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In the Defense of Ontological Foundations for Conceptual Modeling

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In his article entitled "On Ontological Foundations of Conceptual Modeling" (henceforth OFCM), Boris Wyssusek reviews several approaches that have the common objective of investigating how results from areas such as formal ontology in philosophy, cognitive science, semiotics and linguistics can be employed in the construction of a well-founded theoretical basis for the discipline of conceptual modeling in computer science. Despite the title of his essay, which may let the reader think of an analysis of *what* the ontological foundations of conceptual modeling are, Wyssusek wonders *whether* the very idea makes sense, concluding very negatively that "the project of ontology-based conceptual modeling appears to be impossible in principle". We shall bring here arguments against such conclusion, hoping to convince the readers that the *ontology-driven* approach to conceptual modeling is well and alive, and that it dramatically improves the quality of information systems.

Although it mentions very briefly other approaches, Wyssusek's article is very much focused on the so-called BWW approach, an adaptation made by Ron Weber and Yair Wand of the original theory proposed by the Argentinean theoretical physicist and philosopher of science Mario Bunge. In that respect, due to the popularity of BWW, a contribution of OFCM is to make explicit the

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way that approach was formulated, and its differences with respect to Bunge's original work.

Three important characteristics of the "B" and the "WW" parts of the theory have been recognized in Wyssusek's analysis:

1. Bunge's ontology commits to a materialist and, thus, reductionist worldview;
2. Wand and Weber did not actually *select* BUNGE's theory in the strong sense of the term because they did not systematically compare it with other alternatives. In particular, statements such as "I have used Bunge's theory because it articulates constructs and relationships that *appear* [our emphasis] useful in the information systems and computer science disciplines" cannot be satisfied *a priori*. Furthermore, statements such as "in my view it is the best formulated and most complete theory of ontology that I have been able to find" do not have any scientific content since, at minimum, the author should make transparent under which criteria the ontology can be considered the most complete and best formulated, and which are the ontologies that he was able to find;
3. Once Bunge's theory had been "selected", the further choice of ontological categories that gave rise to BWW was made in an *ad hoc* way, i.e., Wand and Weber chose some of these categories on the basis of their own experience and on what appeared to be useful for information and computer scientists. Moreover, without making the necessary ontological commitment to Bunge's theory, they were able to adapt the semantics of the selected categories to fit their needs. A convenient move, although—as Wyssusek observes—one that weakens any claim of well-foundness of the resulting ontology.

Making these facts explicit is without doubt an important contribution of Wyssusek's article, since it facilitates the debate on different approaches for developing ontological foundations for conceptual modeling. However, despite the criticisms, the author seems to fall in the same trap of Wand and Weber, namely, he also approaches ontology as if Bunge's ontology was the only available scientific ontology. As if denying materialism one would also necessarily deny a scientific approach to ontology. A posture which is also manifested in the article's bibliography: there are no references to philosophical theories in ontology outside Bunge's work.

The author comments on the following statement by Wand and Weber (Weber 1997a, p. 73): "Like the ontological researchers in philosophy, they, too, were concerned with how humans structure their conceptions of the world". His comment is: "The latter claim is obviously at variance with (not only) Bunge's understanding of ontology, since ontology *is not* 'concerned with how humans structure their conceptions of the world'. Rather, ontology is concerned with 'concrete objects' (Bunge 1977, p. 6). […] 'The investigation of the patterns of representation […] belongs to psychology, epistemology and methodology (Bunge 1974b, p. 104)'—but, for obvious reasons, *not* to ontology" (Wyssusek 2006, p. 73).

This passage summarizes the core of the argument defended in OFCM. In short, Wyssusek generalizes Wand and Weber's view of conceptual modeling as well as Bunge's view of ontology, and concludes that there is no relation between the two. In particular, he makes the claims that (1) conceptual modeling is about how humans *structure* their knowledge, and (2) ontology is about "concrete objects", and then concludes that there can be no ontological foundations for conceptual modeling.

To negate this conclusion, our line of reasoning will be the following: (1) the way humans structure their knowledge cannot elude ontological issues; (2) ontology is not just about concrete objects; in particular, so-called *formal ontology* is completely neutral for what concerns its domain of application. Note that point (1) alone is sufficient to conclude that ontology is very relevant for conceptual modeling. Point (2) is just an extra clarification.

Let us start our discussion considering the first claim. In a seminal paper on conceptual modeling, its history and evolution, Mylopoulos (1992) defines conceptual modeling as "the activity of formally describing the physical and social world around us for the purpose of understanding and communication". Thus, since conceptual models are descriptions to be used by humans for understanding and communicating about reality, both the choices concerning the representation language adopted and the specific representation structures encoded in such language ought to play a role. However, frequently the choice between alternative representation structures can only be justified on ontological grounds. To show this, let us advance the following example.

Suppose we want to state that a red apple exists. In predicate calculus we would write down a logical formula such as

$$\exists x(apple(x) \wedge red(x)) \quad (1)$$

Although logic provides a rigorous way to assign this formula a precise semantics, its actual real-world interpretation is of course completely arbitrary. In particular, the predicates *apple* and *red* are put here in the same logical footing, regardless of the nature (i.e., the *ontological status*) of the entity types they represent and their different importance for conveying relevant information about a certain individual. First-order logic is indeed completely "flat" in this respect.

In order to overcome the "flatness" of logical languages, *structured* representation languages are adopted. To compare them to purely logical formalisms, Brachman (1979) has introduced the notion of a (so-called) *epistemological* level on top of the logical level. Part of the rationale behind this view is that representation formalisms should be designed to capture interrelations between pieces of knowledge that cannot be smoothly captured by purely logical languages.

Indeed, languages such as UML and EER offer powerful structuring constructs such as classes, relationships (attributes) and sub-classing relations. This means that, if we want to express formula in a language such as UML we would have to face the following structuring choices: either (a) consider that there are instances of Apple that posses the property of being red or, (b) consider that there are instances of Red things that have the property of being an Apple. Using a *many-sorted* logical formalism, we can state either:

$$\exists x{:}Apple.red(x) \qquad (2)$$

or

$$\exists x{:}Red.apple(x) \qquad (3)$$

Both these many-sorted formulas are equivalent to (1). However, they express very different knowledge structuring choices.

As discussed in (Guarino 1994), structuring decisions, such as this one, are not so much the result from heuristic considerations, but they rather reflect important ontological distinctions that should be motivated and explained. For instance, in this case, the choice (a) can reflect the assumption that the property of being an apple can be classified as a *Natural Kind* whereas Red as an *Attribution* (Guarino and Welty 2000; Guizzardi, Wagner, Guarino, and van Sinderen 2004). Whilst the former property necessarily holds for all its instances (an apple cannot cease to be an apple without ceasing to exist—we say the property is *rigid*), the latter only holds contingently (it is *not rigid*). Moreover, whilst the former supplies a *principle of identity* for its instances, i.e., a principle through which we judge whether two apples are numerically the same, the latter does not supply one (since knowing that *x* and *y* are both red gives no clue to decide whether or not *x=y*).

On the other hand, a formula like (3) sounds intuitively odd: what are we quantifying over? Do we assume the existence of ìinstances of rednessî that can have the property of being apples? The answer coming from philosophical ontology (Quine's (1969) dictum "no entity without identity") is that we should only quantify on things which do have a principle of identity. Insofar as *being red* does not supply such a principle, the structuring choice expressed by (3) cannot be justified. It may be important to note that, besides being well recognized in philosophy and in linguistics (van Leeuwen 1991; Gupta 1980), the role of identity principles is explicitly defended in conceptual modeling (e.g., Chen's (1976) design rationale for ER).

In summary, in many modeling cases, the motivation and explanation for choosing between structuring alternatives which are logically equivalent lies in ontological criteria. In particular, the example above illustrates a recurrent pattern in which a structuring choice results as non-justifiable only after the different ontological nature of the logical properties involved is taken into due account. In this case, the distinction is between rigid and non-rigid properties. It is noteworthy that these distinctions between properties, and the cognitive relevance of those properties that supply principles of identity are supported by a significant number of independent *scientific* experiments (Guizzardi 2005).

Contra Wyssusek, we claim that conceptual modelers are sometimes indeed working with ontological questions. Examples include: Is there one unique identity criterion for all objects? Is this type subsumed by multiple supertypes? Is there such a thing as a property of properties? Is this parthood relation transitive? Even one of the questions easily dismissed by the author, namely, "Is a community anything but the set of its members?" is a genuine ontological question (extensional identity criteria for intentional collectives) often recurring while modeling enterprises. Indeed, in our experience, there are dozens of recurrent conceptual modeling problems whose solution relies on answering ontological questions. In the sequel, we shall briefly mention just three of them.

(a) *Role modeling with multiple admissible types*: Suppose that a company has two kinds of customers: individual persons and organizations. Van Belle (1999) put the problem as follows: "How would one model the customer entity conceptually? The Customer as a supertype of Organisation and Person? The Customer as a subtype of Organisation and Person? The Customer as a relationship between or Organisation and (Organization or Person)?". This problem led Steimann (2000) for example, to propose a complete separation of role and type hierarchies in conceptual models – a solution that implies a radical transformation to the meta-models of most of the current conceptual modeling languages.

The ontological approach adopted in (Guizzardi et al. 2004) not only allowed to propose a more parsimonious solution to this problem, but also a general one that is captured in a general modeling pattern. The adequacy of this modeling pattern is also demonstrated by examples in that article. It is important to emphasize that the solution proposed could only be developed by analyzing the identity and behavior of different kinds of properties, represented by classifiers in conceptual modeling languages. The theory of universals, individuation and identity employed in that article, further refined in (Guizzardi 2005), is a genuine ontological theory.

(b) *Harmonization of different notions of roles and the counting problem*: Another topic discussed in (Steimann 2000) is the multitude of senses in which the notion of role is used in the conceptual modeling literature. Two of these senses have been deemed as largely incompatible, namely, (i) roles as a sort of anti-rigid universals exemplified by instances of certain admissible types, and (ii) roles as a sort of rigid universals exemplified by *ad-hoc* entities (so-called *qua-entities*). Examples of conceptual modeling approaches that assume the former sense abound (e.g., Guarino and Welty 2000; Steimann 2000). The latter sense has been proposed initially in (Wieringa, de Jonge, and Spruit 1995) to address a problem known as *The Counting Problem*, which has a serious impact on the everyday practice of conceptual modeling. In (Guizzardi 2005), by using a well-founded ontological theory based on philosophical literature we have been able to: (i) provide ontological interpretations for the two senses of roles aforementioned; (ii) harmonize these two notions by showing that they are not competing conceptions of the same entity type but that they are conceptions of complementary entity types; (iii) propose a solution to the Counting Problem.

(c) *Nature of parthood relations*: Parthood relations are important modeling concepts from several perspectives: (i) cognitive – for the realization of many important cognitive tasks (Tversky 1989); (ii) ontological – serving as a foundation for the formalization of other entities that compose a foundational ontology [16]; (iii) software design—some modal properties of part-whole relations will impose constraints on the life cycles of objects implementing these relations. Although the notion of parthood is represented in practically all conceptual modeling languages (e.g., OML, UML, EER, LINGO), it is often understood only superficially in these languages, incorporating merely the very minimal axiomatization that the notion requires. Properties of part-whole relations have been a much discussed theme in ontological research since Husserl's third Logical Investigation and Lesniewski's first Mereological System in 1916 (Simons 1987; Varzi 1996). Ontological questions answered by such theories include: What are the minimum meta-properties of parthood relations? Are parthood relations always transitive? Is there one unique kind of parthood relation irrespective of the kinds of the involved relata? What kind of relation holds the parts of a whole together? Are there objects that only exist being part of a specific whole (or of a whole of certain kind)? Are there objects that only exist having a specific object as part (or a part of a specific kind)?

To answer these questions, we need to combine ontological analysis with cognitive and linguistic considerations. In (Artale, Franconi, Guarino, and

Pazzi 1996), an extensive ontology-based analysis of modeling problems concerning parthood relations has been given; in (Guizzardi 2005) and (Vieu and Aurnague 2005), a solution to the difficult and recurrently discussed problem of transitivity of (functional) parthood relations has been offered, based on an ontological analysis of the notion of function and functional dependence.

In conclusion, we believe that the examples above bring enough evidence of the role played by ontological analysis in conceptual modeling.

Let us now go back to the second claim made by Wyssusek, i.e., that ontology is about "concrete objects". Indeed, reducing the inventory of reality to contain only this sort of entities results from a specific ontological choice made by Bunge, implicitly adopted by Wyssusek. However, many ontological theories countenance the existence of abstract entities. For instance, most theories that commit to the existence of repeatable universals accept the existence of universals as abstract patterns of features. Other examples of abstract entities typically considered as constituents of ontologies are numbers, sets, classes, forms, and regions. In fact, although, typically, a "concrete object" is defined as an object extended in time and space, Bunge seems to define concrete objects (or things) to be the set of things which are part of the world. Now, BUNGE's universals, albeit immanent, are not part of the world. As a consequence, according to this definition, his concept of law (a cornerstone of his theory) is not a concrete thing. Ergo, even for Bunge, in a strong sense, ontology cannot be only about concrete things.

Another part of Wyssusek's claim which reflects Bunge's specific ontological choices is the idea of *materialism*. Although Bunge's ontology commits to a reductionist monism, many other theories are, in contrast, *pluralist*, meaning that they conceive reality as organized in levels or strata which are not reducible to one another (Chmielecki 1998; Searle 2000). It is important then to emphasize that reductionism is merely one among other possible ontological choices (and for sure it is not generally accepted). Moreover, a non-reductionist ontology is not necessarily a non-scientific ontology.

Finally, ontology is not a one-branch discipline. In (Strawson 1959), the philosopher Peter Strawson draws a distinction between two kinds of ontological investigation, namely, *descriptive* and *revisionary metaphysics*. Descriptive metaphysics aims to lay bare the most general features of the conceptual scheme that are in fact employed in human activities, which is roughly that of common sense. The goal is to make explicit the ontological distinctions underlying natural language and human cognition. As a consequence, the categories refer to cognitive artifacts more or less depending on human perception, cultural imprints and social conventions (Masolo, Borgo, Gangemi, Guarino, and Oltramari 2003), and do not have necessarily to agree on the principles advocated by the natural sciences. Nonetheless, the very existence of these categories can often be empirically uncovered by research in cognitive sciences (Keil 1979; 1992; McNamara 1986; Xu 2004; Xu and Carey 1996; Xu and Baker 2003; Xu, Carey, and Quint 2004) in a manner that is analogous to the way philosophers of science have attempted to elicit the ontological commitments of the natural sciences. Revisionary metaphysics, conversely, is prepared to make departures from common sense in light of developments in science, and considers linguistic and cognitive issues of secondary importance (if considered at all).

Whilst a descriptive ontology aims at giving a correct account of the categories underlying human common sense, a revisionary ontology is committed to capture the intrinsic nature of the world in a way that is independent of conceptualizing agents. Nonetheless, the taxonomies of objects produced by both approaches can be shown to be to a large degree compatible with each other, if only we are careful to take into account the different granularities at which each operates (Smith and Brogaard 2002).

The conclusion is that although ontology might not be concerned with how humans structure their conceptions, it can certainly be concerned with categories underlying these conceptions. After all, as discussed by Chmielecki (1998), it is epistemology that desperately needs ontological foundations, not the other way around. To put it in different way, although it is true that structuring is about epistemology, and meaning is about semantics, the justification of both the validity of many structuring choices and of the grammaticality of many sentences can only be made on ontological grounds. For instance, it is a language issue that in patterns such as “Exactly five x were in the kitchen last night” and “The y which is the same as the z”, only the replacement of x, y and z by a common noun will render sentences which are grammatical. However, the reason why this is the case is, ultimately, an ontological one, namely: (i) both reference and quantification require the thing (or things) which are referred to or which form the domain of quantification to be determinate individuals, i.e., their conditions for individuation and identity must be determinate; (ii) only sortal universals can carry conditions for individuation and identity; (iii) common nouns are the linguistic counterparts of sortal universals.

In summary, we strongly disagree with the view defended in OFCM that claims the impossibility of developing ontological foundations for conceptual modeling. In fact, quite the contrary, we advocate that it is not only possible to develop these foundations, and in a scientific way, but also that this is a necessary step to be taken if conceptual modeling is to become a mature discipline with sound principles and practices. As Bunge himself recognizes, *every science presupposes some metaphysics*. However, ontology is not a one-branch discipline and, about this point, we also disagree with WAND and WEBER that a revisionist ontology such as BUNGE's would supply the best foundations for conceptual modeling. After all, an area concerned with creating models of reality for the purpose of understanding and communication, should commit to a foundational theory that, albeit ontological, takes human language and cognition seriously.

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