# Ontology as Meta-Theory: A Perspective

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**Abstract.** A significant research program involving the ontology of Mario Bunge has been underway for the past two decades to examine the theoretical underpinnings of information systems. In recent years there has been increasing doubt about founding such a program on a single ontology. This has culminated in an article by Boris Wyssusek in which the whole program of (philosophical) ontology in information systems more generally has been questioned. In this paper we address the question: Is there a role for ontology in information systems? We return to basic principles in addressing this question and in so doing we address the issues raised by Wyssusek's article.

## 1 Introduction

There has been much ado concerning ontology in informatics1 in recent years. This ontological discourse can be said to have started with the seminal work of Wand and Weber (1995) commenced in the mid-1980s. In their 1989 paper (Wand and Weber 1989) Wand and Weber were concerned with understanding the foundations of information systems models with the view to improving their relationship with the physical world being modeled. Their investigation of the link between model and system naturally gave rise to ontological questions and thus we have a burgeoning field of investigation into ontology in information systems and its use in meta-modeling.

In actuality this view is not completely accurate as there are several caveats to the use of the *Ontological Approach* in understanding and evaluating models and modeling theories. The first is that the ontology used is almost exclusively that of Mario Bunge (1977; 1979). In turn Bunge's ontology encourages a certain viewpoint when understanding information systems and consequently on the research stemming from Bunge's ontology.

The second is that models and meta-models are often confused in practice. Boris Wyssusek in his article suggests that this may be a confusion stemming from the use of Bunge's ontology as a meta-theory, although Bunge's ontology, just as Chisholm's ontology or Aristotle's ontology or any other ontology, simply assumes to outline what exists, and to explain the "furniture of world" (physical and non-physical) and no more. The usefulness of the *Ontological Approach* comes more from the comparisons that can be made of actual models and modeling languages (or theories/formalisms) rather than any more absolute statements about the acceptability or otherwise of any specific modeling language.

The third is that the terms and concepts, formulation, and hierarchy presented within any ontology, necessarily reflect the ontological commitments of the author and one cannot take the formalism without also adopting some of its ontological commitments.

These points are raised by Boris Wyssusek in his paper. Our paper is a response to Wyssusek's paper and aims to clarify, extend and investigate the use of ontology in informatics research. Before we can do that, however, it is worth reminding readers as to exactly what is ontology.

## 2 What is Ontology?

Ontology, as defined in the philosophical literature, is a mature and evolving field of study that questions the categories and nature of existence. It is related to epistemology and there are epistemological questions that arise from enquiries in ontology but ontology and epistemology are separate fields of enquiry. The following definitions of ontology cover its basic aims and scope of enquiry.

- "The study of being in so far as this is shared in common by all entities, both material and immaterial. It deals with the most general properties of beings in all their different varieties" (Kim and Sosa 1995).

- “Ontology, understood as a branch of metaphysics, is the science of being in general, embracing such issues as the nature of existence and the categorial structure of reality. […] Different systems of ontology propose alternative categorial schemes. A categorial scheme typically exhibits a hierarchical structure, with ‘being’ or ‘entity’ as the topmost category, embracing everything that exists” (Honderich 1995).

Any specific ontology defines the most general categories of “what exists”. It describes the nature of these categories and it tells us how these categories are related. It specifies what is needed to describe reality without specifying the instances of any category by expressing general terms and concepts so to do. Precisely because ontology does not aim to specify each instance of a category it plays the role of a meta-theory for theories or languages that do aim to describe instances. Further, for an ontology to have any meaning beyond the immediate it must provide categories so that reality can be described, in terms of those categories, at any point in time (either now, or in the future, or in the past). Examples of ontologies include Aristotle’s ontology, Brentano’s ontology, Bunge’s ontology and Chisholm’s ontology.

Every ontology comes equipped with a number of *philosophical commitments*, for example, Bunge’s ontology assumes a *materialist*, *scientific realism* which are its philosophical commitments while Chisholm’s ontology assumes a *commonsense realism,* which are its philosophical commitments. An ontology’s philosophical commitments are important as they influence the view of reality set down in the categories of the ontology, and in the nature of those categories.

An ontology, with its attendant philosophical commitments, may be incompatible with a certain epistemological stance. For instance, taking Boris Wyssusek’s example, an extreme materialist will preclude the use of phenomenological research methods, while a common-sense view would not reject a phenomenological research method.

# 3 Applying Ontology to Study Modeling Languages

If ontology is a classification of the “furniture of the world” (identifying those sorts of things that exist) then how can it help in the study of informatics? One of the chief reasons given in the literature for the use of ontology in informatics is to help study the modeling languages and their underpinning theories. It is worth restating the argument upon which this is based. We hold that there are three pillars that must guide the use of ontology in understanding modeling languages.

## 3.1 Pillar 1: Meta-Modeling not Modeling

The first point to note is that many, if not all, modeling languages have some form of underpinning theory. For the E-R family of models (Chen 1976) it is the theory of sets and relations, which also applies to object oriented notations, while UML's interaction diagrams (Booch et al. 1999) are not mathematically defined they do, however, have a rigorous definition that allows informal analysis. Automata (Aho et al. 1974; Eilenberg 1976; Peterson 1981; Johnsonbaugh 1997) and State-charts (Harrel 1987) too have their mathematical foundations and more recent systems theories such as, Process Algebra (Hoare 1985; Milner 1989), Modal and Temporal Logics (Stirling 1995; Fitting and Mendelsohn 1999), are based on logic, and Port-Hamiltonian networks (van der Schaft and Schumacher 2000) are founded in mathematical physics. This list hardly scratches the surface. To use an ontology as yet another modeling language ignores the progress made over the past decades in systems theory and loses richness in the ontology.

Rather than seeking yet another underpinning theory for modeling notations, we seek instead to better understand the efficacy of different approaches and the implicit ways in which each captures the world. For this use, ontology is entirely appropriate. Our manifestation of this is to use an ontology to explore the meta-theory implicit in a given modeling language.

Further, we claim that we are modeling a reality, whether it has been realized at this point of time or not, not undertaking conceptual modeling. As Barry Smith (2004) argues, the standard term, "conceptual modeling", is a misnomer. What we are really doing is modeling reality, whether it is our current reality, a past reality, or a future reality. For example, one may be using UML to design a software artifact. By so doing one is envisaging a future reality where the software system exists. Models enable us to understand aspects of the future system. Ontology is entirely appropriate to assess the fit of a modeling language to undertake task from a particular viewpoint.

## 3.2 Pillar 2: No 'Gold Standard'

Ontologies provide a catalogue of what exists according to the philosophical commitments of the author. Change the philosophical commitments and the ontology itself is different. Further, even within the same school of philosophical commitments, different ontologies will cut the world differently. For example, some will concentrate on endurants (focusing on things that have existence over time) while others will cut the world according to perdurants (focusing on processes, events, and the like).

So, what is the best ontology with which to assess modeling languages? Each ontology captures a certain viewpoint from its philosophical commitments and so gives a different perspective on the modeling language. The logical result is that there cannot be one 'gold standard' ontology that will suffice for all meta-model evaluations.

### 3.3 Pillar 3: Methods are Critical

What then are appropriate methods by which to explore the meta-models of modeling languages? Based on the other pillars, we envisage two methods: *ontological evaluation* and *ontological comparison*. The aim of the method of ontological evaluation is to compare the ontology embodied in a modeling language with a reference ontology selected from the range of ontologies available. Further, in conducting an ontological evaluation we are seeking to provide qualitative answers, for specific modeling languages, to questions such as:

- How well does the modeling language capture reality relative to an ontology?
- How similar are a range of modeling languages? (having conducted ontological evaluations of a range of modeling languages using a particular reference ontology)

How then are the two methods constructed and what is the critical element in their conduct? We address this in the following two sections.

## 4 The Method of Ontological Evaluation

The method of ontological evaluation has four basic steps. *Step 1*: Determine the set of concepts from the reference ontology to be used in a forward evaluation. This set of concepts we call the reference concepts. *Step 2*: Determine the set of concepts from the ontology (meta-theory) implicit but embodied in the modeling language to be used in a backward evaluation. This set of concepts we call the modeling concepts. *Step 3*: Perform a forward and backward evaluation of the two sets of concepts and tabulate the results. *Step 4*: Analyse the results. We elaborate below.

The first step is to determine the basic set of concepts on which the forward evaluation will be based. The chosen concepts must be appropriate for the modeling language under study. When studying data modeling languages, for example, only the static or structural concepts are required because that is the common nature of the data modeling languages.

The second step resembles the first and involves determining the set of concepts from the modeling language. Each modeling language will have a different group of terms and concepts for modeling. For example, the E-R language uses different terms from that used by UML.

The third step involves the 'two way' comparison of concepts from each of the reference ontology and the ontology embodied in concepts from a modeling language. It is performed utilising concepts from the modeling language as well as the reference ontology according to our convictions earlier articulated as Pillar 2—the reference ontology is not the only theory in that other reference ontologies could be used. Nor is the reference ontology necessarily better than the ontology embodied in any modeling language. Further, the comparison is at the level of concepts behind terms thus moving beyond the specific names or terms used to signify the concepts.

The relationship between terms in an ontology and a modeling language and their concepts is explained and presented through semiotics: Each term through its associated concept in a reference ontology or the ontology of a modeling language, spans part of a semantic field (Eco 1976), or conceptual plane (Culler 1976; Cruse 2000). Alternatively, each term from an ontology possesses an essential depth (Liska 1996) which similarly evokes the conceptual span of a term.

Using the idea of degree of overlap in semantic field or conceptual plane, one can build a picture of how much an ontology's terms and concepts are reflected in those of a modeling language. Critically, however, conceptually evaluating a modeling language using an ontology reveals the story behind the indicative results from step 3. The analysis of the qualitative results presents issues beyond the direct comparison of concepts and is used to explore the nature of the gaps in coverage that are evident from the results as presented in Step 3 and the implications of these on the modeling language under study.

# 5 The Method of Conceptual Comparison

The method of conceptual comparison seeks to compare a number of modeling languages by analysing the results of conducting a series of ontological evaluations against a reference ontology. The method consists of repeated applications of the method of ontological evaluation against a range of different modelling languages. The results indicate the degree to which the reference ontology is reflected in the ontology of that range. In conducting the series of ontological evaluations we are testing each language against the selected and independent view of reality as represented by a reference ontology.

As a direct consequence, the method of conceptual comparison can be used to determine how wide spread and to what degree a reference ontology is reflected in the ontologies implicit in a range of modeling languages. The analysis of results sheds light on the ontological dominance of a reference ontology with a range of modeling languages.

# 6 Conclusion

Our aim in this paper has been to re-iterate our position regarding ontologies and the use of ontologies to shed light on efficacy of modeling languages.

Based on our approach, we hold to three principles for applying ontology in informatics. Firstly, that ontology is about understanding meta-models not models themselves. This way ontology is most useful in analyzing the meta-theoretic commitments implicit in modeling tools, and, indeed the categories in a specific ontology can only be used at the meta—theoretic level. Secondly, that no one, best ontology exists. There is likely to be a range of ontologies that can inform our modelling theories. Thirdly, that carefully established methods based on the concepts contained in, and the philosophy of, ontologies are critical to the success of ontological evaluations in informatics. In this way it is the philosophy and the meaning of categorial commitments that have a more fundamentally important role in methods than the formalisms (if relevant) of an ontology.

Concluding, the principles we hold go a long way to addressing the issues raised by Boris Wyssusek. Firstly, we acknowledge that there is no best ontology for use in informatics. Secondly, that it is the terms, concepts, and philosophy that define an ontology not the notation each ontology may require for (formal) expression. Further, that not all ontologies can be expressed formally. Thirdly, that method must utilise all that ontology has to offer for ontology to be useful in informatics.

# Notes

1. By "informatics" we broadly intend computer science, information systems, and software engineering and related disciplines.

# References


Aho, A. V., Hopcroft, J. E., and Ullman, J. D., *The Design and Analysis of Computer Algorithms*, Addison-Wesley, Reading, 1974.

Booch, G., Rumbaugh, J., and Jacobson, I., *The Unified Modelling Language User Guide*, Addison-Wesley, Reading, 1999.

Bunge, M., *Treatise On Basic Philosophy: Volume 3: Ontology I: The Furniture of the World*, Reidel, Dordrecht, 1977.

Bunge, M., *Treatise On Basic Philosophy: Volume 4: Ontology II: A World of Systems*, Reidel, Dordrecht, 1979.

Chen, P. P., "The entity-relationship model—toward a unified view of data," *ACM Transactions on Database Systems* (1:1), 1976, pp. 9–36.

Cruse, D. A., *Meaning in Language: An Introduction to Semantics and Pragmatics*, Oxford, Oxford University Press, 2000.

Culler, J. D., *Ferdinand de Saussure*, Fontana, London, 1976.

Eco, U., *A Theory of Semiotics*, Indiana University Press, Bloomington, 1976.

Eilenberg, S., *Automata, Languages and Machines*, Academic Press, New York, 1976.

Fitting, M., and Mendelsohn, R. L., *First-Order Modal Logic*, Kluwer, Dordrecht, 1999.

Harrel, D., "Statecharts: a visual formalism for complex systems," *Science of Computer Programming*, (8:3), 1987, pp. 231–274.

Hoare, C. A. R., *Communicating Sequential Processes*, Prentice-Hall, Englewood Cliffs, 1985.

Honderich, T. (ed.), *The Oxford Companion to Philosophy*, Oxford University Press, Oxford, 1995.

Johnsonbaugh, R., *Discrete Mathematics*, Prentice-Hall, Upper Saddle River, 1997.

Kim, J. and Sosa, E. (eds.), *A Companion to Metaphysics. Blackwell Companions to Philosophy*, Blackwell, Oxford, 1995.

Liska, J. J., *A General Introduction to the Semeiotic of Charles Sanders Peirce*, Indiana University Press, Bloomington, 1996.

Milner, R., *Communication and Concurrency*, Prentice-Hall, New York, 1989.

Peterson, J., *Petri Net Theory and the Modelling of Systems*, Prentice-Hall, Englewood Cliffs, 1981.

Smith, B., “Beyond concepts: ontology as reality representation,” in *Formal Ontology in Information Systems*, A. Varzi and L. Vieu (eds.), IOS Press, Amsterdam, 2004, pp. 73–84.

Stirling, C., “Modal and temporal logics for processes,” in *Logics for Concurrency (Structure versus Automata)*, F. Moller and G. Birtwistle (eds.), Springer, Berlin, 1996, pp. 149–237.

van der Schaft, A. J., and Schumacher, J. M., *An Introduction to Hybrid Dynamical Systems*, Springer, London, 2000.

Wand, Y., and Weber, R., “An ontological evaluation of systems analysis and design methods,” in *Information Systems Concepts: An In-depth Analysis*, E. D. Falkenberg and P. Lindgreen (eds.), Elsevier, Amsterdam, 1989, pp. 79–107.

Wand, Y., and Weber, R., “On the deep structure of information systems,” *Information Systems Journal*, (5:3), 1995, pp. 203–223.