Applying Foundational Ontologies in Conceptual Modeling: A Case Study in a Brazilian Public Company

Stefane Melo, Mauricio B. Almeida

Universidade Federal de Minas Gerais, Belo Horizonte, Brazil
stefanems@ufmg.br, mba@eci.ufmg.br

Abstract. Information Systems (IS) should be based on consistent representations of the reality. Poor modeling results in problems throughout the IS development. Ontologies are key instruments for the improvement of conceptual modeling since they are able to provide well-defined semantics. This paper discusses the application of foundational ontologies in conceptual modeling, presenting partial results of a case study in which real UML diagrams were assessed according to ontological principles. Our findings indicate that violations of ontological restrictions of part-whole relations are somehow usual in modeling practices. In order to cope with this, we make a proposal for using part-whole relations based on ontological constraints, with the aim to seek for improvements in the practice of conceptual modeling.

Keywords: Conceptual modeling, Foundational ontology, Part-whole relations, Interoperability.

1 Introduction

Information Systems (IS) should be based on consistent representations of a knowledge domain, with the aim to meet the requirements for which they were planned, as well as to ensure the quality of the system according to the user´s perspective. In this context, conceptual modeling has a significant role, even though a desirable modeling is often neglected insofar as time and financial restrictions arise. For the long term, lack of interoperability between systems has been caused by ad-hoc models, which result in inadequate representations of reality and cause problems for communication.

Within the realm of IS, ontologies can be used to describe the meaning of symbols, which are employed according to a particular view of the world [7]. Indeed, ontologies share some features with conceptual models. However, ontologies are supported by strong theoretical foundations, which enable them to work as a kind of meta-model, or a kind of reference. This characterization as a reference allows ontologies to express a shared conceptualization for a community of users in a very rigorous way and without ambiguities. Nowadays, the ontology approach is being considered and debated in context of the Software Engineering and the Business Applications communities, mainly for its proximity to the (conceptual and business) modeling fields, to the UML language and the fields of software component re-use and integration.

This paper describes research carried out in the scope of an on-going project within a Brazilian public company, which involves modeling and development of a large-scale IS. We present a case-study that describes the partial results of the application of a foundational ontology to activities of conceptual modeling. Throughout our research, we have evaluated the matching between conceptual models developed in the company and ontological standards. We have found so far that certain semantic relations between entities of the models, which has been established by system analysts involved in the project, do not meet ontological criteria.

2 Theoretical Background

In this section, we provide an overview of the important concepts that represent a required background to understand our research.

2.1 Ontology for Information Systems

Ontologies are an interdisciplinary matter, since it is subject of study in several research fields [1]. In the scope of computer science, ontologies can be used as software engineering artifacts applied to several contexts. For example, they can be used for the IS modeling, as a kind of meta-model and the applied in knowledge representation [6].

Ontologies has been applied in modeling insofar as they can aid in the selection of the modeling grammar for domain representation, in the understanding of phenomena represented by diagrams and in the definition of the meaning of entities with the aim of reducing ambiguity [15]. Foundational ontologies have been used to seek of better level of quality in modeling [17].

Since the late 80s, it could be observed an increasing interest in the application of foundational ontologies for evaluation processes and reengineering of conceptual modeling languages. Examples of foundational ontologies are: the Basic Formal Ontology [16], the Descriptive Ontology for Linguisitics and Cognitive Engineering (DOLCE) [5], the General Formal Ontology (GFO) [10] and the Unified Foundational Ontology (UFO) [9] and the Enterprise Ontology [4].

2.2 Foundational ontologies for conceptual modeling

The pioneering research on ontologies applied to information systems is a result of extension of the theory of Bunge [20]. The Bunge approach resulted in a realistic philosophical ontology, which considers the possibility of objective human knowledge, which is based on scientific method [18]. Bunge-Wand-Weber ontology (BWW) is a proposal that provides a theoretical basis for evaluating modeling practices and capacity of representation languages. Wand and Weber [19][20] describing criteria, called ontological completeness and ontological transparency, made possible the mapping between the constructs of a modeling language and ontological constructs defined by BWW.

One initiative that makes use of BWW is the Unified Foundational Ontology (UFO). UFO is a foundational ontology developed to support the activities of both conceptual and organizational modeling. UFO is the result of a merge of GFO [10], parts of DOLCE and principles of OntoClean methodology [8]. The UFO is composed by three levels, which reflect the world stratification: (i) UFO-A (endurants), an ontology of objects; (ii) UFO-B (perdurants), an ontology of events; (iii) UFO-C (social and intentional entities), an ontology of social entities including linguistic aspects [9]. In order to make possible the activity of conceptual modeling via UFO, it was proposed a conceptual modeling language that uses the ontological constraints of UFO-A as modeling primitives. Such language, which is named OntoUML, was specified above the UML 2.0 meta-model, namely, the Meta-Object Facility (MOF) [14]. The goal was to ensure the mapping between MOF and UFO-A structure [9].

2.3 Part-whole relation as semantic relation

In the context of conceptual modeling, a domain is represented by the identification of relevant concepts in that domain and by the relations among them. Research on semantic relations is extensive, but it is possible to identify some important semantic relations. One of the most important of them for purposes of conceptual modeling is the so-called part-whole relation [1], [3], [11], [12].

The standard language for modeling, known as Unified Modeling Language (UML) [14], one of the most widely used notations for the development and modeling of IS, encompasses the following semantic relations [2]: generalization/specialization, association, aggregation, composition. To develop conceptual models is important to treat the relation as the base of the domain being represented. In this paper, we focused on the application of part-whole relations in conceptual modeling of IS.

The part-whole relations in the scope of UML are specified in aggregation or composition relations [14]. In first case, an aggregation is represented by a whole and a part where the existence of these elements separately makes sense. In second case, a composition is represented by the relation between a whole and a part where the existence of these elements does not make sense when separated as a strong form of aggregation.

In the context of relations that compose UFO defined by [9], we highlight the meronymic relations, referring to the part-whole relations. In particular, there are two meta-properties associated to this relation: is-essential (isEssential) and is-inseparable (isInseparable). The first implies that only the whole is existentially dependent of part, and the second implies that the part and the whole do not exist separately. These two concepts refer to the concepts of aggregation and composition in UML, which also addresses the coexistence between parts and wholes.

According to [9], UML defines only two types of part-whole relations, the aggregation and composition. That's because the UML metamodel considers only single general definition for objects, being indifferent to the ontological distinctions between entity types. In order to cover this gap, the UFO considers four types of part-whole relation, based on types of entities that compose the meronimyc relations, called: subQuantityOf, subCollectionOf, memberOf and componentOf (Fig. 1).

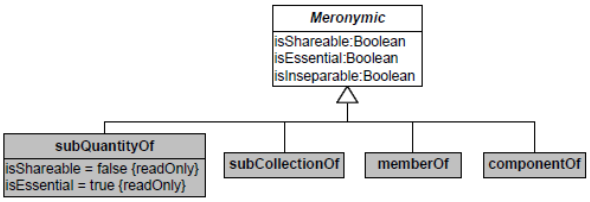

Fig. 1. Types of part-whole relations in UFO [9].

The Fig. 2 illustrates the types of individuals addressed in the four part-whole relations in UFO: Collective, Quantities and Functional Complexes.

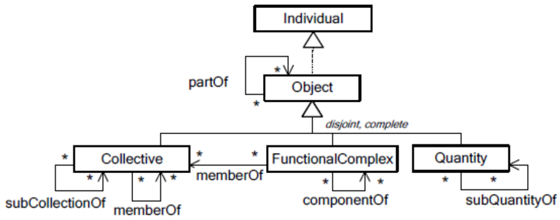

Fig. 2. Types of entity in part-whole relations [9].

1. Quantities: Always refer to the amount of matter. For example, water, sugar, wine, etc. The subQuantity of matter always refers to the same type of matter. Any subQuantity of water remains water (Fig. 3).

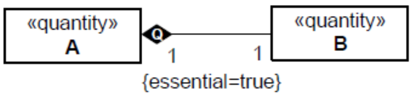

Fig. 3. Part-Whole relation among quantities - subQuantityOf [9].

2. Collectives: They may have parts which are not of the same type, such as tree and forest. In this case, a whole it is not infinitely divisible, i.e., a forest is not can be composed by only of a tree, but a set of trees. This element can be represented in the memberOf relation, when dealing with the relation between singular and plural entities or subCollectionOf, when dealing with the relation between plural entities. The Fig. 4 and Fig. 5 represents these two types of relationships mentioned.

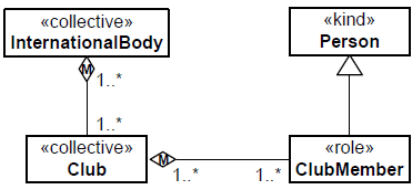

Fig. 4. Example of memberOf relation [9].

Fig. 5. Example of SubCollection relation [9].

3. Functional complexes: Differently of the collectives, in the functional complexes each element may have a specific role. For example, among a fleet of ships may exist defense ships, storage ships. The complexes are composed of parts that play multiple roles in the context of a whole. The parts of a complex have in common that they have a functional link with the whole complex. In other words, all parts contribute to the functionality (or behavior) of the whole (Fig. 6).

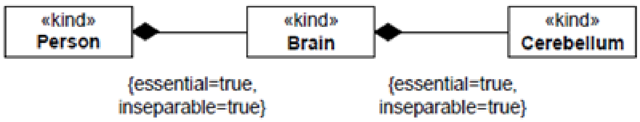

Fig. 6. Example of componentOf relation between complexes [9].

The classification of entities through the types defined by [9] represents a step forward in the understanding domains even before its representation in a diagram.

3 Case Study

The case study described in this paper focuses on real activity of conceptual modeling through UML, in the scope of a IS development project in a large Brazilian public company. This project is oriented to business process management and contains many business processes related to public management in their scope. It is in this context that our research has been performed.

The study consists of steps that compose the evaluation of domain models and a proposal for improvement for the conceptual modeling based on Unified Foundational Ontology (UFO). Our ongoing research is nowadays in the stage of testing a proposed methodology for the evaluation of semantic relations. We present here this proposed methodology and the partial results.

3.1 Methodology

The first stage of the research corresponds to the evaluation of domain models made during the development of the project. Then a proposal for improvement to the modeling was carried out according to our findings.

The methodology used for evaluation consists of the following steps: i) Examination of domain models; ii) Selection of models to be evaluated; iii) Mapping the UML models to OntoUML; iv) Verification of the models adherence to the ontological pattern of UFO through the OLED[1] tool v) Proposal of correction of models through the ontological criteria and retest in OLED until the elimination of errors.

In order to perform the verification of domain models in OLED, we needed a mapping of the original models in UML to OntoUML syntax. This corresponds to the classification of concepts and relations through the definitions documented in the project specification requirements and the types of elements contained in the UFO. Then, the mapped models were submitted to verification in OLED. In the cases in which the OLED tool accused modeling errors during the tests, the model was then rebuilt according to the requirements, experts working on the project and UFO's specification. The model was tested and rebuilt again and again until the tool no longer points out modeling errors. From preliminaries results obtained, it was possible to note that some relations have not been well defined by business analysts involved in the project, mainly our focus, that is, the part-whole relations. In order to solve this particular situation, it was proposed a checklist table to support analysts in defining the elements of the domain under modeling. This checklist defined mandatory criteria to be observed, which are based on types of entities and relations about part-whole relations specified in UFO.

The criteria presented in the Table 1 identify and classify the elements analyzed in the domain, as well as the part-whole relations present in the model. In order to do this, we compare each element of the domain to the list of criteria. At the end of the modeling activity, more consistent mappings were defined among concepts and relations.

Table 1. Table of criteria

Criteria	Sub-criteria	Description of criteria/sub-criteria
C1		Quantity always relates to amount of matter and sub quantity (part) is the same kind of matter of the quantity (whole). If a term defined for the domain representing a quantity or a sub quantity, probably exists a part-whole relation.
C2		Collectives and Functional Complexes refer to objects. So, it is worth classifying the elements are objects in domain and verify the existence of collective or functional complexes. If there are such objects of these types, can be a signal of part-whole relations.
	SC1	Collectives may be a subset of individuals, with same kind of objects in parts and wholes like in subCollection relation, or may be represented by different types of individuals, like in memberOf relation.
C3		Functional Complexes are composed by parts that play multiple roles in the context of the whole. Then, objects with this characteristic should be observed throughout the domain context. The existence of this

[1] OLED - OntoUML Lightweight Editor. http://code.google.com/p/ontouml-lightweight-editor/

		type of object in domain indicates a possible part-whole relation, like aggregation or composition, for example.
	SC2	All parts of a complex must have a functional link with the whole, because they all contribute to functionality (or the behavior) of the complex.
	SC3	The dependence attributes is essential, when the whole is existentially dependent of part, and is inseparable, when the part and the whole do not exist separately, can determine relations as aggregation or composition.

3.2 Experiment

Our research adopted a population of twenty three domain models available at time of this research. In this population, we selected randomly, by draw, a sample of ten models for testing, in order to obtain results that can represent the project in question (at this stage, we did not intend to represent the entire set of models available in the company). For size limitations of this article, we selected one model from the sample, in order to illustrate the proposed methodology. The selected model is named State Administration.

The first step of the experiment performs a mapping of the UML model to the OntoUML language, to ensure that tests are possible in OLED. Then, the model re-written in OntoUML is tested in the OLED. From the result returned by the OLED, we verified the requirements and ontological criteria. The model is re-done and re-tested until no more errors were found.

3.3 Results

The Fig. 7 presents the original model of State Administration, made by the analyst's team (mod.1). Then, the mod.1 was rewritten in OntoUML language (mod.2, Fig. 8) and finally imported in OLED for the tests.

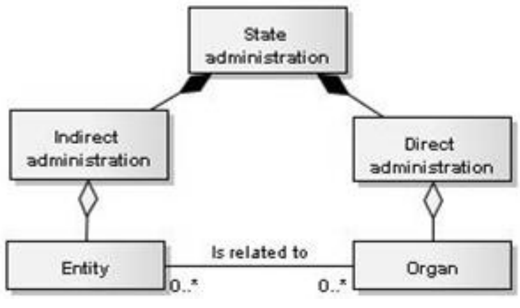

Fig. 7. State Administration domain model (mod.1) made in UML.

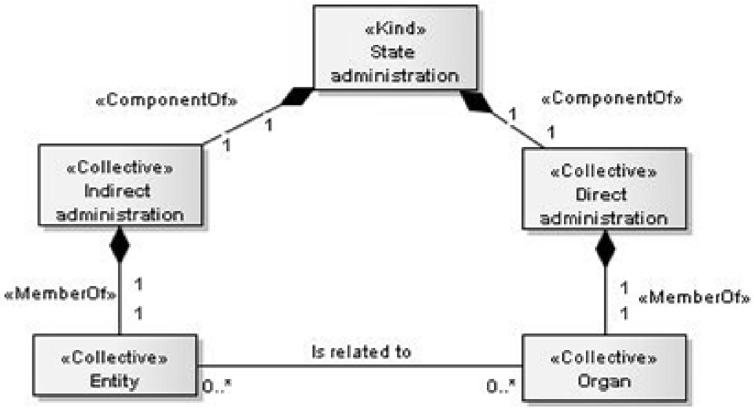

Fig. 8. State Administration domain model (mod.2) rewritten in OntoUML.

OLED returned problems in tests of mod.2, as seen in Fig. 9. So, the model was re-written and tested again, until the elimination of problems.

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ERROR: The model is not valid sintatically. The following error(s) where found:

[unnamed] (<<memberof>>) - The sum of the minimum cardinalities of the parts must be greater or equal to 2

[unnamed] (<<componentof>>) - componentOf relates individuals that are functional complexes (part)

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[unnamed] (<<componentof>>) - componentOf relates individuals that are functional complexes (part)

Model verified in 21.345 ms, 4 error(s) found
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Fig. 9. Results of the OLED verification of the State Administration model.

In the State administration model, we observed that the relationships identified as part-whole relations actually are specialization and association relations (mod.3, Fig. 10). According to the business processes, the requirements and UFO criteria, the Indirect and Direct Administrations are types of State Administration and are not parts of it. So, the same criteria can be observed for Entity and Organ, which are actually types of Indirect and Direct Administration, respectively, and are not parts.

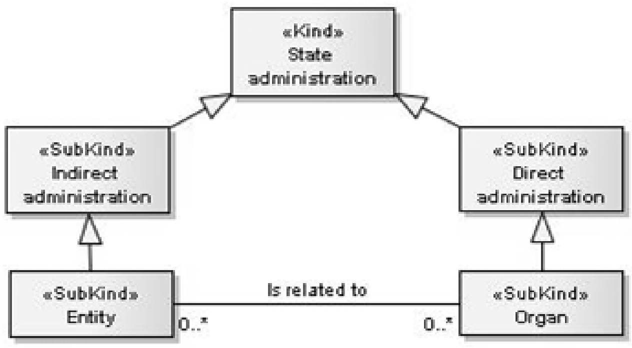

Fig. 10. New State Administration model (mod.3), proposed in OntoUML.

After the model was rewritten OLED no more returned errors, as can be seen in Fig. 11.

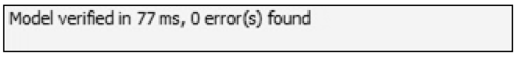

Fig. 11. Final results of the OLED verification for State Administration model.

3.4 Discussion

Automatic checking of ontological constraints through OLED enabled the identification of conceptual issues in models, generating new models of the business domain under evaluation.

With the results of tests in OLED, we observed that the decisions of analysts represented in models did not meet UFO ontological constraints, revealing modeling problems in the original model.

Ontologies can help analysts to better understand the semantics of the business domain in which they are involved. However, it is known that the own understanding of ontologies is not simple or trivial. With the intention to make this understanding easier, for those who are not involved with ontologies, we propose a preliminary table of ontological criteria.

4 Final Remarks

This paper discussed the application of foundational ontologies in conceptual modeling of IS and aimed to present partial results of a case study that evaluates real domain models in a software development project. We make use of UFO-A ontology in order to propose improvements to the conceptual modeling activity. Until now we obtained empirical results that indicate issues in modeling within the project analyzed related to part-whole relations. During the process of rewritten the models, it was necessary the review the business processes and the corresponding specification requirements. We could observe that for this aim it is essential that business processes and requirements are clearly defined and mapped, which does not always happen. From these findings and from studies on ontology, we proposed improvements.

This case study has not exhausted the verification of adherence to the ontological domain models to UFO patterns. In the next research steps will be proposed templates for types of part-whole relations described in the criteria table (Table 1), as a more practical way to support modeling. We also intend to analyze some questions about the test results for the entire sample of ten models such as: percentage of models that have part-whole relations; percentage of models with part-whole relationship that contains errors; percentage of the most common errors. This analysis will allow us an assertive inference about the use of part-whole relations in the context of population of models analyzed.

5 References

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