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An analysis of ontologies and their success factors for application to business

Christina Feilmayr, Wolfram Wöß *

Johannes Kepler University Linz, Institute for Application Oriented Knowledge Processing (FAW), Altenberger Straße 69, 4040 Linz, Austria

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ABSTRACT

Ontologies have been less successful than they could be in large-scale business applications due to a wide variety of interpretations. This leads to confusion, and consequently, people from various research communities use the term with different – sometimes incompatible – meanings. This research work analyzes and clarifies the term *ontology* and points out its difference from taxonomy. By way of two business case studies, both their potential in ontological engineering and the perceived requirements for ontologies are highlighted, and their misuse in research and business is discussed. In order to examine the case for applying ontologies in a specific domain or use case, the main benefits of using ontologies are defined and categorized as technical-centered or user-centered. Key factors that influence the use of ontologies in business applications are derived and discussed. Finally, the paper offers a recommendation for efficiently applying ontologies, including adequate representation languages and an ontological engineering process supported by reference ontologies. To answer the questions of *when* ontologies should be used, *how* they can be used efficiently, and *when they should not be used*, we propose guidelines for selecting an appropriate model, methodology, and tool set to meet customer requirements while making most efficient use of resources.

1. Introduction

Computer science and software engineering are relatively recent disciplines compared to other sciences and philosophy. The field continues to evolve as languages mature, representations develop, and the ability to devise solutions to new challenges increases with more advanced software and hardware systems. Artificial intelligence (AI) has been a significant challenge for computer scientists, and while the community has yet to develop "true" human-level machine intelligence, the pursuit of AI has led to the development of knowledge representation and semantic relationships [1,2]. An *ontological representation* allows modeling meaning in systems that are to be implemented using a programming language and a database schema. Unlike general software development approaches, such as object-oriented programming models, which enable the transformation of a model into a useful software artifact [3], an ontological model allows software to be generated that can evaluate semantic relationships, validate statements made within a domain of knowledge, and provide much richer rules for information management [4]. As required in artificial intelligence, an ontological model allows known facts and/or assumptions to be used to derive a conclusion or to make inferences (i.e., reasoning).

However, although ontological engineering has been applied for decades, there are still very few truly ontology-based systems that exploit all the benefits of an ontology-based approach (i.e., reasoning) and do much more than classify knowledge into convenient categories. This paper does not aim to provide a broad discussion of the term *ontology* merely by comparing the semantic differences between several definitions. Rather, the remainder of this paper focuses on the analysis of ontologies and their

* Corresponding author. Tel.: +43 732 2468 4184; fax: +43 732 2468 4200.
E-mail addresses: christina.feilmayr@jku.at (C. Feilmayr), wolfram.woess@jku.at (W. Wöß).

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frequent misuse in research and business and examines why ontologies have not been as successful as they could be in large-scale business applications. Ontological engineering is discussed in detail and compared with both entity-relationship modeling for conceptual database design and software engineering for software design in order to identify their proven benefits and best practices and, whenever possible, to adapt them to ontological engineering.

This paper seeks to clarify the benefits of an ontology-based approach. First, reasons for the frequent misuse or rare use of ontologies in research and business are discussed to examine when ontologies should be used, how they can be used efficiently, and when they should not be used. Guidelines to support the decision for a correct model, methodology, and tool set to meet the project specifications and the customer requirements are proposed. For this purpose, the resources available should be used most efficiently as it is widely established in software engineering to clearly identify which approach to take under given circumstances with a high degree of confidence. Considering the benefits of a clear and machine-interpretable basis for *meaning* in a system built on ontologies, this is a great opportunity to improve knowledge management and decision making in software systems. Another important benefit of an ontological approach, as discussed further below, is that concepts, their meaning, and their relationships can be shared [5]; this makes possible a clear and unambiguous agreement between a larger number of participants and offers new opportunities in terms of data interchange and data interpretation by machines.

Section 2 provides an overview of ontologies and their background, including a brief discussion of their benefits and a differentiation from taxonomies, and concludes that the general understanding of ontologies is low. This has an impact on their uptake and further deployment, including reuse. In Section 3, case studies from industry and research (i) point out their potential for ontological engineering and their perceived requirements for ontologies and (ii) identify reasons for the misuse of ontologies in research and business. Section 4 discusses in detail the benefits of appropriately used ontologies. Further, it provides a comparative classification of other existing models and technologies, whose relations to ontologies to support the decision for the best-suited methodology or method for each case. Ontological modeling is compared to other conceptual modeling approaches in Section 6, which leads to the question whether ontological engineering is a new development or just a new term for something that already exists. Examining the field of software engineering reveals a number of ontological engineering developments that have trailed software engineering process models. As demonstrated, the software engineering community has already dealt with most of the process models and engineering challenges, and while there are more subtleties and abstractions in the area of ontological engineering, a main goal of this paper is to motivate ontological practitioners to consider adopting some of software engineering's successful techniques, including the increasing reuse of existing ontologies by applying reference ontologies. Finally, ontological engineering is motivated as a separate and valuable discipline. The discussion concludes with (i) indicators and recommendations for choosing appropriate models and tools and (ii) a critical analysis of ontologies and their application in business in order to improve the maturity and capabilities of ontological engineering. This process must be accompanied by a mature community understanding of what is being discussed and, most importantly, when a project is or is not ontologically based. In order to provide a recommendation for efficient application of ontologies in a (business) project, the following key influencing factors and requirements were identified as being relevant:

- Requirement for sharing
- Semantic expressiveness
- Complexity of the universe of discourse
- Size of the sharing community (ontology stakeholders)

Table 1
Definitions of and references for important terms related to ontologies.

Term	Definition	Reference
Ontological representation	An ontological representation is used to represent defined knowledge. The term *ontology* is frequently used as a short form of *ontological representation*.	Our definition.
Conceptual model	A conceptual model focuses on capturing and representing certain aspects of human perceptions of the real world.	[6]
	A conceptual model is intended to capture knowledge about a real-world domain.	[7]
Ontological model	The term ontological model is often used synonymously with the term ontology.	[1]
	An ontological model is created to analyze the meaning of common conceptual modeling constructs.	[7]
Knowledge framework	A knowledge framework supports the analysis of an area of knowledge. Within this framework, features of an area are identified in the form of a specific terminology and concepts that shape that area of knowledge. At a minimum, one considers the four basic processes of creating, storing/retrieving, transferring, and applying knowledge.	Accords with the definition of [8]
Knowledge representation	(i) Most fundamentally a surrogate, a substitute for the thing itself, used to enable an entity to determine consequences by thinking rather than acting, i.e., by reasoning about the world rather than taking action in it. (ii) A set of ontological commitments. (iii) A fragmentary theory of intelligent reasoning. (iv) A medium for pragmatically efficient computation. (v) A medium of human expression, i.e., a language in which we say things about the world.	[9]
Semantic relations	Semantic relations are relations between concepts. A relationship covers associations between concepts that go beyond hierarchical ones; thus, they are conceptually associated to such an extent that the link between them should be made explicit.	Adapted from [10]