

Ontology Usefulness in Human Tasks: Seeking Evidence

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Abstract

Ontologies have become popular in a wide range of domains in recent years. Although there is a large number of ontologies in existence, a review of ontology literature indicates a lack of clarity on the notion of ontology usefulness. To understand how ontologies are used and what evidence exists for their usefulness, we conducted a systematic literature review of published research to understand current thought and practice. Our analysis shows that ontologies have been used in many fields, with the use categorized into two settings: use in computer systems and use to support human tasks. While there is strong evidence for the usefulness of ontologies in computer systems, a paucity of research exists to clarify the usefulness of ontologies as tools to support human tasks, especially in settings related to sharing domain understanding (an oft cited benefit of ontology use). In addition, our analysis of methodologies for ontology construction indicates that most methodologies lack prescribed activities for evaluation of usefulness. In this paper, we explore ontology use and evidence of usefulness, and propose research opportunities related to exploring ontology usefulness with respect to supporting human tasks.

Keyword

Ontology, Conceptual Modeling, Shared Understanding

INTRODUCTION

Ontologies are used in different fields of business, science and engineering to model phenomena, situations or domains of interest. They are a basis for knowledge transfer, developing domain understanding, or simulating the subject matter they represent. The use of ontologies has been generalized to both computer systems and humans. For example, ontologies can facilitate the communication between humans, the interoperability between computer systems, and also improve the specification, reliability and reusability of computer systems (Uschold and Jasper 1999).

Given the wide range of ontology use, the usefulness of a given ontology thus becomes an important factor to study. By ontology usefulness we refer to the degree to which the ontology achieves its intended use. Thus usefulness can be measured by different metrics depending on the purpose of use. For example, if ontologies are designed to provide domain understanding, a measure of usefulness commonly used in conceptual-modeling studies is the effectiveness of transfer of knowledge (Bera *et al.* 2011). Using ontologies beyond their designed use is likely to affect their usefulness, for example, an ontology developed to assist a communication system in healthcare and an ontology developed to validate the quality of conceptual models are not the same; hence applying these ontologies for purposes they were not intended for may affect their usefulness. Moreover, different levels of generality and formality, and the various ways of representing ontologies, may moderate usefulness in a given setting.

While some authors consider ontologies to be a useful tool for humans (Fensel 2001; Uschold and Jasper 1999), the ways in which ontologies can be used in the human context and evidence for claimed usefulness among humans are not evident in literature. On the other hand, usefulness of ontology in the computer system context can be validated through prototypes and their functionality, whose efficiency, in some cases, is measured experimentally. For example, Delir Haghighi et al. (2013) conducted an evaluation through an intelligent decision support system in medical emergency management.

In this paper, we aim to explore the notion of ontology usefulness in human tasks. To do so, we conducted a systematic literature review of a substantive body of knowledge pertaining to the study of ontologies. This paper presents a brief background on ontologies, followed by the results of our review, which provides an overview of evidence of ontology usefulness in relation to various uses of ontologies, as well as the role of ontology usefulness in various ontology development methodologies, and identification of open research issues relating to the study of ontology usefulness in human tasks. We conclude the paper with a summation of the results and identify further research gaps, opportunities and limitations.

BACKGROUND CONCEPTS

In general, the term ‘ontology’ defines the branch of philosophy that studies the nature and structure of reality (Wand *et al.* 1995). However, this term is also used in other research fields in science and engineering to express a range of diverse meanings. The proliferation of varying ontology definitions stems from the high number of ontology variants and how they are classified. Ontologies have been classified in different ways by researchers depending on their: level of generality, type of structure and conceptualization, appearance, scope, functionality and degree of formality. Although the classifications vary from one author to other, the two most commonly-used classifications are those based on the level of generality and the degree of formality.

According to the level of generality, ontologies can be top-level ontologies or domain ontologies. Top-level ontologies try to describe abstract and general concepts (Grimm *et al.* 2011) such as space, time, matter, objects, events, or actions. Because these ontologies are independent of any domain (Guarino 1998), top-level ontologies can be shared across different domains and applications, and reused as a basis for developing domain ontologies (Grimm *et al.* 2011). Some examples of top-level ontologies are Cyc’s Upper Ontology (Lenat and Guha 1989), Bunge-Wand Weber ontology (Wand and Weber 1993), and the Basic Formal Ontology (Grenon and Smith 2004). These ontologies are often called ‘ontologies of IS’ because they describe the basic constructs of IS (Fonseca 2007). The second generality level, domain ontologies, capture the knowledge or describe the vocabulary related to a generic domain, such as medicine, geography or project management (Grimm *et al.* 2011). These ontologies are called ‘ontologies for IS’ because they describe the vocabulary related to a generic domain, task or activity (Fonseca 2007). The number of ontologies that exist in this classification is high – these ontologies can be found in different fields of science and engineering, and are explained in the following sections. Normally, these ontologies should specialize the terms of a top-level ontology; however most ignore top-level ontologies and/or the work done in philosophical ontologies. This can be problematic because top-level ontologies contribute to the creation of better domain ontologies (Smith 2008).

The representation of ontologies varies from the informal to the formal. The formality of an ontology determines to what extent it is axiomatised by means of logical statements about the domain (Grimm *et al.* 2011). In function of its formality, an ontology can be represented as a thesaurus, a concept schema, a taxonomy, a conceptual data model, a rule base, or a general logical theory (Sharman *et al.* 2004) (see Figure 1). For example, ontologies can be represented as a semantic network composed of interlinked concepts. While such a representation may be easy to interpret because of the simplified representation, it may lack important information, such as particular kinds of axioms (Grimm *et al.* 2011). Ontologies can also be represented through formal languages that allow the capture of all the knowledge related with the domain in question (Gómez-Pérez *et al.* 2004). One example of such a language is the Web Ontology Language (OWL), which is commonly used in the formalization of ontologies. It is important to note that although ontologies can be represented in many informal ways, representations that lack an organized semantic structure cannot be considered ontologies (Guarino *et al.* 2009). For example, a set of terms without any kind of organization or structure that facilitate to understand the domain is just a set of terms and not an ontology.

This situation has made it difficult to achieve consensus about what ontologies are. To clarify this issue, specific efforts have been undertaken to define ontologies. For example, Almeida (2013), Fonseca (2007), Giaretta and Guarino (1995), Hepp (2008), Kishore and Sharman (2004), and Weber (2002) all contribute to the discussion of ontologies by providing their interpretation of what an ontology is. However, a lack of consensus still remains and, as a result, each field has adopted its own definition. Nonetheless, considering the general purpose of ontologies, ontologies can be broadly defined as a shared conceptualization of reality, which, according to Hepp (2008), can be defined by formal means or informal means. Therefore, we consider ontologies to be conceptualizations of reality, as agreed to by a group of experts, defined specifically and with varying levels of

generality, varying representations and varying levels of formality. Moreover, ontologies are conceptualizations of the elements that compose a domain as opposed to being a detailed description of that domain. Although such detailed descriptions can be achieved through instances, the artefact would no longer be considered an ontology, but a knowledge base.

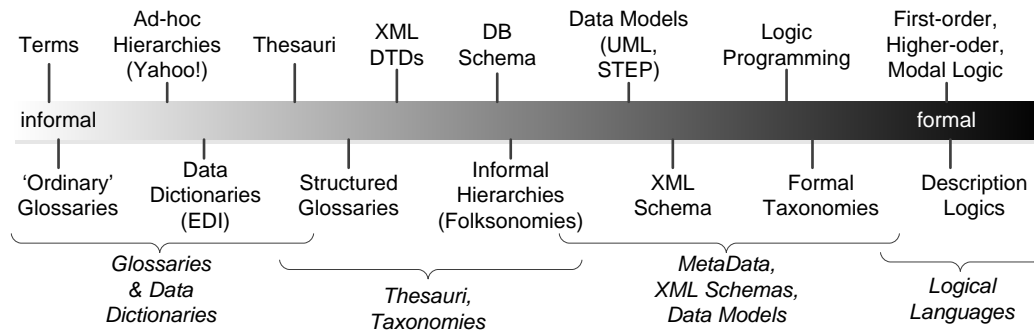


Figure 1. Ontology Representation (Guarino *et al.* 2009).

RESEARCH APPROACH

To understand popular use of ontologies, as well as insights on ontology usefulness, we conducted a systematic search of literature to identify the most cited and relevant papers for our analysis (Webster and Watson 2002). To identify relevant publications we considered journals, papers, books, and book chapters since 1985. The selected timeframe was chosen because the initial references to ontologies rose to prominence in the late 1990s and early 2000s (Figure 2). We therefore chose to commence our literature review in 1985 in order to encapsulate any early, but significant papers.

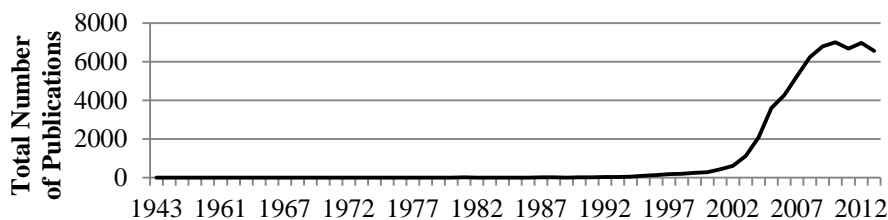


Figure 2. Number of Publications per Year Related to Ontologies in the Scopus Database.

After establishing the time frame and publication sources, we used the terms ‘ontology’, ‘ontologies’, and ‘ontological’ to search publications in the Scopus database, which returned over 69,000 hits. To obtain a more focused result, as well as for analytical feasibility, we limited our search to titles only, which resulted in 23,618 publications. Given the volume of relevant work, we focused further on identifying the most impactful publications – i.e. to proxy a reasonable set of publications that can be analyzed. We considered two metrics: the age-weighted citation rate and the number of citations since publication. The age-weighted citation rate (AWCR) is calculated for each publication considering the paper age and the number of citations. Using a threshold of AWCR greater than 115 and the number of citations greater than 23, a set of 135 publications was selected for the final analysis. This threshold was considered because one of the most important publications in the ontology-engineering-field theory (Gruber 1993) had a $AWCR = 229$ ($AWCR_g$). Hence we wanted to have a set of publications with similar relevance, that is, at least 50% of the $AWCR_g$ or a number of citations greater than the 10% of the $AWCR_g$ if the previous condition does not hold.

Although the systematic review allowed us to find a set of relevant and highly impactful publications, this approach may have eliminated significant references because of the high threshold used. Therefore, we also used an exploratory search to find additional relevant publications related with the use and usefulness of ontologies. This kind of search did not follow a strict approach, instead it involved using related keywords and phrases in online search tools, and doing backwards and forwards searches on the citations of references found in the first step (Tamm *et al.* 2011).

Using Google Scholar we searched for ‘ontology usefulness’, ‘ontology use’, ‘ontology usability’, and ‘ontology applicability’. The results of these queries allowed us to identify 26 publications, which were added to the previously identified set (resulting in a total of 161 papers). The 161 publications were reviewed in full by one researcher to identify relevant insights about the use and usefulness of ontologies. To do this, each paper was coded through three different phases in order to reduce bias (Neuman 2011). First, some preliminary codes were established and the publications codified. Then, these codes were organized in categories, new codes were

considered, and some discharged. Finally, only six main codes, namely, field of application, nature of use, agent (system or human), type of ontology (domain ontology or top-level ontology), type of ontology representation (formal language or informal language), and type of usefulness evaluation (empirical, theoretical, none) were considered in the findings. The codes formed the criteria for our analysis, the results of which are presented in the next section.

Finally, to further reduce the risk of missing relevant papers, we performed an additional Scopus search using the terms ‘ontology’, ‘ontologies’ or ‘ontological’, and ‘shared understanding’, ‘cross understanding’, ‘common understanding’, ‘similar understanding’ or ‘joint understanding’ in the title, abstract and keywords of publications since 1985. The query returned 319 results which titles were compared with our initial 161-paper set and then reduced to 244 results after eliminating duplicates papers. Consequently, this set of papers was analyzed through the use of the NVivo¹. First, we filtered papers that did not have stemmed words of the terms ‘empirical’, ‘existential’, ‘experiential’, ‘experimental’, ‘objective’ or ‘observational’. We did so to find papers that provided empirical evidence. Second, in the filtered set of papers, we searched for stemmed words of ‘person’, ‘member’, ‘individual’, ‘participant’, ‘subject’ or ‘group’ to find papers that have conducted empirical research with participants. This filtering process results in 216 additional papers that were analyzed in full text in order to identify empirical evidence. The results are presented in the next section.

RESEARCH FINDINGS

By definition, and according to studies on ontology use (Guarino 1998; Studer et al. 1998; Uschold and Jasper 1999), ontologies can be applied to any area in which a representation of reality is required. Ontologies can also be applied to different situations and scenarios, such as the interoperability of computer systems, the development of better conceptual models for IS, or for improving domain understanding, among others.

To identify the types of uses that are common in practice we looked for the application of such ontologies on the set of publications that we selected. The results show that ontologies are used in many fields within science and engineering. For example, in IS, ontologies can be used to facilitate conceptual modeling (Wand *et al.* 1999), as a basis for evaluation and improvement of process modeling notations (Recker et al. 2009), as components of computer systems (Lutz and Klien 2006), as repositories of information (Neches *et al.* 1991) and facilitators of interoperability of the semantic web (Berners-Lee *et al.* 2001), among others. Similarly, in biology, ontologies can be used as repositories of information that contain vocabularies and classifications of genes, as components of computer systems for the retrieval and extraction of biological information, or for the integration and extension of gene databases (Horrocks and Patel-Schneider 2011). Ontologies have also been used in industry in operations research and management science. In these settings, they are used to provide a shared understanding of manufacturing-related terms, the reuse of knowledge resources within globally extended manufacturing teams (Lin et al. 2004), as part of the architecture of decision support systems (Niaraki and Kim 2009), or to model knowledge related to product configuration (Yang et al. 2009).

When the different types of applications are considered, it is clear that there are two general uses of ontology: one relating to the use of ontologies for the support of computer systems and the other relating to the support of human tasks (Table 1). These findings are significant because the use and the usefulness of ontologies should not be generalized. Indeed, differences exist between the ontologies used to support systems and those used to support human tasks, and hence clarification is required.

Although the use of ontologies can be extensive in the two general types of use, for the support of computer systems, we found that ontologies can be used to facilitate information retrieval, to enable the interoperability or communication between computer systems (e.g. semantic web), to represent and store knowledge, as components of operation of computer systems (e.g. support decision systems based on ontology) among other uses. When it comes to ontology use for the support of human tasks, we found that ontologies are used to benchmark and explore the quality and representational capability of conceptual modeling grammars, to improve conceptual modeling tasks, to provide individual understanding of a particular domain, to facilitate the construction of domain ontologies, and to provide shared understanding among users. In summary, even though the numbers of categories are limited, we consider they are general enough to cover other subtypes of use. For example, tasks such as cognition improvement could fit into the category of domain understanding task or shared-understanding task depending on whether this subtype of use is at the individual or at the group level. Also, because ontologies can be used to provide shared understanding among a group, ontologies also can be applied, for example, in team decision making and negotiation, among others.

Table 1 also shows that both formal and informal representations of ontologies are used to support human tasks. For example, visual ontologies (Bera *et al.* 2011) and ontologies presented through the use of a computer system

¹ NVivo is a software package for qualitative data analysis: <http://www.qsrinternational.com>.

(Kim 2012) have been found to provide support for knowledge identification (a task related with domain understanding). When ontologies are used to support systems, they by necessity, must be represented in a formal language. For example, OWL is the common language that is used to implement ontologies that will work with the semantic web (Horrocks and Patel-Schneider 2011). Although some studies show that formal ontologies are used to support human tasks, the ontologies in those studies are used embedded in computer systems. Thus, in these studies, it is difficult to establish under what circumstances the ontology itself supports the human task, rather than the system supporting the task. In other words, it is unclear in these studies whether it is the ontology or the system, or both, that support the human task.

Table 1. Use of Ontologies vs. Types of Representation.

Types of Use	Types of Representation	
	Informal	Formal
Computer Systems Support	0.0%	100.0%
Information retrieval	0.0%	100.0%
Interoperability	0.0%	100.0%
Knowledge representation	0.0%	100.0%
Systems based on ontology	0.0%	100.0%
Other	0.0%	100.0%
Human Task Support	73.1%	26.9%
Analysis of Conceptual Modeling Grammars	100.0%	0.0%
Conceptual modeling	92.9%	7.1%
Domain Understanding	50.0%	50.0%
Ontology construction	0.0%	100.0%
Shared understanding	60.0%	40.0%

While the benefits of ontologies in systems can be validated through prototypes and their functionality, the benefits of ontologies for support human tasks are more difficult to show, with only empirical evidence able to indicate their usefulness. To clarify this aspect, we searched for empirical evidence that supports ontology usefulness in supporting human tasks. Table 2 shows that there is considerable evidence that indicates that ontologies do indeed support tasks related to conceptual modeling, domain understanding, and ontology construction. For example, in the context of conceptual modeling, Recker *et al.* (2011) demonstrated how ontological deficiencies in modeling grammars affect conceptual modeling, Gašević *et al.* (2009) assessed how ontologies can support some activities in the software development life cycle, and Sugumaran and Storey (2006) tested the use of ontologies as support for the design of databases. Despite these contributions, there is a lack of empirical evidence to support the usefulness of ontologies developed with the purpose of facilitating shared understanding, even though many ontologies were developed with this aim in mind – e.g. the enterprise ontology (Uschold *et al.* 1998), manufacturing system engineering ontology (Lin *et al.* 2004), V4 service business model ontology (Al-Debei and Fitzgerald 2010), the ontology for software requirements modeling (Innab *et al.* 2012), to name just a few. In fact, after the full text analysis of the additional 216 papers that we collected, we also could not find any evidence that allow us to justify the effectiveness of ontologies to facilitate shared understanding.

Table 2. Empirical Evidence of Usefulness of Ontologies.

Types of Use	Usefulness Empirical Evidence	
	Yes	No
Systems Support	64.0%	36.0%
Information retrieval	75.0%	25.0%
Interoperability	40.9%	59.1%
Knowledge representation	67.3%	32.7%
Systems based on ontology	100.0%	0.0%
Other	50.0%	50.0%
Human Task Support	30.8%	69.2%
Analysis of Conceptual Modeling Grammars	50.0%	50.0%
Conceptual modeling	28.6%	71.4%
Domain Understanding	100.0%	0.0%
Ontology construction	33.3%	66.7%
Shared understanding	0.0%	100.0%
Total	56.5%	43.5%

Because of the lack of empirical evidence for the usefulness of ontologies in establishing sharing domain understanding, we analyzed whether highly-cited methodologies for building and evaluating ontologies include any approach for evaluation of usefulness in such settings. In this analysis, we considered that ontology evaluation may occur at two distinct stages. The first is related to the evaluation of the ontology before it is put into use, that is to say, the *desired usefulness* of the ontology. Whereas the second scenario is related to the evaluation of the ontology after it is put into use, that is, the resulting usefulness of the ontology. The results of the analysis show that most ontology development methodologies lack the evaluation of ontology usefulness, i.e. evaluation of the ontology post-implementation. Table 3 summarizes selected characteristics of these methodologies. Although some methodologies consider an evaluation of the ontology, these approaches are more focused on only assessing the quality of the ontology content, and do not pay particular attention to understanding whether the ontology itself is useful. For example, the methodology used for developing the enterprise ontology (Uschold and King 1995) has four phases of development: to identify the purpose of the ontology, to build the ontology, to evaluate the ontology, and to document the ontology. Despite this multi-stage process, in the evaluation phase the methodology prescribes evaluation from a knowledge-representation point of view, which is more likely related to a sought quality parameter rather than actual usefulness. Similarly, OntoClean (Guarino and Welty 2009) is an evaluation methodology that allows validation of the ontological adequacy and logical consistency of taxonomic relationships, but it lacks recommendations to evaluate other aspects, such as the usefulness of the ontology.

Table 3. Ontology Development Methodologies.

Methodology Name	Development Process	‘Desired’ Usefulness Evaluation	‘Resulting’ Usefulness Evaluation
Cyc (Guha and Lenat 1990)	x		
N/A- (Gruber 1995)	x		
Based in Enterprise Ontology (Uschold and King 1995)	x	x	
Based in TOVE (Grüninger and Fox 1995)	x	x	
KACTUS (Gómez-Pérez <i>et al.</i> 2004)	x		
METHONTOLOGY (Fernández-López <i>et al.</i> 1997)	x	x	
Based in SENSUS (Swartout <i>et al.</i> 1996)	x		
Ontology Development 101 (Noy and McGuinness 2001)	x		
Based in On-To-Knowledge (Staab <i>et al.</i> 2001)	x	x	
DILIGENT (Tempich <i>et al.</i> 2005)	x	x	
HCOME (Kotis and Vouros 2006)	x	x	
OntoClean (Guarino and Welty 2009)		x	
UPON (De Nicola <i>et al.</i> 2009)	x	x	
DOGMA (Jarrar and Meersman 2009)	x		
Based on DO4MG (Delir Haghighi <i>et al.</i> 2013)	x	x	x
NeOn (Suárez-Figueroa <i>et al.</i> 2012)	x	x	x
Based on CoMOn (Syed Abdullah <i>et al.</i> 2013)	x	x	x

Of those methodologies that propose to evaluate ontology usefulness, the purpose is focused on the perceived usefulness of the ontology and/or usefulness through application systems instead of the ontology’s usefulness for human tasks. One example of this is the methodology used in the development of the DO4MG ontology (Delir Haghighi *et al.* 2013), which evaluates the usefulness of the ontology through a decision support system that uses the ontology; however, empirical evidence of its application by users is not considered. Also, although the NeOn methodology (Suárez-Figueroa *et al.* 2012) suggests the evaluation of usefulness, it is orientated towards the evaluation of the application in which the ontology is applied. In addition, in the methodology used to develop the Compliance Management Ontology (CoMOn) (Syed Abdullah *et al.* 2013), ontology usefulness is evaluated as perceived by users; however, they do not attempt to explore actual ontology usefulness. Thus, although there are many methodologies for the construction and evaluation of ontologies, they lack a well-structured prescription of how to evaluate the usefulness of ontologies for the specific purpose of shared domain understanding.

DISCUSSION AND RESEARCH OPPORTUNITIES

In this study, we performed a structured literature review to investigate the nature of use and usefulness of ontologies. In this section, we summarize the research findings, and identify research opportunities going forward.

First, the analysis of types of use shows that ontologies can be applied for two general purposes: the support of systems and as tools to support human tasks. Although it is clear that ontology usefulness in the context of supporting systems can be justified through the high number of applications and popular use, the usefulness in the context of human tasks is not clear. Thus, a theoretical explanation of the usefulness of ontologies for specific purposes is necessary. Such a theory should explain what internal and/or external factors of the ontology affect the usefulness of that ontology with respect to the context for which it was developed. For example, a theory of usefulness for the specific purpose of domain understanding should incorporate factors such as representation, visualization, levels of knowledge represented, the impact of the users' cognitive process, ontology extension, to mention but a few. Some of these factors have already been the focus of research in other ontology contexts. For example, Bera *et al.* (2011) found that graphical representations of ontology are better than other informal representations, and provided a set of guidelines for effective representation of ontologies for the support of knowledge identification tasks.

Second, the analysis of representation types indicates that ontologies used within systems are always represented formally (not surprisingly, given that such ontologies need to be machine-readable), but both formal and informal ontologies have been used to support human tasks. However, human-task related studies that claim that a formal ontology is used, typically involve a system or IT artifact to implement the ontology, thus making it difficult to establish whether it is the ontology that is useful or the system itself. Accordingly, theories of ontology usefulness should establish the boundaries of the ontology before it becomes a computer system in order to know if the ontology itself is useful.

Third, ontology literature indicates that one of the main uses is to provide shared understanding between humans. However, our findings show that there is no empirical evidence of ontology usefulness in this setting. Thus, there is a need for empirical evidence that supports or refutes such usefulness. Indeed, it is important to know to what extent ontologies are useful for this task and what factors (external or internal to the ontology) impact the usefulness. For example, Bera *et al.* (2011) provide empirical evidence of the usefulness of ontologies for knowledge identification, but this empirical evaluation is related with the understanding at the individual level and not at the group level. Shared understanding, which can be defined as the variance of understanding of a domain in a particular group, is a group construct, and thus, must be evaluated at the group level.

Finally, the findings related to ontology construction methodologies show a lack of recommendations for the evaluation of usefulness among humans. Although a theory of ontology usefulness may clarify the factors that impact usefulness and empirical evaluation may quantify the impact of those factors, it is also important to establish recommendations for ways to evaluate the actual usefulness with respect to their use in supporting human tasks. Additionally, construction recommendations to maximize ontology usefulness in those settings would be of great benefit. Most of the current ontology construction methodologies were developed taking into account mainly the final use among systems and not the use among humans; thus an improvement in the construction and evaluation methodologies is required.

CONCLUSIONS

In this study, we performed a literature review that considered different methods of analysis to understand the nature of use and usefulness of ontologies. The results of this review show that while ontologies are popular and frequently used in different areas of science and engineering, it remains unclear under which conditions ontologies are useful. According to our literature survey, ontologies can be useful in two principal scenarios, one of which is use for systems support. The literature we examined supports the claim that ontologies are useful in such a setting. For example, ontologies are useful for information retrieval, interoperability of computer systems, knowledge representation and knowledge bases, to name a few. Literature also claims that ontologies are useful to support humans tasks, e.g. to facilitate conceptual modeling, domain understanding of individuals, ontology construction, or provide shared understanding. While we found some empirical evidence that indicates usefulness of ontologies to support conceptual modeling, develop better domain understanding of individuals, and support ontology construction, no evidence was found to support claims of usefulness for establishing a shared understanding, which is a group construct that must be studied at the group level. In addition, we also found that methodologies for ontology construction typically focus on evaluating desired usefulness, but do not assess actual usefulness, especially in regards to the human task context.

Accordingly, to address these gaps in the body of knowledge, we articulated some research opportunities for the academic community. These include, in particular, establishing a theory of ontology usefulness, conducting

empirical studies to explore ontology usefulness in the context of shared understanding, and extensions to ontology construction methodologies.

Our study is not without limitations. Due to the large volume of related publications (in the tens of thousands, making full analysis not feasible), we used a restrictive threshold in our systematic review. This strategy eliminates many publications from the analysis. However, we complemented this approach with an exploratory search in which we identified a number of publications related to applied ontologies. Second, a single coder was used during the analysis of the publications, which could introduce bias. However, to reduce this risk, our approach consisted of three coding iterations as explained in the approach section.

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