Ontological framework for supply chain modeling and management

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Abstract: Formal ontological analysis is a methodology that builds on some philosophical notions in order to guide the process of building ontologies whose structure is correct. This paper presents an ontological model of supply chain in hierarchical structure with metaproperties of its parts which characterize the behavior of concept properties. We describe concepts in terms of their characterizing features (attributes) and we also describe the role played by these features in the concept definitions.

1 Introduction

In present time many publications deal with ontology development, ontological methodology and with the creation of ontological tools for the solution of different tasks in different areas [2], [3], [4], [5]. Ontology usually consists of a set of classes or concepts, their definitions and axioms about them. Methodology of ontology development may be considered in the following steps:

- specification is the determination of classes or concepts
- conceptualization is the modeling at the knowledge level by, for example, tables an graphs
- formalization uses, for example, a formal language or some frames
- implementation uses, for example, a special language of ontology.

Many current applications, such as commerce, production, delivery, sale etc., which appear also in supply chain, with different types of resources or agents to interoperate with each other may be solved on the basis of the ontological methodology. In some cases, interoperation becomes more complex, because agents may have been developed independently; therefore the assumption that agents use the same communication language and the same terminology in a consistent way cannot be made. When dealing with independently developed agents, their interoperability with humans and others depends on the agent ability to understand them, which leads us directly to ontology. Ontology are an explicit formal specification of a shared conceptualization, where a conceptualization refers to an abstract of some phenomenon by having identified the relevant concepts of that phenomenon, explicit means that the type of concepts used, and the constraints on their use are explicitly defined, formally refers to the fact that the ontology should be machine readable. The ontology provides a formally defined specification of the meaning of those terms that are used by agents during the interoperation.

Agents can differ in their understanding of their environment them, in their goals, and their capabilities, but they can still interoperate in order to perform a task. The interoperation among agents is the result of reaching an agreement based on a shared understanding, mainly obtained by the reconciliation of the differences. This kind of reconciliation might be accomplished by merging the ontology to which the agents involved refer, that is, by building a single ontology that is the merged version of different agents ontology, which often cover similar or overlapping domains [4].

One of the possible ways for the solution of the tasks introduced above might be the meta level approach. The meta properties we propose, namely Mutability, Mutability Frequency, Reversible Mutability, Event Mutability, Modality, Prototypicality, Exceptionality, Inheritance, Inheritance and Distinction, encompass semantic information aiming at characterizing the behavior of properties in the concept description. We claim that this characterization is very important in order a precise specification of the semantics of the concepts. Such characterization is essential if we want to perform a formal ontological analysis, in which knowledge engineers can precisely determine which formal tools can be used in order to build an ontology, which has a taxonomy that is clean and not very tangled. The novelty of this characterization is that it explicitly represents the behavior of attributes over time by describing the permitted changes in a property that describes the concept. It also explicitly represents the class membership mechanism by associating with each attribute a qualitative quantifier representing how properties are inherited by sub-concepts. Finally, the model does not only describe the prototype properties holding for a concept, but also the exceptional ones. By providing this explicit characterization, we are asking knowledge engineers to make more hidden assumptions explicit, thus providing a better understanding not only of the domain in general, but also of the role a concept plays in describing a specific domain [5].

In the next part we shell try to apply these idea and solutions for the supply chain management (SCM).

2 Formalization of supply chain ontology

2.1 Characteristics of supply chain management

A supply chain is considered as a loop from customers' demand to customer's satisfaction with final product or service. It consists of a chain of producers, suppliers, distributors, and transporters. A supply chain is a complex and dynamic system, which has the character of hybrid-distributed system. In MAS language, a supply chain can be modeled as a system of intelligent agents, which agree to cooperate to reach the final goal. A new, modern, and cost-effective implementation of supply chain management (SCM) is enabled by rapidly developing information and communication technologies.

SCM is a process of creating and configuring a supply chain, identifying measuring metrics in the chain, determining weak points in the chain and working to achieve the best results to meet customer demands.

Supply chain management aims to develop strategies for managing all resources (raw materials, services) and balance cumulative demands and supplies includes five following steps:

Plan – a strategic part of SCM. The aim is to develop strategies for managing resources and balance demands and supplies. A set of metrics to monitor the SC efficiency has to be proposed.

Source - the aim is to choose a set of suppliers for producing goods and services. This part includes pricing, delivery and payment process.

Goods and materials - are transformed to final products. This step is a manufacturing part of SCM. All activities are done through the following steps: scheduling, testing, packaging, preparation for delivery.

Deliver - coordination orders from customers, developing a network of warehouses, distribution and transportation of products to customer, invoicing system to receive payments from customers. This part is known as "logistics"

Return - deals with a problematic of defective products, how they can be returned to producer and how custumers ale dealt to satisfy their requirements on problematic products. A "help desk" application are used in this part.

Each basic SC is a chain of Source, Make and Deliver process. A SCM is different for various systems, depending on specific requirements, which must be analysed in a process of establishing a SC. The two basic classes of producing systems are well known. They are "produce-to-stock" and "produce-to-order". Dairy and bakery are very specific among other industries. Products must be delivered fresh and produce to stock is not allowed from the point of effectiveness. A very close co-operation of all parts in a SC is strongly required. Specific order policies are proposed to avoid over-production. Conversely producers are anxious to satisfy customers' demands in order not to loose any of customers. A market driven model of production management is proposed to manage such a system of SC. The basic scheme of SC is shown in Figure 1. Production gets customers' demands and purchases material from suppliers on the basis of this demands. Products are delivered to distributors where they are for sale for customers.

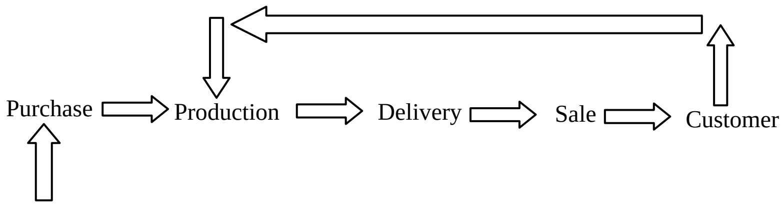

Fig.1. A basic scheme of SCM

2.2 Procedure of the supply chain ontology creation

On the basis of the supply chain definition and characteristics and according to the procedure of ontological analysis introduced above in this part we try to create the metagraph and metatables of SC ontology as the meta level approach [1].

We assume that the ontologies are represented as a graph along with a set of logical rules (which in our case might correspond with the rules of multi agent system). Formally, an ontology:

$$\boldsymbol{O = (G, R)}$$

is represented as a directed labeled graph $\boldsymbol{G}$ (which expresses the hierarchical order of SC performance and procedure) and a set of rules, for example, evaluation and negotiation. The graph:

$$\boldsymbol{G = (V, E)}$$

comprises a finite set of nodes $\boldsymbol{V}$ and a finite set of edges $\boldsymbol{E}$**.** The label of a node is given by a noun phrase that represents a concept name. The label of an edge is the semantic relationship among the concepts and can be null if the relationship is not known or not realizable. The label of an edge can be any user defined relationship. The set of relationship the pre-defined semantics is for example (class O, subclass O, Part O, Attribute O, Instance O, Value O). In general, other relationships may be interpreted too. It depends on the complexity of the system. For our SC case we will consider with local evaluation of nodes, mutual communication and negotiation among nodes. According to the supply chain procedure shown in Fig.1, the metagraph of SC ontology is introduced in Fig. 2.

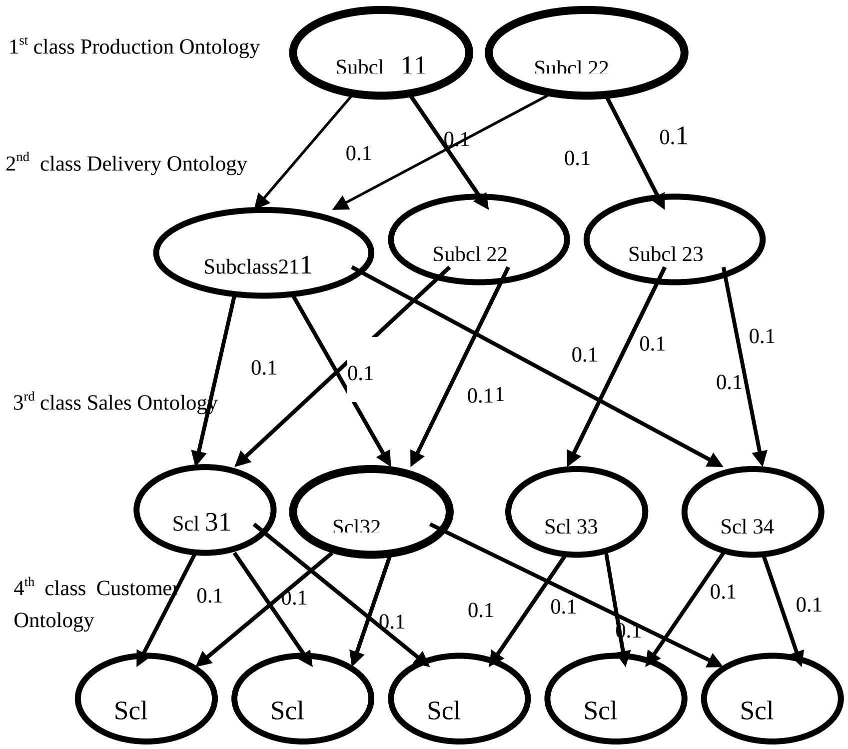

Fig.2. Metagraph of SC ontology

Table 1 is the corresponding metatable to the metagraph with illustrative variables for classes 1,2,3,4.

Table 1: Illustrative variables for classes 1, 2, 3, 4.

Term of production			Term of delivery		Term of sales		Term of customer	
Type	Capacity	Time	Type	Capacity	Type	Capacity	Type	Capacity
1	x_1	t_1	1	y_1	1	z_1	1	k_1
2	x_2	t_2	2	y_2	2	z_2	2	k_2
			3	y_3	3	z_3	3	k_3
					4	z_4	4	k_4
							5	k_5

In the above table x, y, z and k are the variables of SC; their values depend on the given situation during the performance of SC and on the properties of the classes and their resources.

The SC ontology from the aspect of its management (scheduling) with different type of classes (and kind of resources), different mode of their performance and different time of production has the following attributes (see Chapter 1) [6]:

Mutability, which models the liability of a concept property to change; a property is mutable if it can change during the concept lifetime.

Mutability Frequency, which models the frequency with which a property can change in a concept description,

Event Mutability, which models the reasons why a property may change.

Modality, which is used to express the way in which a statement is true or false, which is related to establish whether a statement constitutes a necessary truth and to distinguish necessity from possibility. The term can be extended to qualitative measure the way in which the statement is true. For the solution of this problem in the framework of SC an objective function is used and for its evaluation is used the negotiation rule.

Considering all of this attributes it is possible to suggest the management or scheduling ontology of SC by considering the clustering ontology. This is based on the similarities between the concepts to different classes and their resources, where class represents a different aspect of the domain knowledge. We assume that the ontologies modeling the classes and their resources are consistent, non redundant and well structured. Further we assume that the ontologies have been built with a methodology including a formal evaluation step. The cluster hierarchy permits the co-existence of heterogeneous ontologies.

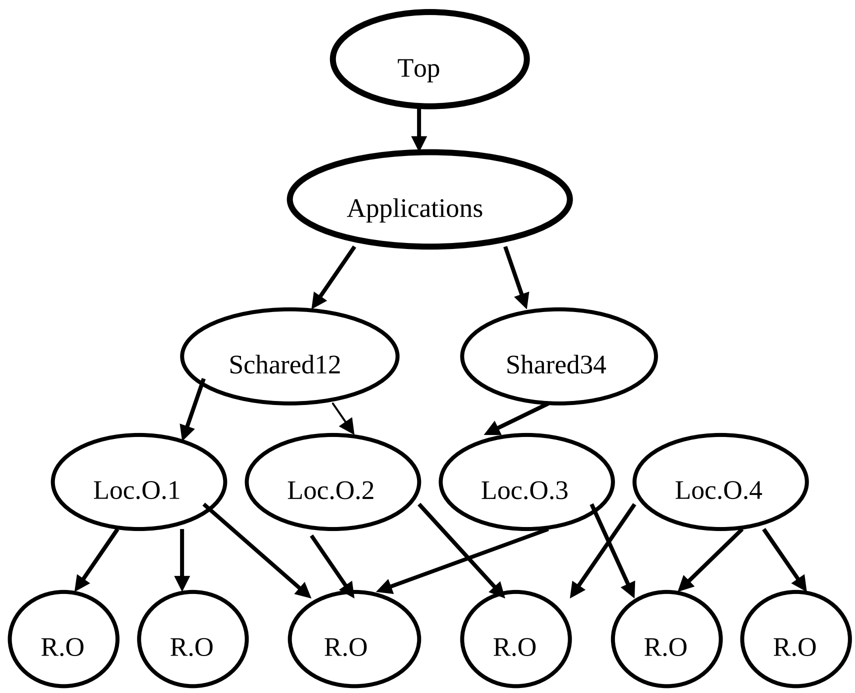

Fig. 3 Hierarchically ordered control ontology structure

Figure 3 illustrates the particular structure of possible control ontologies, where *Local Ont. 1*, *Local Ont.2*, *Local Ont.3*, *Local Ont.4*, are the local ontologies; *Shared 1,2* is the ontology shared by ontologies 1 and 2. Analogously, *Shared 3,4* is the ontology shared by the local ontologies 3 and 4. *Shared 1,2,3,4* indicates the ontology shared by the two below and in this example the application ontology is denoted as the *Application Ontology*. RO represents *Resource Ontology*.

In the hierarchically ordered control the *Local Ontologies* are the nodes of classes (their resources represent the sub-ontology) situated on the lowest level of control ontology structure. In each of these ontologies the concepts are described in terms of attributes and relations valid in the ontologies structure. Concepts of control ontology are hierarchically organized by middle and top level, which allows passing down of information

3 Conclusions and future work

In this paper are illustrated some approaches for the application of *Ontology theory* to the modeling, scheduling and management of SC. This application considers flexible properties of SC from the aspect of SC performance effectiveness.

The developing of *Ontology theory* for SC may include some criteria concerned to the time and cost factors of the SC performance. The multi agent system properties created by intelligent agents could be used for the research of the above problems as well.

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