVE [3], [4] and ENTERPRISE [11] ontologies. Some parts of specific ontologies have also been considered. These ontologies cover different areas such as Professional Learning and Competencies with the ontology of FZI-Karlsruhe [10], organization modelling with UEML-1 [1], or Service Oriented Architectures with the SOA Open Group ontology; among others.

Beyond the use of existing ontologies, we have developed our own about certain relevant fields for our SME context (organization, quality, production, innovation, etc.). Nevertheless, we risk being confronted by a double issue concerning contradictions at the knowledge level: they may appear among different knowledge sources and also within the same knowledge source. It is because of these issues that we have decided to develop separate ontologies and to separately process these two sources of contradictions.

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[1] Like a kind of a committee of experts.

Firstly, we have developed an ontology about the organization models based on the main works of Henry Mintzberg [6]. This ontology integrates the concepts that describe the company structure and models, the relationships among concepts and the restrictions to those concepts according to the company characteristics (its size, for example, which is relevant for this project). We have chosen to use this source because it is a clear reference in the organizations theory field, at least, at the concept level. The works of this author have been widely quoted, commented and refined.

Secondly, we have developed an ontology about production systems based on [2]. This reference is a choice of our industrial partner.

2.2 Architecture of the Multi-Agent System

The system is being implemented as a MAS. Each agent will reason with a specific ontology and the set of associated rules. We use a blackboard for communication among agents (Fig. 1)

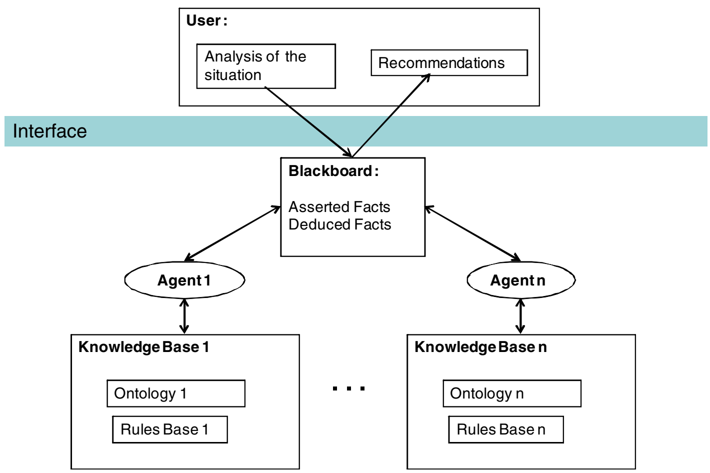

Fig. 1. The MAS system

The user (a consultant, for instance) translates his own situation analysis into "asserted facts" through the interface.

Each agent has the same behaviour: It examines the blackboard to identify the facts corresponding to concepts it knows. In this case, it launches reasoning about these facts and, in the end, it writes the deduced facts on the blackboard.

Finally the consultant uses these deductions to organize them into recommendations.

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 combined, at least, by topic. In previous publications [8], we have presented an approach to aggregate results coming from different ontologies. This approach includes a strategy to solve the many limitations resulting from the use of ontologies whose contents are closely related.

3 Example: An Industrial Case Study

This is a real case study that has been manually solved by our industrial partner. Our goal here is to test if our reasoning approach based on modular ontologies produces the same results or others.

The case study is about a SME whose main activity is metal sheet bending. The initial facts identified by the consultant were about problems in organization and security (for confidentiality reasons we cannot describe the situation more thoroughly). These problems were reflected by the disorganization in work-orders, the chaotic layout, and the misinformation among actors. The situation had begun to cause accidents.

With this situation in mind, we have decided to test the example with only two agents: Agent 1 will reason on the production ontology based on [2]; while Agent 2 will reason on the organizations theory ontology based on [6].

3.1 Initialisation

The first task of the consultant in the company is to have an overview of the situation. This overview is obtained through one or several interviews and permitted us to identify a set of concepts and facts associated to one of our ontologies.

Facts will be expressed as predicates in first order logic. Arguments to predicates are concepts in our ontology. Facts will be written in lower case while concepts will be capitalized.

The analysis of the initial situation of this company led to the following facts:

```
intermittent-production
produce-what-is-sold
small-serial-production
raw-material(Sheet)
delete(Operation-not-generating-Saleable-Value)
```

Both agents examine the contents of the blackboard. Agent 1 is able to identify some of its own facts, so it launches its reasoning tasks. Agent 2 remains stand-by as it does not recognize any asserted fact as its own.

3.2 Operation of Agent 1

The facts identified by Agent 1 allow the identification of the relationships and rules in the production ontology that may be launched to predict plausible evolution, thanks to the inference engine. The initial set of facts permits the launching of the following rules by Agent 1 (see Fig. 2 for the inference tree):

$R_{C1.1}$: delete(Operation-not-generating-Saleable-Value) ⇒
    simplify(Physical-Flow)

$R_{C1.2}$: intermittent-production ⇒
    decrease(Stock) AND
    decrease(Work-In-Process)

$R_{C1.3}$: intermittent-process ⇒ is-difficult(Good-Layout)

$R_{C1.5}$: small-serial-production ⇒ functional-layout

The rules launched by Agent 1 produce new facts that are written on the blackboard.

```
decrease(Stock)
decrease(Work-in-Process)
reactivity
functional-layout (This fact is equivalent to the fact homogeneous-
section-layout[2])
```

We can iterate this process:

- Find rules which can be launched,
- Deduce new facts (for example, `decrease(Delay)` after applying rule $R_{C2.1}$)

When no more rules can be launched by Agent 1, the process is finished and the agent is able to write its final set of deduced facts on the blackboard:

```
decrease(Delay)
decrease(Work-In-Process)
need(Circulation-Graph)
simplify(Product-Flow)
```

3.3 Links between the Ontologies

This first analysis was made with the production ontology only.

But, ontology experts have identified semantic equivalences among concepts and predicates in both ontologies.

For instance, `Reactivity` (defined in the production ontology) is semantically equivalent to `Speed-of-Response` in the organization ontology. Therefore, we can also define semantic equivalence between facts:

```
reactivity ≡ increase(Speed-of-Response)[3]
¬reactivity ≡ decrease(Speed-of-Response)
```

After this first reasoning step, Agent 1 has written the fact `reactivity` on the blackboard. A “translation” agent will be able, then, to write `increase(Speed-of-Response)` and, with this new fact, Agent 2 can begin its work.

3.4 Operation of Agent 2

Agent 2 is able to trigger $R_{M1.1}$:

```
R_M1.1: increase(Speed-of-Response) ⇒ increase(Unit-
        Grouping)AND increase(Behaviour-Formalization)
```

[2] This is because the corresponding concepts `Functional-Layout` and `Homogeneous-Section-Layout` have been defined as equivalent classes in OWL.

[3] A concept is not the same thing as a fact, this is why we have written `reactivity` in lower case, to identify it as a fact or predicate.

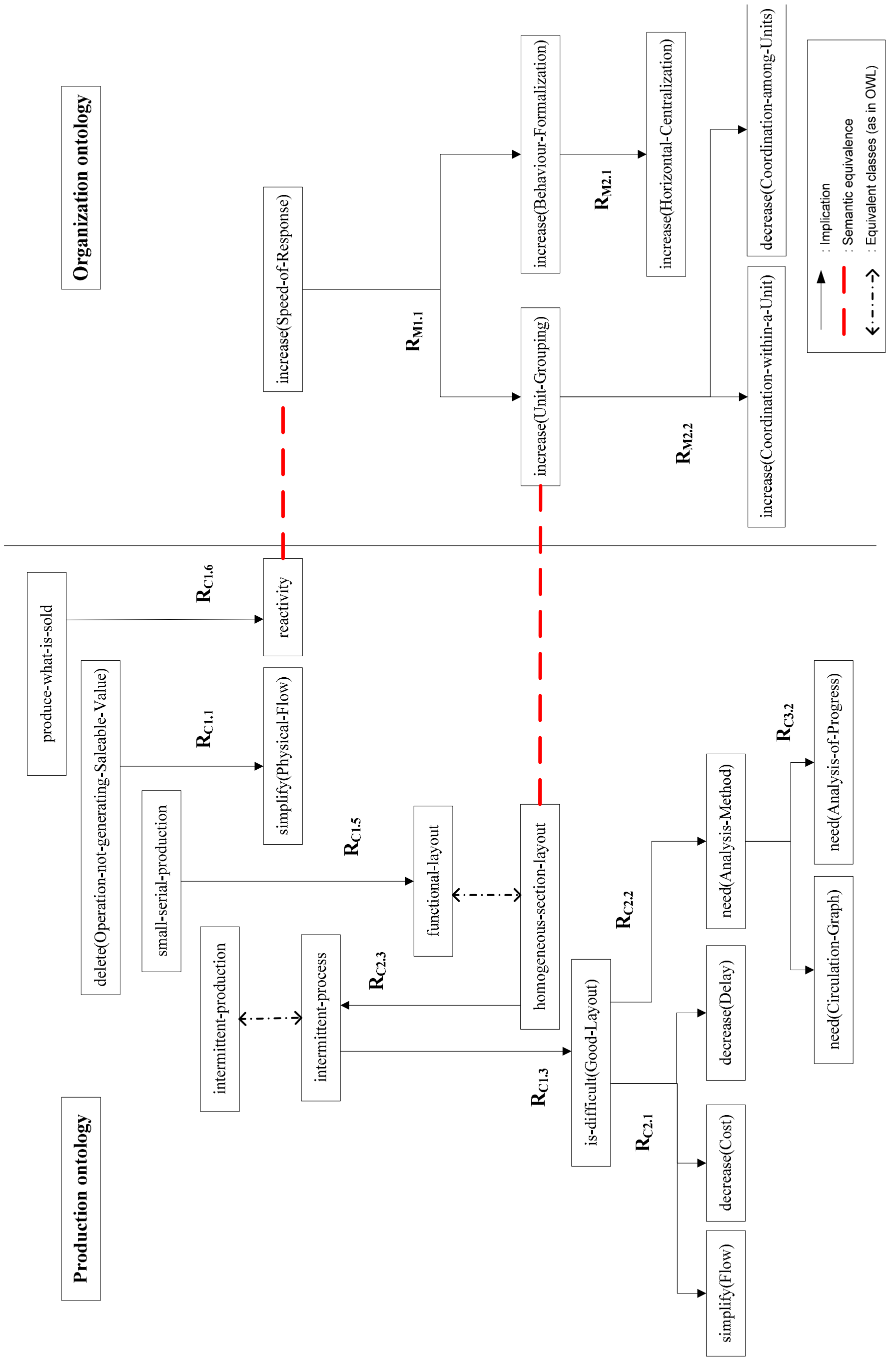

Fig. 2. A sub-set of the inference tree for the agents

This rule leads to the definition of two facts which will be written on the blackboard. There are, then, new rules that can be launched by the agent:

```
R_M2.1: increase(Behaviour-Formalization)⇒
           increase(Horizontal-Centralization)
R_M2.2: increase(Unit-Grouping)⇒
           decrease(Coordination-among-Units) AND
           increase(Coordination-within-a-Unit)
```

The final set of deduced facts by Agent 2 includes:

```
increase(Unit-Grouping)
increase(Behaviour-Formalization)
increase(Horizontal-Centralisation)
increase(Coordination-within-a-Unit)
decrease(Coordination-among-Units)
```

3.5 Aggregation of Results

As explained in Section 2.2, reasoning with multiple ontologies implies the production of many pieces of results related to a limited topic.

The strategy we proposed to tackle this problem [8] is articulated around two key points: the choice of the combining method and the partitioning of ontologies.

In this case study and using these two ontologies, the system has deduced the following set of facts:

```
increase(Unit-Grouping)
increase(Behaviour-Formalization)
decrease(Delay)
decrease(Work-In-Process)
need(Circulation-Graph)
```

The MAS was then able to produce five sets of linked concepts. For each concept in the deduced facts, a close exploration in the ontologies is done, to identify the set of linked concepts to that one.

These sets of concepts are related to the following topics: `Flow`, `Reactivity`, `Type-of-Production`, `Delay` and `Stock`. The use of this strategy of aggregation reduces the number of sets of concepts and adds new ones. The overall number is therefore reduced to two: `Flow`, `"Reactivity / Type-of-Production / Delay / Stock"`. This situation could be further improved by the addition of other instances of concepts. These new instances are suggested to the consultant for identification and validation. The consultant can then choose to extend the number of instances to complement its initial model or restart the MAS with a new query. This fact therefore needs interaction between the system and the consultant. This part of our work is focused on a GUI solution and is currently being evaluated.

3.6 Recommendations

The set of facts after aggregation is at the heart of the report that the consultant will hand to the company.

The case we have described in this example has already been manually processed by our industrial partner without the help of the knowledge based system. We have compared the consultant's conclusions and the system's conclusions.

It is interesting to see that there is a set of proposals common to both reports (`increase(Unit-Grouping)` or `need(Circulation-Graph)`, for instance) but also that the knowledge based system has been able to propose new ideas, such as `need(Analysis-of-progress)`, or `increase(Behavior-Formalization)`. These new propositions have been positively evaluated by the consultant.

Even if this example remains quite simple, the interest of the approach is the use of close modular ontologies to propose new solutions to the consultant and assist him in his work.

4 Conclusions

In this article we have presented our first results about a knowledge-based system to assist consultants in their analysis and diagnosis of SMEs. This system consists in a set of knowledge bases whose contents are heterogeneous and this fact raises several issues.

Firstly, there is the management of knowledge structures and backgrounds. It takes the form of complex cycle phases including acquisition, use and maintenance. There is, also, the manipulation of huge quantities of knowledge by the consultant; his expectation is to obtain innovative solutions with several alternatives coming from the system. Also, as he has to be able to explain his recommendations to his client, he needs to understand the suggestions and analysis provided by the system.

To solve these issues, our approach is to split the different fields of knowledge into smaller modular and homogeneous bases. This approach is supported by the exclusive use of formal ontologies. This point is motivated by the possibilities of manipulation of knowledge and a strict framework imposed by this type of ontology. In this way, we hope to combine the advantages of rigorous knowledge manipulation, adaptability to particular cases and readability of the results.

This approach by close modular ontologies is possible because the ontologies reflect different points of view on the same reality and because these discrepancies among points of view (usual in companies) only question the logical coherence in certain parts of the model. Arbitration among the different points of view will be, in the end, the responsibility of the consultant.

The main objective of our project is to improve the efficiency and performance of business advice to SMEs (and neither to propose solutions to a problem, nor to have the consultant's work done by the software).

To do this, the targeted system aims at providing suggestions to help address those areas in which a consultant is less efficient.

All the suggestions are related to the point of view of an expert; these suggestions may be close, complementary and sometimes contradictory.

To introduce the notion of multiple points of view, each software agent is associated with 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 combined, at least, by topic.

The innovative results come when some parts of these different KBs are combined at the end of an automatic study.

The main interest of our development is the capacity to aggregate results coming from different ontologies or previous case-studies (no matter if the sources are obsolete), as we are more interested in the differences among those sources rather than in the consensual aspects. These differences would lead the consultant to a more thorough reflection about the results.

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