Ontology & Computers

URL: http://en.wikipedia.org/wiki/Ontology (adapted/edited)

Ontology is a study of conceptions of reality and the nature of being. In philosophy, **ontology** (from the Greek ὤν, genitive ὄντος: of being (part. of εἶναι: to be) and -λογία: science, study, theory) is the study of being or existence and forms the basic subject matter of **metaphysics**. It seeks to describe or posit the basic categories and relationships of being or existence to define entities and types of entities within its framework.

Some philosophers, notably of the **Platonic** school, contend that all nouns refer to entities. Other philosophers contend that some nouns do not name entities but provide a kind of shorthand way of referring to a collection (of either objects or events). In this latter view, mind, instead of referring to an entity, refers to a collection of mental events experienced by a person; society refers to a collection of persons with some shared interactions, and geometry refers to a collection of a specific kind of intellectual activity.

As a philosophical subject, **ontology** chiefly deals with the precise utilization of words as descriptors of entities or realities. Any **ontology** must give an account of which words refer to entities, which do not, why, and what categories result. When one applies this process to nouns such as electrons, energy, contract, happiness, time, truth, causality, and God, **ontology** becomes fundamental to many branches of **philosophy**.

Ontology has one basic question: **"What exists?"** Different philosophers provide different answers to this question.

One common approach is to divide the extant entities into groups called **"categories".** However, these lists of categories are also quite different from one another. It is in this latter sense that **ontology** is applied to such fields as theology, information science and artificial intelligence.

Further examples of ontological questions include:

- What is **existence**? Is existence a ***property***? What does it mean to say something does not exist? Is existence properly a ***predicate***? Are sentences expressing the existence or non-existence of something properly called ***propositions***?
- What is an **object**? Can one give an account of [what it means to say that an object exists]?
- What could it mean to say that non-physical objects (such as times, numbers, souls, or deities) exist?
- What constitutes the **identity** of an object? When does an object go out of existence, as opposed to changing?
- What features are essential, as opposed to merely accidental, attributes of a given object? What are an object's properties or relations and how are they related to the object itself?

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URL: http://www.formalontology.it/section_4.htm (adapted/edited)

Definitions of Ontology

From Christian Wolff to Edmund Husserl

INTRODUCTION

a) *One of the best available dictionaries gives the following definition of Ontology*:

> "1. A science or study of being: specifically, a branch of metaphysics relating to the nature and relations of being; a particular system according to which problems of the nature of being are investigated; first philosophy.
>
> 2. a theory concerning the kinds of entities and specifically the kinds of abstract entities that are to be admitted to a language system."(1)

b) *The first sense is commonly used in the philosophical tradition:*

> "In contemporary philosophy, formal ontology has been developed in two principal ways. The first approach has been to study formal ontology as a part of ontology, and to analyse it using the tools and approach of formal logic: from this point of view formal ontology examines the logical features of predication and of the various theories of universals. The use of the specific paradigm of the set theory applied to predication, moreover, conditions its interpretation.
>
> The second line of development returns to its Husserlian origins and analyses the fundamental categories of object, state of affairs, part, whole, and so forth, as well as the relations between parts and the whole and their laws of dependence - once all material concepts have been replaced by their correlative form concepts relative to the pure 'something'. This kind of analysis does not deal with the problem of the relationship between formal ontology and material ontology."(2)

c) *The second sense is used in research on Artificial Intelligence and Knowledge Representation; one of the best known definitions is Tom Gruber's:*

> "An *ontology* is an explicit specification of a conceptualization.
>
> The term is borrowed from philosophy, where an ontology is a systematic account of Existence. For knowledge-based systems, what "exists" is exactly that which can be represented. When the knowledge of a domain is represented in a declarative formalism, the set of objects that can be represented is called the universe of discourse. This set of objects, and the describable relationships among them, are reflected in the representational *vocabulary* with which a knowledge-based program represents knowledge. Thus, we can describe the ontology of a program by defining

a set of representational terms. In such an ontology, definitions associate the names of entities in the universe of discourse (e.g., classes, relations, functions, or other objects) with human-readable text describing what the names are meant to denote, and formal axioms that constrain the interpretation and well-formed use of these terms." (3)

This definition has been criticized by Nicola Guarino that, after examining seven possible interpretations of ontology, (4) *writes:*

"A starting point in this clarification effort will be the careful analysis of the interpretation adopted by Gruber. The main problem with such an interpretation is that it is based on a notion of conceptualization (introduced in: Genesereth, Michael R. and Nilsson, L. "Logical Foundation of Artificial Intelligence" Morgan Kaufmann, Los Altos, California, 1987) which doesn't fit our intuitions, (...): according to Genesereth and Nilsson, a conceptualization is a set of extensional relations describing a particular state of affairs, while the notion we have in mind is an intensional one, namely something like a conceptual grid which we superimpose to various possible state of affairs. We propose in this paper a revised definition of a conceptualization which captures this intensional aspect, while allowing us to give a satisfactory interpretation to Gruber's definition." (5) Guarino gives this definition: "Since this paper is deliberately addressed to an interdisciplinary audience, it is advisable to pay attention to some preliminary terminological clarifications, especially because some crucial terms appear to be used with different senses in different communities'. Let us first consider the distinction between "Ontology" (with the capital "o"), as in the statement "Ontology is a fascinating discipline" and "ontology" (with the lowercase "o"), as in the expressions "Aristotle's ontology" or "CYC's ontology". The same term has an uncountable reading in the former case, and a countable reading in the latter. While the former reading seems to be reasonably clear (as referring to a particular philosophical discipline), two different senses are assumed by the philosophical community and the Artificial Intelligence community (and, in general, the whole computer science community) for the latter term.

In the philosophical sense, we may refer to an ontology as a particular system of categories accounting for a certain vision of the world. As such, this system does not depend on a particular language: Aristotle's ontology is always the same, independently of the language used to describe it. On the other hand, in its most prevalent use in AI, an ontology refers to an engineering artifact, constituted by a specific vocabulary used to describe a certain reality, plus a set of explicit assumptions regarding the intended meaning of the vocabulary words. This set of assumptions has usually the form of a first-order logical theory, where vocabulary words appear as unary or binary predicate names, respectively called concepts and relations. In the simplest case, an ontology describes a hierarchy of concepts related by subsumption relationships; in more sophisticated cases, suitable axioms are added in order to express other relationships between concepts and to constrain their intended interpretation.

The two readings of ontology described above are indeed related each other, but in order to solve the terminological impasse we need to choose one of them, inventing a new name for the other: we shall adopt the AI reading, using the word conceptualization to refer to the philosophical reading. So two ontologies can be different in the vocabulary used (using English or Italian words, for instance) while sharing the same conceptualization." (6)

(1) *Webster's Third New International Dictionary*

(2) Liliana Albertazzi - "*Formal and material ontology*" in: Roberto Poli & Peter Simons (ed.) - "Formal Ontology" - Kluwer 1996 p. 199

(3) Tom Gruber "*A translation approach to portable ontology specifications*". In: *Knowledge Acquisition* 5, (1993) pp. 199-220

(4) Nicola Guarino - "*Ontologies and Knowledge Bases. Towards a terminological clarification*" (1995) p. 1

(5) ibid. p. 2

(6) Nicola Guarino "*Formal ontology and information systems*". In: N. Guarino (ed.), *Formal Ontology in Information Systems*. Proceedings of the First International Conference, Trento, Italy, 6-8 June 1998. IOS Press, 1998 p. 4

URL: http://www.formalontology.it/history.htm (adapted/edited)

History of Ontology

To begin with we want to state that **ontology** should be seen only as an interdiscipline involving both philosophy and science. It is a discipline which points out the problems of the foundations of the sciences as well as the borderline questions, and which further attempts to solve these problems and questions. **Ontology** is not a discipline which exists separately and independently from all the other scientific disciplines and also from other branches of philosophy. Rather, **ontology** derives the ***general structure of the world***; it obtains the structure of the world as it really is from knowledge embodied in other disciplines. If one examines the history of philosophy one sees that **ontology** has never solved or attempted to solve the questions about the structures of our world independently, apart from the other philosophical disciplines or apart from the sciences. As is expressed by this symposium's topic, **"Language and Ontology"**, **ontology** has derived the world's structure from other disciplines which describe reality, and has thus relied upon the languages of other disciplines. A common belief is that this derivation of the world's most general structures from the knowledge of other disciplines is **ontology**'s only task. But now the belief is that in doing **ontology** one always selects the most important and most general laws from among all the laws which the various disciplines have to offer at any given time. Further, the **ontologist** interprets and generalizes those laws and must endeavor to establish certain of them as the most fundamental and general structures of our world.

If **ontology** is a discipline which uses knowledge from various other disciplines then it is obvious that, in the course of the history of philosophy, **ontology** must have developed in a most dramatic fashion. If we look at the actual history of **ontology** we find confirmation of our claim. **Ontology** mirrors, so to speak, the level of our knowledge of the world at any given time. For instance, **Plato** and the **Platonists** have assumed that one could derive our world's most general empirical structures from an ideal world of **Platonic Forms**. Of this world of **Forms** it is said that one can experience it intuitively and that its existence has to be presupposed ***a priori***. For this derivation, one needs only two relations, ***methexis*** and ***parousia***. **"Methexis"** means "participation" or what we would call "representation"; **"parousia"** means "manifestation" (of the ideas in the world) or what we would call "interpretation". These ontological procedures are explained in **Plato**'s ***Parmenides***.

For **Aristotle**, the main task of philosophy was not to perceive the world of ideas, but to experience the empirical world and acquire knowledge about it (***Metaphysics***, Chapter 9). He created the first system of **ontology** in the form of an **ontology** of substances. **Aristotle**'s search for the world's true structures is interestingly opposed to **Plato**'s. For **Aristotle** the ***general properties of things***, that is, those properties of things which constitute their ***invariant form***, have to be found through a cognitive process. These general properties of things are ***universal structures or patterns***. These universal patterns are to be defined and axiomatized. For this task one calls on logic for help. The end result is that **universals** become generally comprehensible.

Here one may ask as **Porphyry** did what **universals** really are. The answers that have been proposed are numerous. They include: **Platonic** ideas, substances residing in things, concepts or representations in the human mind (**conceptualism**), terms or predicates contained in our language (**nominalism**), and mathematical-theoretical constructs in the languages of present day theories. The question about the very nature of universals (**general structures**) has occupied philosophy and the sciences up to the present day as one can see in reading **Heisenberg**'s dialogues with **Schrödinger** where this question is discussed at length.

In the Middle Ages the concern with **universals** continued. Various elaborate systems evolved, including, importantly, varieties of **conceptualism** and **nominalism**. A decisive turn in the history of **ontology** is connected with the writings of **Goclenius**, **Wolff**, and **Leibniz**. **Goclenius** needs to be mentioned for he is credited with the first use of the term **'ontology'**. Like all **ontologies**, so also **Wolff**'s, has to be made dependent upon the level of knowledge existing at his time. Knowledge for **Wolff** is logical knowledge. He established the interdisciplinary character of his **ontology** by deriving the most **general laws of nature and of all things** from the principles of a logic derived from **Leibniz**. According to **Wolff**, it is one of the basic **ontological** structures of everything that exists, that the ***principle of non-contradiction*** and the ***principle of sufficient reason*** are valid in all merely possible worlds in addition to the real world.

Kant rejected **Wolff**'s logic as metaphysical and **Platonistic**. Therefore **Kant** rejected also **Wolff**'s **ontology**. Instead of traditional logic, **Kant** introduced his own ***transcendental logic***. This transcendental logic may be seen as a cognitively oriented method which is founded on concepts. If one wants to gain knowledge, then, according to **Kant**, only those categories (or most general concepts) may be used which fulfill certain spatio-temporal conditions when they are applied. These categories are of subjective origin, that is, created by the human mind. It is a scientific theory, namely, **Newton**'s physics, which furnishes the natural laws which are the basis of **Kant**'s **ontology**. In his **epistemology** (an "auxiliary discipline" of his **ontology** which is contained in the ***Critique of Pure Reason***), **Kant** methodologically explains **Newton**'s physics.

Leibniz's logic stands in the same relationship to **Wolff**'s **ontology**, as the natural laws of **Newton**'s physics and **Kant**'s own **epistemology** stands to **Kant**'s **ontology**. But for **Kant** it is not the world of things-in-themselves which determines his **ontology** but the spatio-temporal categorial system of relations of the phenomena. It is important that here **ontology** can be clearly separated from **epistemology**. **Kant**'s **epistemology** is a ***metatheory*** of the cognitive presuppositions and methods of classical physics. **Kant**'s categorial **ontology** derives from natural laws which are supported and confirmed by empirical evidence of the general structures of the world -- the classical physical world, as we would say today. With this, **ontology** became an interdiscipline, since it is here that for the first time in the history of philosophy and science that scientific results were thoroughly (philosophically) generalized. This is also an important point in the development of the ***ontology of the sciences***. The ***ontology of the sciences*** has progressed enormously in the twentieth century, since many scientific theories with their specialized, cognitively oriented languages and with their specialized mathematical methods did not originate before the twentieth century. Up to now, the ***ontology of the sciences*** is the last chapter of the history of **ontology**.

After **Kant**, **ontology** developed in several directions. **Ontology** of the sciences evolved in **Neo-Kantianism**, **Positivism** and **Neo-positivism**, the philosophy of the ***Vienna Circle***, and in contemporary philosophy of science. On the other side stands **phenomenological ontology**. Phenomenological ontology expanded **Kant**'s phenomenological "reduction" of the world. Its climax is **Husserl**'s **phenomenology** in which the world itself becomes the (world) phenomenon. The world's basic structures exist exactly in that way in which they are experienced (phenomenologically) by human beings. The construction and the structure of the world "happen" in man's pure intentional consciousness ***vis-à-vis*** reality. According to **Husserl**, mathematics and logic also participate in the constitution of the world out of the phenomena. This constitution has a semantical character but happens, nevertheless, without language. **Heidegger**'s fundamental ontology, on the other hand, speaks of an anti-logical and anti-scientific basic experience, which is said to be paramount to all scientific knowledge.

The next decisive step in the development of **ontology** was the result of another development, which had reached its climax in the twentieth century, the development of **formal logic**. Formal logic, and, in union with it, **analytic philosophy**, often show the tendency to dissolve

epistemology into **syntax** and **semantics**, and even **pragmatics**. The syntactical semantic functions, the reference relation, etc., could, in turn, be based upon the respective functions of language, be it ordinary language or the language of the sciences. **Wittgenstein**'s ***reduction of thinking*** to the linguistic medium became an object of a philosophical position whose task was to explain and clarify language. As a result, the **ontology** of the sciences acquires features which are best characterized by "regional linguistic **ontology**". An important result of **Wittgenstein**'s reduction of thinking to language was the dissolution of conceptualistic **ontology**.

From: Werner Leinfellner, Eric Kraemer and Jeffrey Schank (eds.) - *Language and Ontology. Proceedings of the Sixth International Wittgenstein Symposium. 23th to 30th August 1981 Kirchberg am Wechsel (Austria)* - Wien, Hölder-Pichler-Tempsky, 1982, *Preface by The Editors* pp. 18-20.

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URL: http://www-ksl.stanford.edu/kst/what-is-an-ontology.html

What is an Ontology?

This definition was originally proposed in 1992 [http://www-ksl.stanford.edu/KSL_Abstracts/KSL-92-71.html] *and posted as shown below. See an updated definition of ontology (computer science)* [http://tomgruber.org/writing/ontology-definition-2007.htm] *that accounts for the literature before and after that posting, with links to further readings.*

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Short answer:

An ontology is a specification of a conceptualization.

The word "ontology" seems to generate a lot of controversy in discussions about AI. It has a long history in philosophy, in which it refers to the subject of existence. It is also often confused with epistemology, which is about knowledge and knowing.

In the context of knowledge sharing, I use the term ontology to mean a *specification of a conceptualization*. That is, an ontology is a description (like a formal specification of a program) of the concepts and relationships that can exist for an agent or a community of agents. This definition is consistent with the usage of ontology as set-of-concept-definitions, but more general. And it is certainly a different sense of the word than its use in philosophy.

What is important is what an ontology is *for*. My colleagues and I have been designing ontologies for the purpose of enabling knowledge sharing and reuse. In that context, an ontology is a specification used for making ontological commitments. The formal definition of ontological commitment is given below. For pragmetic reasons, we choose to write an ontology as a set of definitions of formal vocabulary. Although this isn't the only way to specify a conceptualization, it has some nice properties for knowledge sharing among AI software (e.g., semantics independent of reader and context). Practically, an ontological commitment is an agreement to use a vocabulary (i.e., ask queries and make assertions) in a way that is consistent (but not complete) with respect to the theory specified by an ontology. We build agents that commit to ontologies. We design ontologies so we can share knowledge with and among these agents.

This definition is given in the article:

T. R. Gruber. A translation approach to portable ontologies. *Knowledge Acquisition*, 5(2):199-220, 1993. Available on line.
[http://tomgruber.org/writing/ontolingua-kaj-1993.htm]

A more detailed description is given in

T. R. Gruber. Toward principles for the design of ontologies used for knowledge sharing. Presented at the Padua workshop on Formal Ontology, March 1993, later published in *International Journal of Human-Computer Studies*, Vol. 43, Issues 4-5, November 1995,

pp. 907-928. Available online.
[http://tomgruber.org/writing/onto-design.htm]

With an excerpt attached.

Ontologies as a specification mechanism

A body of formally represented knowledge is based on a *conceptualization*: the objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them (Genesereth & Nilsson, 1987) . A conceptualization is an abstract, simplified view of the world that we wish to represent for some purpose. Every knowledge base, knowledge-based system, or knowledge-level agent is committed to some conceptualization, explicitly or implicitly.

An **ontology** is an explicit specification of a conceptualization. The term is borrowed from philosophy, where an Ontology is a systematic account of Existence. For AI systems, what "exists" is that which can be represented. When the knowledge of a domain is represented in a declarative formalism, the set of objects that can be represented is called the universe of discourse. This set of objects, and the describable relationships among them, are reflected in the representational vocabulary with which a knowledge-based program represents knowledge. Thus, in the context of AI, we can describe the ontology of a program by defining a set of representational terms. In such an ontology, definitions associate the names of entities in the universe of discourse (e.g., classes, relations, functions, or other objects) with human-readable text describing what the names mean, and formal axioms that constrain the interpretation and well-formed use of these terms. Formally, an ontology is the statement of a logical theory.[1]

We use common ontologies to describe *ontological commitments* for a set of agents so that they can communicate about a domain of discourse without necessarily operating on a globally shared theory. We say that an agent **commits** to an ontology if its observable actions are consistent with the definitions in the ontology. The idea of ontological commitments is based on the Knowledge-Level perspective (Newell, 1982) . The Knowledge Level is a level of description of the knowledge of an agent that is independent of the symbol-level representation used internally by the agent. Knowledge is attributed to agents by observing their actions; an agent "knows" something if it acts *as if* it had the information and is acting rationally to achieve its goals. The "actions" of agents---including knowledge base servers and knowledge-based systems--- can be seen through a tell and ask functional interface (Levesque, 1984) , where a client interacts with an agent by making logical assertions (tell), and posing queries (ask).

Pragmatically, a common ontology defines the vocabulary with which queries and assertions are exchanged among agents. Ontological commitments are agreements to use the shared vocabulary in a coherent and consistent manner. The agents sharing a vocabulary need not share a knowledge base; each knows things the other does not, and an agent that commits to an ontology is not required to answer all queries that can be formulated in the shared vocabulary.

In short, a commitment to a common ontology is a guarantee of consistency, but not completeness, with respect to queries and assertions using the vocabulary defined in the ontology.

Notes

[1] Ontologies are often equated with taxonomic hierarchies of classes, but class definitions, and the subsumption relation, but ontologies need not be limited to these forms. Ontologies are also not limited to conservative definitions, that is, definitions in the traditional logic sense that only introduce terminology and do not add any knowledge about the world (Enderton, 1972) . To specify a conceptualization one needs to state axioms that do constrain the possible interpretations for the defined terms.

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URL: http://tomgruber.org/writing/ontology-definition-2007.htm (slightly adapted/edited)

Ontology

by Tom Gruber
[http://tomgruber.org/]

to appear in the ***Encyclopedia of Database Systems***, Ling Liu and M. Tamer Özsu (Eds.), Springer-Verlag, 2008.

Synonyms

computational ontology, semantic data model, ontological engineering

Definition

In the context of computer and information sciences, an ontology defines a set of representational primitives with which to model a domain of knowledge or discourse. The representational primitives are typically classes (or sets), attributes (or properties), and relationships (or relations among class members). The definitions of the representational primitives include information about their meaning and constraints on their logically consistent application. In the context of database systems, ontology can be viewed as a level of abstraction of data models, analogous to hierarchical and relational models, but intended for modeling knowledge about individuals, their attributes, and their relationships to other individuals. Ontologies are typically specified in languages that allow abstraction away from data structures and implementation strategies; in practice, the languages of ontologies are closer in expressive power to first-order logic than languages used to model databases. For this reason, ontologies are said to be at the "semantic" level, whereas database schema are models of data at the "logical" or "physical" level. Due to their independence from lower level data models, ontologies are used for integrating heterogeneous databases, enabling interoperability among disparate systems, and specifying interfaces to independent, knowledge-based services. In the technology stack of the Semantic Web standards [1], ontologies are called out as an explicit layer. There are now standard languages and a variety of commercial and open source tools for creating and working with ontologies.

Historical Background

The term "ontology" comes from the field of philosophy that is concerned with the study of being or existence. In philosophy, one can talk about an ontology as a theory of the nature of existence (e.g., Aristotle's ontology offers primitive categories, such as substance and quality, which were presumed to account for All That Is). In computer and information science, ontology is a technical term denoting an artifact that is designed for a purpose, which is to enable the modeling of knowledge about some domain, real or imagined.

The term had been adopted by early Artificial Intelligence (AI) researchers, who recognized the applicability of the work from mathematical logic [6] and argued that AI researchers could create new ontologies as computational models that enable certain kinds of automated reasoning [5]. In the 1980's the AI community came to use the term ontology to refer to both a theory of a modeled world (e.g., a Naïve Physics [5]) and a component of knowledge systems. Some researchers, drawing inspiration from philosophical ontologies, viewed computational ontology as a kind of applied philosophy [10].

In the early 1990's, an effort to create interoperability standards identified a technology stack that called out the ontology layer as a standard component of knowledge systems [8]. A widely cited web page and paper [3] associated with that effort is credited with a deliberate definition of ontology as a technical term in computer science. The paper defines ontology as an "explicit specification of a conceptualization," which is, in turn, "the objects, concepts, and other entities that are presumed to exist in some area of interest and the relationships that hold among them." While the terms specification and conceptualization have caused much debate, the essential points of this definition of ontology are

- An ontology defines (specifies) the concepts, relationships, and other distinctions that are relevant for modeling a domain.
- The specification takes the form of the definitions of representational vocabulary (classes, relations, and so forth), which provide meanings for the vocabulary and formal constraints on its coherent use.

One objection to this definition is that it is overly broad, allowing for a range of specifications from simple glossaries to logical theories couched in predicate calculus [9]. But this holds true for data models of any complexity; for example, a relational database of a single table and column is still an instance of the relational data model. Taking a more pragmatic view, one can say that ontology is a tool and product of engineering and thereby defined by its use. From this perspective, what matters is the use of ontologies to provide the representational machinery with which to instantiate domain models in knowledge bases, make queries to knowledge-based services, and represent the results of calling such services. For example, an API to a search service might offer no more than a textual glossary of terms with which to formulate queries, and this would act as an ontology. On the other hand, today's W3C Semantic Web standard suggests a specific formalism for encoding ontologies (OWL), in several variants that vary in expressive power [7]. This reflects the intent that an ontology is a specification of an abstract data model (the domain conceptualization) that is independent of its particular form.

Scientific Fundamentals

Ontology is discussed here in the applied context of software and database engineering, yet it has a theoretical grounding as well. An ontology specifies a vocabulary with which to make assertions, which may be inputs or outputs of knowledge agents (such as a software program). As an interface specification, the ontology provides a language for communicating with the agent. An agent supporting this interface is not required to use the terms of the ontology as an internal encoding of its knowledge. Nonetheless, the definitions and formal constraints of the ontology do put restrictions on what can be meaningfully stated in this language. In essence, committing to an ontology (e.g. supporting an interface using the ontology's vocabulary) requires that statements that are asserted on inputs and outputs be logically consistent with the definitions and constraints of the ontology [3]. This is analogous to the requirement that rows of a database table (or insert statements in SQL) must be consistent with integrity constraints, which are stated declaratively and independently of internal data formats.

Similarly, while an ontology must be formulated in some representation language, it is intended to be a semantic level specification -- that is, it is independent of data modeling strategy or implementation. For instance, a conventional database model may represent the identity of individuals using a primary key that assigns a unique identifier to each individual. However, the primary key identifier is an artifact of the modeling process and does not denote something in the domain. Ontologies are typically formulated in languages which are closer in expressive power to logical formalisms such as the predicate calculus. This allows the ontology designer to be able to state semantic constraints without forcing a particular encoding strategy. For example, in typical ontology formalisms one would be able to say that an individual was a member of class or has some attribute value without referring to any implementation patterns such as the use of primary key identifiers. Similarly, in an ontology one might represent constraints that hold across relations in a simple declaration (A is a subclass of B), which might be encoded as a join on foreign keys in the relational model.

Ontology engineering is concerned with making representational choices that capture the relevant distinctions of a domain at the highest level of abstraction while still being as clear as possible about the meanings of terms. As in other forms of data modeling, there is knowledge and skill required. The heritage of computational ontology in philosophical ontology is a rich body of theory about how to make ontological distinctions in a systematic and coherent manner. For example, many of the insights of "formal ontology" motivated by understanding "the real world" can be applied when building computational ontologies for worlds of data [4]. When ontologies are encoded in standard formalisms, it is also possible to reuse large, previously designed ontologies motivated by systematic accounts of human knowledge or language [11]. In this context, ontologies embody the results of academic research, and offer an operational method to put theory to practice in database systems.

Key Applications

Ontologies are part of the W3C standards stack for the Semantic Web, in which they are used to specify standard conceptual vocabularies in which to exchange data among systems, provide services for answering queries, publish reusable knowledge bases, and offer services to facilitate interoperability across multiple, heterogeneous systems and databases. The key role of ontologies with respect to database systems is to specify a data modeling representation at a level of abstraction above specific database designs (logical or physical), so that data can be exported, translated, queried, and unified across independently developed systems and services. Successful applications to date include database interoperability, cross database search, and the integration of web services.

Cross References

data model, data modeling, knowledge base, knowledge engineering

Recommended Reading

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