A META-CONCEPTUAL MODELING APPROACH FOR CHANGE MODELING IN APPLIED ONTOLOGY

Christophe CRUZ
christophe.cruz@u-bourgogne.fr
Laboratoire Le2i, UMR CNRS 6306, Dijon, France
Perrine PITTET
perrine.pittet@u-bourgogne.fr
Laboratoire Le2i, UMR CNRS 6306, Dijon, France

Abstract. *Formal ontologies are explicitly representation of domain knowledge. Ontology change management should ensure maintaining its consistency, so that its users can continue to cooperate and understand each other. This paper presents a meta-conceptual modeling approach for change modeling in the domain of applied ontology. This modeling approach makes use a mathematical structure to model ontologies and its changes in order to make possible the qualification of changes regarding its consistency. Actually, the paper focuses on the meta-conceptual modeling approach inspired by Guarino's formal ontology building process.*

Keywords: Ontology, Change modeling, Description Logics.
JEL classification: C6 Mathematical Methods, C60 General

1. Introduction

Applied Ontology is a new direction in the field of computer science ontologies recommended by [7]. It is an interdisciplinary science based on philosophy, cognitive science, linguistics and logic. Its purpose is to understand, clarify, communicate and make explicit the assumptions of people about the nature and structure of the world, in order to help them understand each other. This goal is achieved by resolving the semantic heterogeneity that may exist between different conceptualizations of the world.

The world changes over time, impacting the knowledge of every subdomain it contains [1]. Therefore, systems describing the knowledge of a certain domain should be able to consider changes occurred to keep its knowledge representation up-to-date. Formal ontologies are one of them: they explicitly and formally represent the knowledge of a domain in all its forms and modes of existence. Collaboratively developed, a formal ontology allows the domain users to understand each other by sharing the same terminology despite the different assumptions they have on the domain conceptualization. However, due to its completeness, the complexity of its conceptualization can sometimes make the domain knowledge inaccessible for its users. Furthermore, domain users often need to access only a subset of this knowledge. The world changes may impact both domain knowledge and user's assumptions, and their application can turn inconsistent the knowledge represented by the ontology. Consequently, an inconsistent ontology is no longer usable by the domain community. Ontology changes management [2] should ensure maintaining its consistency, so that its users can continue to cooperate and understand each other. Also, a formal ontology requires a collaborative development to take into account every domain user assumption, so does its change management. The problem is the following: how to enable collaborative ontology change management considering changes in the domain and new domain user assumptions? Until

now, existing research in the Semantic Web does not allow such change management for formal ontologies. Therefore, the contribution of this paper consists in designing a meta-conceptual modeling approach to ontology change management dedicated to formal ontologies.
To capture the interest of this approach in this paper, first we will see why, contrary to data models emphasizing structure, formal ontologies should focus on the content. We will then describe the two essential activities identified by the Applied Ontology in the development process of formal ontology. Finally, we will describe our meta-conceptual modelling approach.

2 Ontology: Study of Content

According to Guarino, formal ontology has an inevitable interdisciplinary nature. It is based on the **logical, epistemological, conceptual and linguistical level studies,** which are respectively those of logic, philosophy, cognitive science and linguistics. [6] describes the following table to locate the ontological level compared to these other levels. They are classified according to their level of abstraction from data content.

Table 1. Primitives, interpretation and characteristics of the Ontological Level w.r.t. to the other study levels.

Abstraction Level	***Study Level***	***Primitives***	***Interpretation***	***Main Characteristic***
+	*Logical*	*Predicates*	*Arbitrary*	*Formalization*
↑	*Epistemological*	*Structural relations*	*Arbitrary*	*Structure*
	Ontological	***Ontological relations***	***Constrained***	***Signification***
	Conceptual	*Conceptual relations*	*Subjective*	*Conceptualization*
-	*Linguistic*	*Linguistic terms*	*Subjective*	*Language dependency*

The *Logic* level is used to describe a **formalization**, i.e. the **formal structure of a content** (see Table 1 row 1). It uses predicates, which describe the content properties. For example, the following predicate "being tall", can be used in a proposition noted *beingTall(Peter)*, which describes a property of a content. Predicates allow using logical operators to build logical formulas. But a **logical formula has an arbitrary interpretation**. For example the sentence "Peter is tall or is not tall" does nothing to describe the previous content. It is not conditioned by the content but considers the invariances of the latter, i.e. properties that are true in all reachable states of this content from its original state. The reachability relation describes all the states a content can reach over time or considering different contexts, it does not depend on this content but on the concept referring to this content. Indeed, logic, although very useful for describing the formal structure of a content is independent thereof.
The *epistemological* level describes **structural relationships between contents** to structure the knowledge of the world in general (see Table 1 row 2). For example, the mereology relationship defines an element of the world as a part of another element. "The heart is a part of the human body" is an example of mereology. Similarly, the subsumption relation is used to define an element as a sub-type of another element. "A man is a sub-type of a human" is an example of subsumption. The epistemological level can provide structural characterization content but is in no way conditioned by it. Structuring relations are relationships independent from content.

The *conceptual* level, meanwhile, uses **conceptual relationships**, that is to say relations between **concepts** in order to build a **conceptualization of a domain** of discourse (see Table 1 row 4). A concept can be defined as the mental and abstract of a content. A conceptual relation is used to describe a semantic link between two concepts. For example, the concept *HumanBody* can be connected to the concept *Heart* by relationship *haveOrgan*. The conceptualization of a domain corresponds to the set of conceptual relationships that describes it. It represents a general and abstract knowledge of the domain.
The *linguistic* level is used to **select objects in a domain** of discourse, that is to say, its content, called **references**, referring to **concepts** and using **symbols** of a language, called terms (see Table 1 row 5). It is used to represent a conceptualization in a language. There is a causal relationship between a term, also called **sign**, and a concept, and between this concept and the reference. The reference is the person or thing to which a linguistic expression refers. The sign is the term used to designate this reference in a certain language. The **concept is the meaning of the term**, also called its **intension**. The reference triangle or triangle of meaning [8] illustrates this definition. Figure 1 below illustrates it on the left with one of its possible representations on the right.

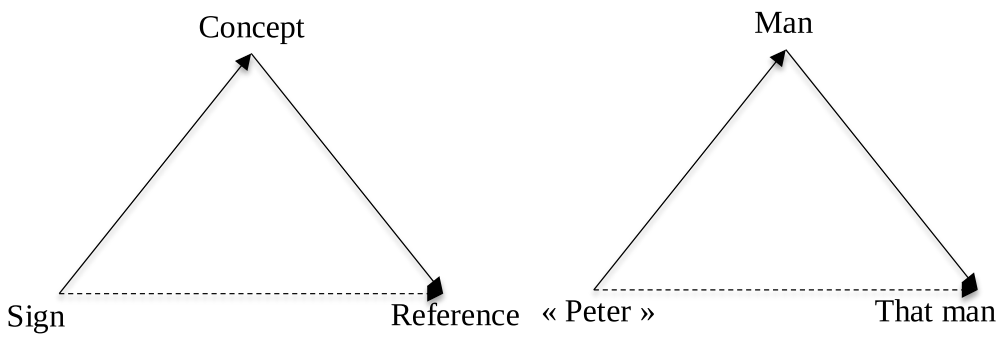

Figure 1. Reference Triangle (on the left) and a Possible Representation (on the right)

On the reference triangle representation on the right, the concept Man symbolizes the term "Peter." The reference "That human" refers to the concept Man to interpret the term "Peter." Indeed, it is only through the concept Man associated with the term "Peter", that it is possible to interpret this term correctly whatever the situation. The relationship between the term and the designated reference is implicit: it is called interpretation.
The *ontological* level is at the heart of these different levels. It can **represent, using a structured language, a structured and logically constrained conceptualization of a content**. This representation is called a **terminology**. For example, the following terminology "if Peter is a Man then it is a Human" builds knowledge from a content by describing a logical relationship between the term "Peter is a man" and the concept "Human". This relationship is called an ontological relation (see Table 1 row 3). The interpretation of a terminology is constrained by this ontological relation and corresponds to the meaning of content. The ontological level is then **conditioned by content**.

3 Formal Ontology Building Process

Figure 2 below, inspired by [10], describes the building process of a formal ontology according to the Applied Ontology orientation. It allows viewing the contribution from the other study levels described above, for the ontological level.
This process undertakes two activities for formal ontologies development.
The **Ontological analysis** which is the **study of the content as such**, that is to say, of the assumptions about the domain, regardless of its representation. It should always be performed

before the representation. First, the phenomena of reality in the domain are identified. Then they are perceived and described through presentation patterns. Each pattern describes an assumption supported by a user of the domain on these phenomena. The final set of patterns is the result of the ontological analysis. More numerous they are, more the analysis is complete.

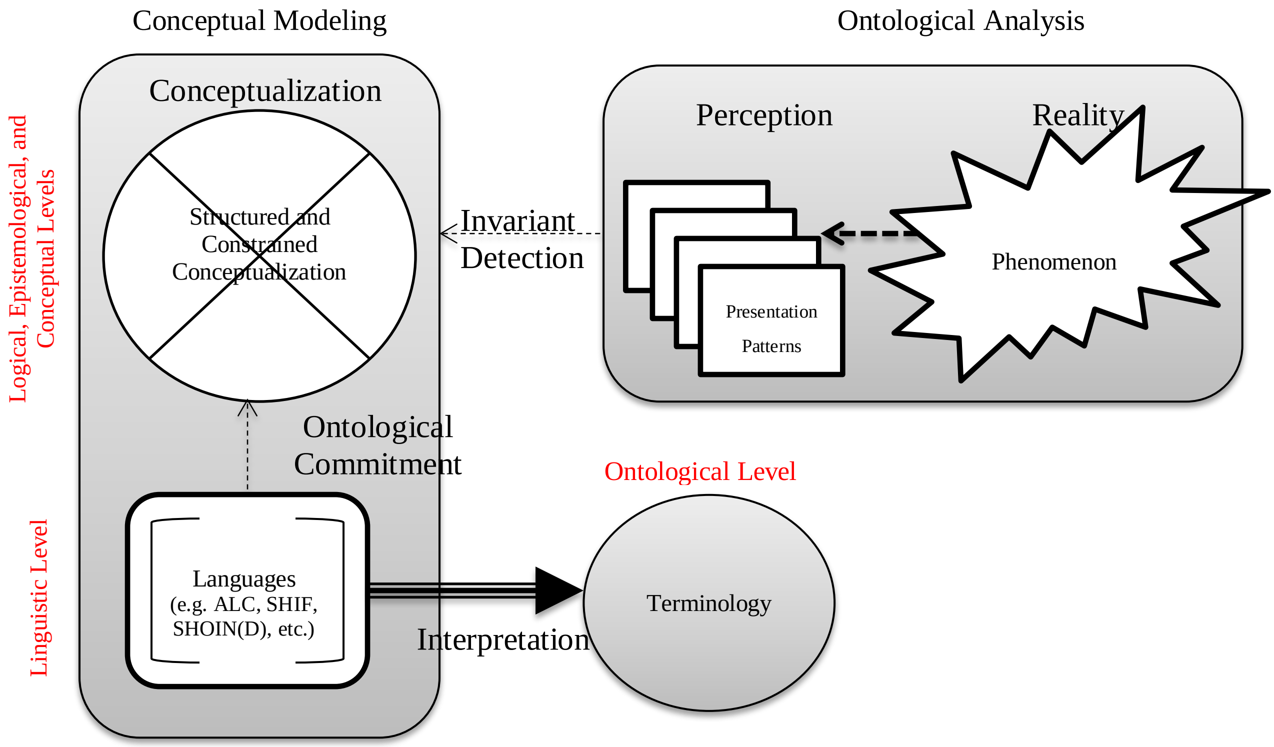

Figure 2. Formal Ontology Building Process According to Applied Ontology

The **Conceptual modeling** which is used to **formally describe the results of the ontological analysis**. It compares the different presentation patterns to formally structure the **invariants** therein. The result of this formalization is called a **conceptualization**. A conceptualization is a formal structure of the reality (or a piece of the reality) as perceived and organized by an agent (person, perceptual object), **regardless of the language** used and of the actual occurrence of a specific situation [9]. It is therefore modeled without representing it in a language. Furthermore, all the conceptual relations and structural constraints logically corresponding to the invariants are identified from the presentation patterns' comparison (see Fig. 2: logical, epistemological and conceptual levels). To produce an ontology, i.e. a terminology (see Fig.2: ontological level), a representation language must then be selected and used to represent this conceptualization (see Fig.2: linguistic level). This language will be used by the domain community to identify referents of this domain. If the conceptualization is verified by these references to the domain content, then the **ontological commitment** is reached.

5. Formal Change Modeling Process for Change Management

According to [4], **description logics** (DLs) are a family of logics that are decidable fragments of first-order logic (FOL) with attractive and well-understood computational properties. DLs have been in use for over two decades to formalize knowledge and notably quality ontologies. In a DL knowledge base, a distinction is drawn between the so-called **T-Box** (terminological level) and the **A-Box** (assertional level). A DL terminology $\mathcal{T}$ (T-Box) is a set of **terminological axioms**, consisting of terminological constructions of ontological elements. Ontological elements are of two types : non-relational and relational elements. Non-relational elements are **concepts, datatypes, role characteristics** and **attribute characteristics**, and relational elements are **roles** and **attributes**.

The choice of a specific expressivity level, for an ontology representation language, depends on the **granularity level required** for the description of a domain. Many representation languages exist in the literature. Some are specifically used in the Semantic Web. However they are neither all formal nor expressive enough to describe formal ontologies. Following the usual Semantic Web representation languages, in the ascending order of their expressivity, **RDF** (Resource Description Framework) language is very poorly expressive. It is used for Web resources description, but its low expressivity limits the resolution of the heterogeneity to **simple metadata comparison**. **RDF-S** (Resource Description Framework Schema) language is a few more expressive. It features the subsumption construct (concept hierarchy, role hierarchy), which allows it to define **vocabularies, taxonomies** and **light ontologies**. However, this language is inadequate for the representation of complex ontologies such as a formal ontology. For example, it is impossible to define a disjunction between two concepts. It is not recommended for the description of ontologies for inference. Description Logics (DLs) and OWL (Web Ontology Language), respectively containing up to 31 and 29 constructs are highly more expressive. Their logical foundation makes them **suitable for formal ontology** description. The ALC logic [3] is the simplest logic language of the Description Logics. More complex languages based on ALC were defined such as SHIF, SHOIN(D) or SROIQ [4]. These languages are not adapted to describe changes on them. Actually, the structure of these languages has to be formalized as well as the language instances. Consequently, we define our particular mathematical structure described in [5].

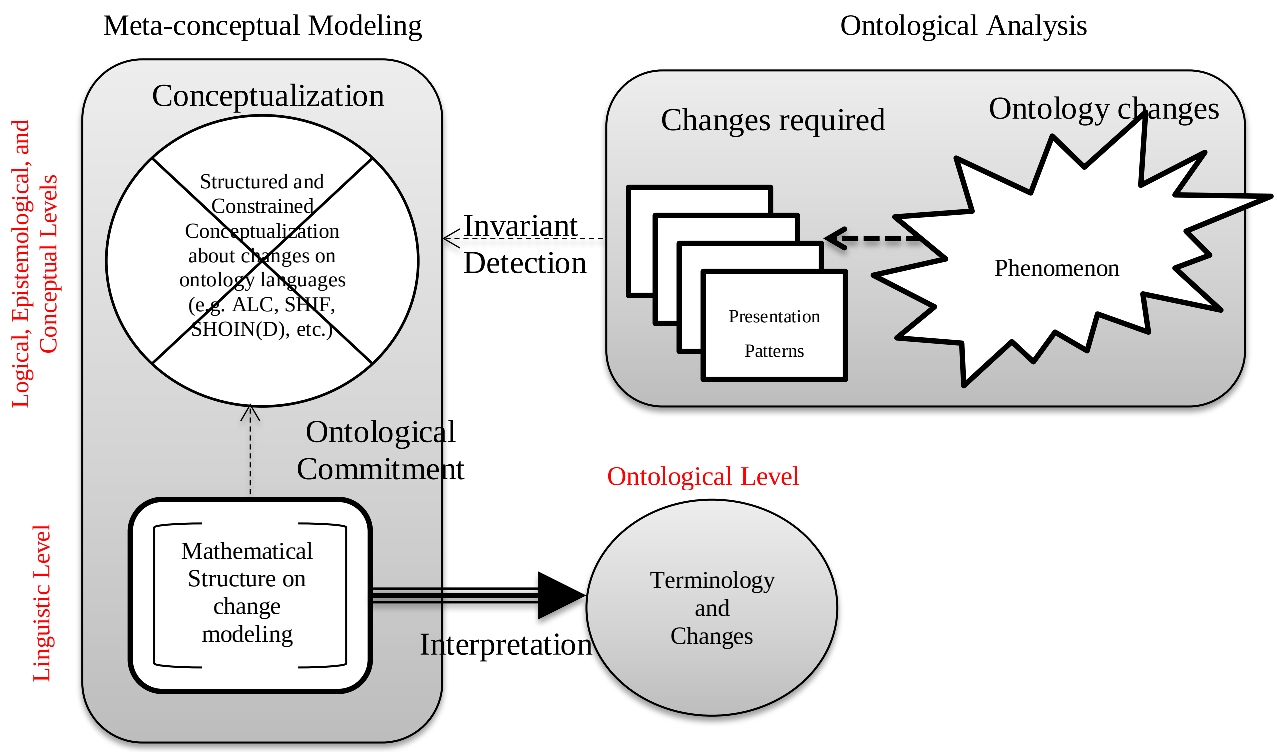

Figure 3. Formal Change Modeling Process

Our mathematical structure defines our language at the linguistic level to reach the ontological commitment required to define the ontological level. Any change is representable in our language which accepts the definition of new constructors of ontology languages (e.g. irreflexivity in OWL2). Our meta-conceptual modeling formally describes the results of the ontological analyses about changes (lexical, structural, and logical) on ontologies. The conceptualization formalizes all the changes that are identified in the ontological analysis. For instance, if the ontological analysis is done on an SHOIN(D) ontology, the meta-conceptualization formalizes all the changes applicable on this language and on the ontology formalized with this language. Then, our mathematical structure models the axioms of the SHOIN(D) language, the ontology, the applicable changes and the required changes. The results of this process are available at the ontological level. The figure 3 shows this process.

6. Conclusion

The research field dedicated to formal ontology is Applied Ontology. This field is a new interdisciplinary direction following the philosophy, cognitive science, linguistics and logic study levels. Its approach is based on the study of the content of the domain rather than on its structure, and the various assumptions that people support on it. Its objective is to produce a formal ontology for the domain community members to understand and share its knowledge, and collaborate, while maintaining their own assumptions. This approach is based on two activities: ontological analysis and conceptual modeling. Ontological analysis is the study of assumptions, or points of view, supported users of a domain about its nature and structure. Conceptual modeling allows to formally describing these assumptions for the purposes of understanding and communication. We applied this process to change modeling of ontologies. It follows the same procedure, identification, conceptualization modeling and formalization, but with a slightly different purpose, which is the representation and the historization of changes on ontologies. Our contribution is at the linguistic level which provides a mathematical structure to model changes.

References

[1] P. Pittet, C. Cruz, C. Nicolle, "An ontology change management approach for facility management", Computers in Industry 65 (9), 1301-1315, 2014
[2] P. Pittet, C. Cruz, C. Nicolle, "Guidelines for a Dynamic Ontology - Integrating Tools of Evolution and Versioning in Ontology", International Conference on Knowledge Management and Information Sharing, Paris, France, 2011
[3] I. Horrocks, "Using an expressive description logic: FaCT or fiction?", KR, 636-645, 1998.
[4] F. Baader, "The description logic handbook: theory, implementation, and applications", Cambridge university press, 2003.
[5] P. Pittet, C. Cruz, C. Nicolle, "Modeling Changes for SHOIN (D) Ontologies: An Exhaustive Structural Model", IEEE Semantic Computing (ICSC), 2013.
[6] N. Guarino, "The ontological level", Philosophy and the Cognitive Science. Hölder-Pichler-Tempsky, Vienna, 443-456, 1994.
[7] N. Guarino, M. A. Musen, "Applied ontology: Focusing on content". Applied Ontology, 1(1), 1-5., 2005.
[8] C. K. Ogden, I. A. Richards, "The Meaning of Meaning: A Study of the Influence of Language upon Thought and of the Science of Symbolism", Magdalene College, University of Cambridge, 1923.
[9] N. Guarino, C. Welty, "Conceptual modeling and ontological analysis", The AAAI-2000 Tutorial, http://www.cs.vassar.edu/faculty/welty/aaai-2000, 1998.
[10] N. Guarino, "Formal ontology, conceptual analysis and knowledge representation", International journal of human-computer studies, 43(5), 625-640, 1995.