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An approach for evaluating enterprise organizational interoperability based on enterprise model checking techniques

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Abstract: A company manager wanting to choose relevant partners in order to respond rapidly and efficiently to a business opportunity must be confident first on the partners' ability and adequacy, second on their organizational interoperability allowing then to collaborate profitably all along the affair. The aim of this paper is to present an approach allowing this manager to identify potential interoperability problems between partners. This approach is based on the specification of interoperability rules, and on the analysis of these rules on enterprise models by using two complementary formal checking techniques.

1. INTRODUCTION

An enterprise network allows, at least, establishing confidence relationships between partners and provides them opportunity for collaboration during business affairs. In this sense, a manager having to face a customer requirement must, first, choose an appropriate set of partners within the network and second manage their interactions all along the affair life cycle. These partners are selected of course for their ability, skills and competencies, but also for their ability to collaborate rapidly, efficiently and with a good average of money and of quality in order to fulfill the customer needs.

The manager has then several information sources to handle for assessing this choice and assuming it till the customer will obtain the required product or service. Enterprise modeling approaches can then help him to understand and to describe more precisely partner profile, organization, behavior and history. Some expertise or simulations on the obtained enterprise models become then possible in order to guide the choice concerning the competencies or to test the organization behavior. However, it remains difficult evaluating the capability of an enterprise to work in collaboration with its partners without any disturbance inducing loss of money and leading time. This capability is closely linked to the level of organizational interoperability of each partner. This level must be then characterized, situated related to a value scale, analyzed and improved as much as possible.

This paper presents an approach allowing to characterize and to analyze the organizational interoperability of an enterprise within the framework of an enterprise network. This paper is organized as follows. Chapter 2 formalizes the problematic of organizational interoperability. Chapter 3 details then the approach before concluding about some perspectives of evolution of this work. Chapters 4 and 5 go deeper in detail of the Rewriting and Checking phases of the approach.

2. PROBLEMATIC

The interoperability is defined in (IEEE, 1990) as "*the ability of two or more systems or components to exchange information and to use* [without any misinterpretation or loss of sense] *the information that has been exchanged*". It is then considered as a major objective an enterprise must reach in order to being able to cooperate with partners, to share and exchange data with them, to manage efficiently common processes and to propose products and services satisfying customer demand, with a maximized added value and improving performances in terms of cost, quality and lead time.

Three axes of interoperability have been differentiated (EIRR, 2006): semantic (signification of speech, meaning of words, etc.), support (tools, hard and software) and organization. This paper focuses on organizational interoperability. This depends from the structure, the available resources (human, material and application), their abilities and capabilities, the different processes, etc. of each partner involved in the collaboration. It is related to the enterprise practices and then to Enterprise Modeling research works.

Organizational interoperability problems exist because each enterprise is growing and prospering isolated from another. Each enterprise has developed its own organization independently from others. Consequently, a given task may not be processed in the same way in two different enterprises and problems can occur at the cooperation border of these enterprises. Let us notice that enterprise interoperability is concerned with companies' collaboration (inter-company interoperability) but the results presented above may completely be applied within one company (intra-company interoperability).

The problematic is then to evaluate the organizational interoperability level of each partner and to detect rapidly the causes of potential problems which can occur during the cooperation.

3. PROPOSED APPROACH: LINKING ENTERPRISE MODELING AND FORMAL ANALYSIS

The research work, currently under development, intents to provide concepts and formal support for reasoning on enterprise models in order to evaluate and detect organizational interoperability problems between partners. The resulting approach is based on four phases:

- **Modeling**: the first phase is the modeling of the cooperating enterprises and the elaboration of the enterprise model corresponding to the cooperation. The interoperability problems are then modeled in this combined model. In the following, we consider that this phase provides the collaboration model presented now. The Sales Department of a phone manufacturing company is to be collaborating with external and independent Retailers in charge of delivering phones to customers. The collaboration process shown Fig. 1 describes the different required activities and interactions of these partners. The goal is to study the interoperability problems which may occur during this collaboration.

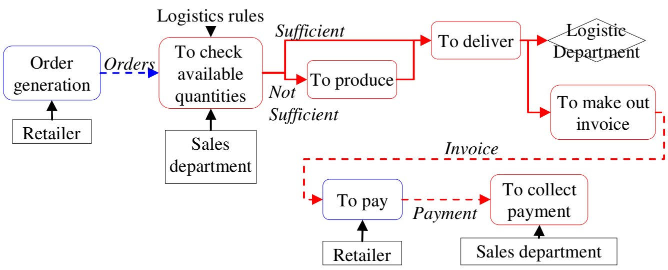


Fig. 1: Collaboration process description

- **Enrichment**: during the second phase, these models are enriched in order to represent organizational elements which are not present in the meta model of the used modeling language. These concepts are however required to analyze organizational interoperability. In fact, most of enterprises modeling languages are conceptual, i.e. they focus on what is processed without giving any information about who does so. However, analyzing organizational interoperability requires this information. Then, it might be necessary to enrich the model by noticing the name of the responsible of an action or a decision (person or service). This allows enriching here the description of the exchanges between different actors.

- **Re writing**: enriched enterprise models checking leads with two main problems. First, many modeling languages exist and are practically used but each language has its own specificities, semantics and constructs. Second, most of modeling languages really used today are semi-formal. This semantic problem of modeling languages and this lack of formalization prevent the use of automated checking mechanisms, procedures and tools. The approach proposes to re write enterprise models based on classical enterprise modeling languages in tiers models based on a formal language. The obtained model, without sense ambiguity, will allow checking formal rules or properties describing interoperability characteristics and requirements. In order to be able to apply two kinds of complementary checking techniques described in the following, the third phase aims at the re writing of the enriched model into two kinds of graphs: simple graph from the Graph Theory and a formal knowledge modeling and analysis language called Conceptual Graphs (Sowa, 1984, Chein *et al.*, 1992).

- **Checking**: The first checking technique consists to check interoperability rules on simple graph such as proposed by (Blanc et al. 2007). This technique allows testing rapidly relevant interoperability problems between partners. It requires enriching the knowledge gathered into each enterprise model before being able to translate it into graphs and the definition of graph analysis rules. The second technique is based on property specification and formal checking mechanisms based on Conceptual Graphs such as proposed by (Kamsu Foguem *et al.* 2004, Chapurlat et al. 2006). It allows identifying more detailed and more complex interoperability problems. This technique requires identifying and specifying formally organizational interoperability properties inspired by interoperability rules proposed in the first approach.

The next sections detail the rewriting and checking mechanisms proposed in the approach.

4. RE WRITING

1. *Graph theory*

The graph theory has been chosen because of its possible generalization to several modeling languages which are often graph-based. It allows representing interoperability nodes where or when exchanges between partners exist, these exchanges being either products or information. Another advantage of using a transformation into graphs is to allow the selection and extraction of the relevant information concerning interoperability from the various enterprise modeling languages. By relevant, we mean the information which concerns only the exchanges inside the perimeter of the concerned project of collaboration. This allows having a clear, sufficient but detailed vision of exchanges.

2. *Conceptual Graphs for interoperability modeling and analysis*

The partners' enterprise models must be taken into account whatever may be the modeling language used for obtaining it, the detail level or the modeler's point of view. This induces to define as formally as possible how these models currently based on different meta models can be interpreted without ambiguity nor loss of sense during the re writing process. Conceptual Graphs are used as described in the following.

A Conceptual Graph is a formal knowledge representation with textual and graphical notation. It is a finite, connected, directed and bipartite graph composed of an alternation of nodes called *concepts* and of nodes called *relations*. A concept is a couple

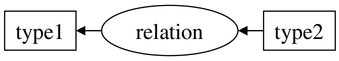
[<type>: <marker>] *or* type: marker

Where:

- type describes the conceptual modeling entity which is handled in the modeling language. For example, type will be Process, Activity, Resource, …
- marker describes an instance of the modeling entity created and handled during the enterprise modeling process. For example, the concept [Resource: 'MachineM1'] shows there exists an occurrence of Resource called 'MachineM1'.

A relation allows describing a link between two types.

[type1]←(relation)← [type2] or



It is oriented and indicates how the destination type is impacted by the source type. It may be then instantiated in order to describe how a concept interacts with another one in the partner's enterprise model. For example, the Resource called 'MachineM1' has a relation called 'transform' with the product called 'P1':

The re writing technique is then the following:

- All the possible types and relations are extracted and formalized by experts during a Formalization Process (FP) illustrated Fig. 3. This process starts from the meta model established in UML of each modeling language. Modeling entities and modeling relations used in the enterprise models are analyzed and compared when necessary with other types coming from other modeling languages. This allows checking the possible ambiguity between equivalents or opposite types. They are then gathered and formalized into hierarchical lattices called respectively concepts lattice and relations lattice. The concepts lattice represents all the possible modeling entities which have to be taken into consideration during the interoperability analysis process (IAP). All the possible relations between concepts are gathered into the relations lattice. This lattice is obtained by translating each relation role between modeling entities of the meta model in a relation between concepts described in the concept lattice.
- Each marker is extracted during a Model Rewriting Process (MRP) (Fig. 3). This generates a unique conceptual graph G by translating simultaneously all the partner enterprise's models in this unique conceptual graph. G gathers then all the knowledge described in these models thanks to the two lattices proposed before. MRP is based on formal rules respecting semantic and structure of the used modeling languages. This rewriting process follows the MDA approach principles (Bézivin *et al.*, 2001; OMG, 2003).

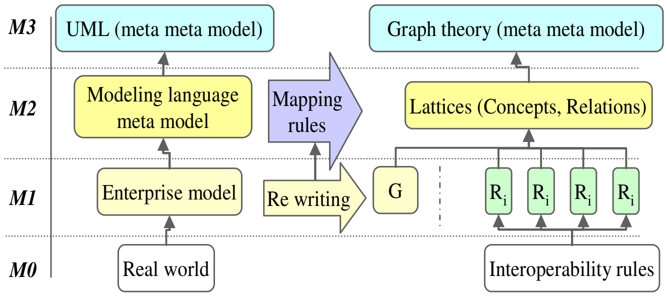


Fig. 2: MRP and RDP illustration

5. CHECKING

1. Simple graphs

A set of rules applicable to the classical graph has been defined in order to detect and evaluate possible interoperability problems. These rules are generic (applicable to all graphs) or specific to one domain and then determined by specialists of interoperability. Five kinds of generic rules have been proposed in (Blanc, 2006, Blanc et al., 2007) to identify:

- The nodes of the graph without return loop,
- Critical nodes (or interoperability bottleneck),
- The longest path in the graph in terms of lead time,
- The path for which the risk of heterogeneity is the most important (path 1) with the highest number of arcs, 2) for which the nodes have the highest number of connections with other nodes of the graph and 3) which has the highest number of exchanges in a fixed lead time, taking into account the period indicated on each arc),
- Where the global management of projects in the global supply chain may be improved.

These rules are generic rules. If needed, specific rules dedicated to given enterprises or collaboration types, must be defined by users. However, they remain too limited in order to detect or to characterize more complex interoperability problems. For example, they may evolve all along the collaboration duration taking into account the dynamic of the collaboration, events coming from the environment, etc. So, the second technique of analysis is proposed in order to complete the information.

2. Conceptual Graphs

First of all, an interoperability rule is modeled as a property (Lamine, 2001) i.e. a constrained causal relation between a cause and an effect. The cause describes the condition under which the rule must be verified. It has to take into account the characteristics (organizational, functional as non-functional ones) of the different modeling entities used in the partners' models in order to describe processes, resources, flows and activities to be carried on during the collaboration.

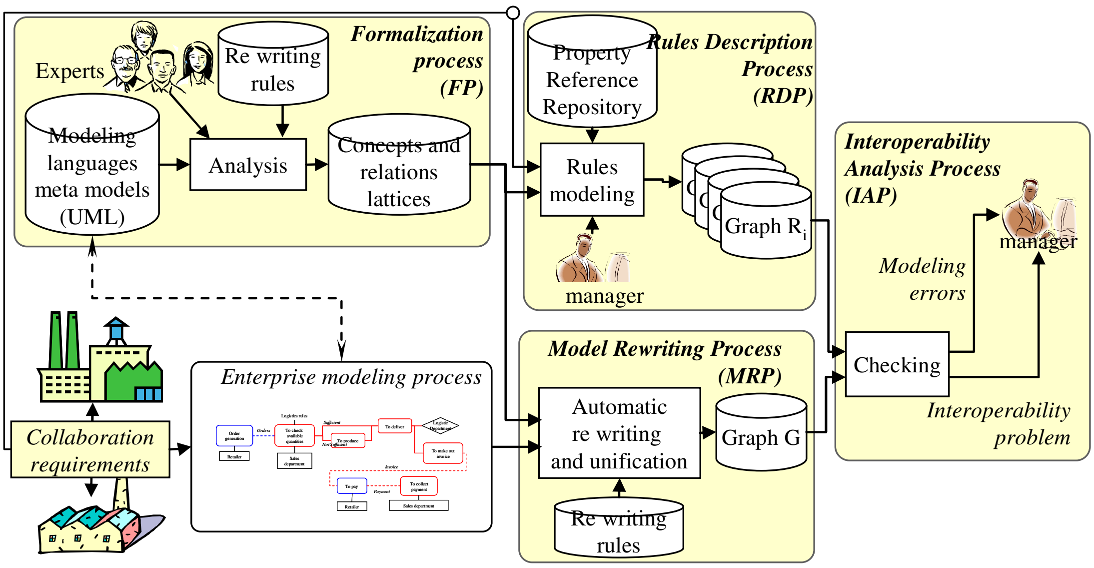


Fig. 3: processes and approach

The effect describes the conclusion i.e. one or several expected impacts of this collaboration on the behavior of the considered partners. This effect is perceptible thanks to variations of the characteristics of some other modeling entities. The relation linking cause to effect may be of different types (logical, temporal, influence (Pearl, 1999) or emergence) and constrained in order to take into account specific situations or hypothesis under which the rules have to be checked.

Managers must dispose rapidly and in confidence of a set of predefined and relevant interoperability properties adapted to the enterprise type and the collaboration nature. For doing this, the approach proposes:

• To describe a set of generic rules by using natural language. Considering the example of collaboration given in Fig. 1, an example of such simple rule is the following. The format of the data exchanged between two partners must be the same or at least it must be interpretable without any misunderstanding or loss of sense by the partner who receive the data. This rule allows for example to detect the problems of data transmission (orders, invoice and payment must be understandable by each of the partners) in the proposed process as shown in Fig. 4.

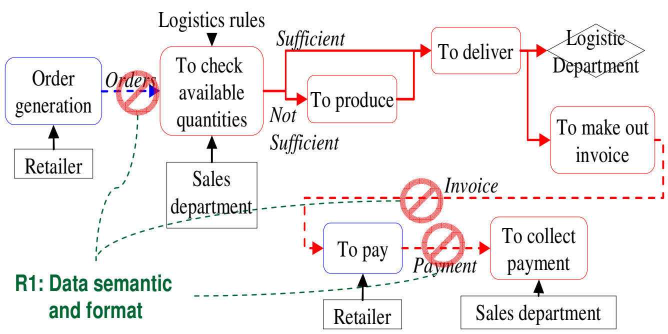


Fig. 4: Application of R1 to detect data semantic and data format problems

All the possible rules are defined by experts from the domain and then translated as properties directly by using Conceptual Graphs. In other words, experts manipulate natural language for describing each rule R_i which are translated into separated conceptual graphs R_i by using the Rules Description Process (RDP). This process respects the two lattices defined during the re writing phase. At this stage of the work, interoperability rules are modeled by using dynamic and static rules which are particular types of Conceptual Graphs. The graph shown Fig. 5 is the model of the previous rule. It highlights the separation between the cause and the effect of this rule. If the graph corresponding to the causes matches with a part of the conceptual graph G then the effect must be checked in the same way on G. If it is not, then there is a modeling error or a real interoperability problem.

• To pool all properties into a database named the Property Reference Repository (Chapurlat *et al.*, 2005). This allows manager to dispose of a central repository of knowledge related to interoperability rules and problems already encountered in the real world. Indeed, this data base, illustrated in Fig. 3, may be enriched taking new experiments into account.

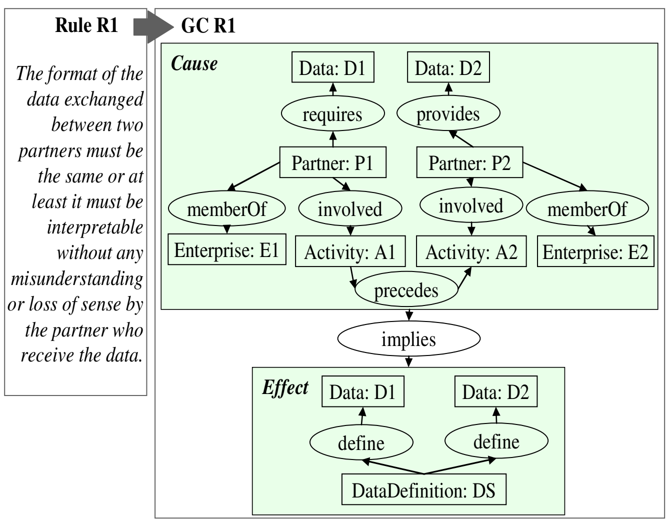


Fig. 5: Example of rule graph R_1

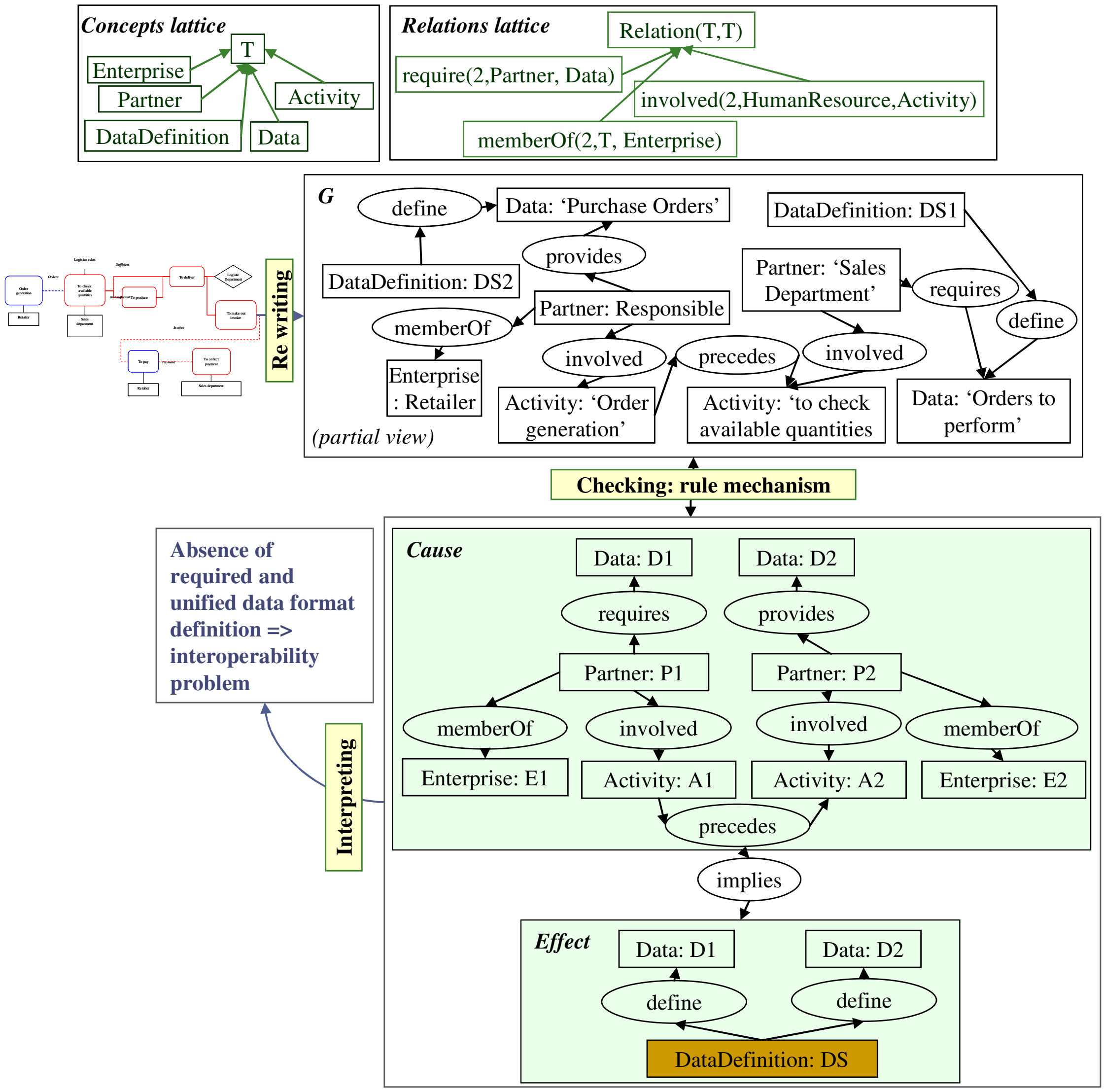


Fig. 6: Illustration of the approach

Then, mathematical mechanisms associated to the conceptual graphs and handled by using the Cogitant platform (Cogitant, 2005) are then used to support the interoperability analysis process (IAP). In the current state of the project, dynamic and static rules proof are used for checking the graph G such as proposed in (Chapurlat *et al.*, 2006) for risk analysis. An important point of this approach is that these mechanisms can make new knowledge required by the actors appear in order to improve the analysis process of interoperability.

Fig. 6 illustrates briefly the approach. The collaboration model between Retailers and Sales Department is translated into the unique conceptual graph G thanks to the lattices of concepts and relations and to the rewriting rules defined by experts. A conceptual graph rule analysis mechanism allows verifying if the cause part of R1 is verified by G then the effect part of R1 must be also checked.

In the example the rule R1 applied to the chosen collaborative process allows to highlight different problems of data coherence due to the different definition and type of the data.

6. CONCLUSION

The proposed composite approach based simultaneously on interoperability rules specification, rewriting and formal checking mechanisms offers different advantages. First, it allows specifying dynamically (adding, removing, replacing or interpreting from different manners) the interoperability rules without any modification of the reasoning mechanisms. Second, the Properties Reference Repository helps the manager to specify these rules by using existing rules, taking into account type of enterprise and nature of the collaboration links and following what we can call some 'good practices'. Third, the property model gives a lot of possibilities to describe complex rules. Last, the formal level of modeling and of the analysis mechanisms provide exhaustive proofs in terms of confidence and quality. However, some limitations are induced most by the formal aspect. Indeed, it is possible that some very complex rules and then properties may lead to enrich the modeling languages by adding new concepts and relations as proposed in the first approach. Temporal properties cannot be proved in the current state of the work due to the a-temporal characteristic of the Conceptual Graphs. Last, formal aspect can be considered as a little bit disturbing.

Then, perspectives and expected results of this research work consist in the provision of:

- a maturity profile of organizational and managerial interoperability of an enterprise, and
- a global methodology integrating and simplifying the use of the two approaches.

This must stay opened to a third approach based now on guided simulation.

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