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VON ROSING, Mark, LAURIER, Wim and POLOVINA, Simon
<http://orcid.org/0000-0003-2961-6207>

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The Value of Ontology

Mark von Rosing, Wim Laurier, Simon M. Polovina

INTRODUCTION

It is generally accepted that the creation of added value requires collaboration inside and between organizations.[1] Collaboration requires sharing knowledge (e.g., a shared understanding of business processes) between trading partners and between colleagues. It is on the (unique) knowledge that is shared between and created by colleagues that organizations build their competitive advantage.[2] To take full advantage of this knowledge, it should be disseminated as widely as possible within an organization. Nonaka distinguished *tacit* knowledge, which is personal, context specific, and not so easy to communicate (e.g., intuitions, unarticulated mental models, embodied technological skills), from *explicit* knowledge, which is meaningful information articulated in clear language, including numbers and diagrams.[3]

Tacit knowledge can be disseminated through *socialization* (e.g., face-to-face communication, sharing experiences), which implies a reduced dissemination speed, or can be *externalized*, which is the conversion of tacit into explicit knowledge. Although explicit knowledge can take many forms (e.g., business (process) models, manuals), this chapter focuses on ontologies, which are versatile knowledge artifacts created through externalization, with the power to fuel Nonaka's knowledge spiral. Nonaka's knowledge spiral visualizes how a body of unique corporate knowledge, and hence a competitive advantage, is developed through a collaborative and iterative knowledge creation process that involves iterative cycles of externalization, combination,[4] and internalization.[5] When corporate knowledge is documented with ontology, a knowledge spiral leads to ontology evolution.[6]

The next section of this chapter defines ontologies, discussing their level of context dependency and maturing process. The third section of this chapter discusses the state of the art in a business context, while the fourth section introduces directions for future research and development. A summary is presented in the last section.

WHAT IS ONTOLOGY?

The term *ontology* can refer to a philosophical discipline that deals with the nature and the organization of reality.[7] Ontology, as a philosophical discipline, is usually contrasted with epistemology, which is a branch of philosophy that deals with the nature and sources of our knowledge. However, an *ontology* is an artifact—more precisely, an intentional semantic structure that encodes the set of objects and terms that are presumed to exist in some area of interest (i.e., the universe of discourse or semantic domain), the relationships that hold among them, and the implicit rules constraining the structure of this (piece of) reality.[8,9] In this definition, *intentional*

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refers to a structure describing various possible states of affairs, as opposed to extensional, which would refer to a structure describing a particular state of affairs. The word *semantic* indicates that the structure has meaning, which is defined as the relationship between (a structure of) symbols and a mental model of the intentional structure in the mind of the observer. This mental model is often called a *conceptualization*.[10] Semantics are an aspect of semiotics, like syntax, which distinguishes valid from invalid symbol structures, and like pragmatics, which relates symbols to their meaning within a context (e.g., the community in which they are shared).[11]

ONTOLOGY CLASSIFICATION BASED ON CONTEXT DEPENDENCY

Ontologies can be classified according to their level of context dependency.[12] *Top-level* or *foundational ontologies* are context independent because they describe very general concepts, such as space, time, and matter, which are ought to be found in any context. *Task* and *domain ontologies* all relate to the context of a specific domain (e.g., banking, industry) or task (e.g., accounting, sales). Domain and task ontology terms are specializations of top-level ontology terms or terms used in a domain or task ontology with a wider scope (e.g., business-to-business (B2B) sales is a subcontext of sales), which means that they are directly or indirectly founded on top-level ontology terms. Finally, *application ontologies* relate to a very specific context (e.g., accounting in the banking industry, B2B sales in a single sales department). Their terms can be defined as specializations of domain and task ontology terms.

ONTOLOGY MATURITY AND THE MATURING PROCESS

Ontologies can also be classified according to their level of maturity. At the lowest level of maturity, we find *emerging ontologies*, which are rather ad-hoc, not well-defined, individually used, and informally communicated natural-language artifacts.[13] Within the ontology spectrum, which ranges from highly informal to formal ontologies, controlled vocabularies, glossaries, and thesauri, are suitable ontology formats for such informal ontologies. A *controlled vocabulary*, which is a finite list of terms with a unique identifier, is the most rudimentary ontology. A *glossary*, which is a controlled vocabulary in which each term's meaning is given using natural language statements, is a slightly richer ontology.[14] Both controlled vocabularies and glossaries provide a list of unrelated or implicitly related terms. Some of these emerging ontologies mature to become *folksonomies* or common vocabularies, which are shared within and collaboratively improved by a community. Like most emerging ontologies, folksonomies use an extensional notion of conceptualization, which means that the terms are defined through examples rather than through descriptions.[15]

Folksonomies can mature to become *formal ontologies* through the organization of their terms using relationships. These relationships can be ad hoc, as in thesauri, or hierarchical, as in classification schemes.[16] A *thesaurus* increases ontology expressiveness by adding relations (e.g., synonyms) between terms in a controlled vocabulary. However, thesauri do not necessarily provide an explicit term hierarchy (e.g., specialization-generalization), which is a feature of classification schemes. A *classification scheme* contains informatory "is-a" relations, a *class hierarchy* strict specialization–generalization relations. Strict specialization–generalization relations create a treelike hierarchy, with a generic term as the root and more specific terms, which inherit meaning from the more generic concepts (e.g., the root) they are related to, as branches and leafs. The formality level of a class hierarchy can be increased by adding instantiation as a relation. Instantiation distinguishes between a meaningful term, which is often called a class (e.g., a car), and the terms that are examples of this class, which are often called instances (e.g., my car, your car). Inference rules can be derived from classification schemes and class hierarchies. For example, if a car is a kind of vehicle, then my car is also a vehicle. This implies that everything that can be said about vehicles can be said about my car. At a higher level of thesaurus expressiveness, *frames* include information about potential properties and relationships of classes and their instances (e.g., a car might have a price).[17]

The final phase in the maturing process is called the axiomatization.[18] An *axiom* is a statement for which there is no counter-example or exception.[19] *Value restrictions*, which increase the expressiveness of a frame by discriminating valid from invalid relationships between properties of classes and their instances,[20] are examples of axioms. Other examples of axioms include mathematical equations that relate properties, or logical restrictions on classes and their instances (e.g., disjointness constraint). Some ontologies also provide heuristic value restrictions (e.g., most cars consume fuel, most cars have one owner).

When an ontology was not formalized earlier, the axiomatization phase is often combined with the articulation in a formal language. This formality is a critical aspect of a well-known ontology definition, which dictates that an ontology needs to be a "formal specification of a shared conceptualization."[21] In this definition, the word *specification* requires that an ontology is an appropriate representation of its universe of discourse, which is typically referred to as but not limited to a (semantic) domain. The word *shared* refers to the need for social agreement about and shared understanding of the terms in the ontology. *Formal* refers to the fact that ontologies are frequently written in a formal (and often also machine-readable) language, which is a set of finite symbol structures taken from a finite alphabet of symbols[22] and defined by syntax.

STATE OF THE ART

Building and maturing an ontology is a collaborative and iterative process that requires thought and effort. The process also produces several valuable byproducts, including a better understanding of the organization.[23] Through documentation, structuring, and analysis of business process information, ontology development has been found to support business process detection,[24] continuous process refinement,[25] and defining process performance indicators.[26] Ontology engineering also requires discussion, which may yield valuable feedback, to reach consensus and obtain a conceptualization that is shared by all stakeholders. LEGO refers to this shared conceptualization as "One truth for all."[27] Several domain ontologies for business have been developed. Their main purposes are knowledge exchange[28] and knowledge management covering and bridging[29] several subdomains of business (e.g., business plans and other strategies,[30-36] operations,[37,38] finance,[39] accounting[40,41]), and auxiliary disciplines (e.g., information management,[42,43] requirements engineering,[44,45] information systems design,[46] and the development of the semantic web[47]).

Corporate knowledge is often visualized using conceptual modeling grammars (e.g., business process modeling notation (BPMN)). It has been demonstrated that an ontological assessment of such a modeling grammar (through semantic mapping) increases the perceived usefulness and ease of use.[48] An ontological assessment uses the knowledge embedded in ontologies to assess the expressiveness of modeling grammars by mapping grammar constructs to concepts of a relevant ontology.[49] The resulting mapping is called a semantic mapping and is proof of a modeling grammar's ontological commitment. The grammar constructs can be textual, iconic, or diagrammatic and are often referred to as symbols.[50] A semantic mapping can reveal grammar incompleteness, construct redundancy, excess, and overload.[51] *Construct deficit* occurs when one or more ontology concepts lack an equivalent grammar construct, which signals that the grammar is incomplete. *Construct redundancy* occurs when an ontology concept corresponds with two or more grammar constructs. *Construct excess* can be observed when one or more grammar constructs lack an equivalent ontology concept. *Construct overload* occurs when a grammar construct matches with two or more ontology concepts.

Next to symbols that can be mapped to ontological concepts, *modeling grammars* provide rules that prescribe how symbols, which refer to ontology concepts, can be combined to model real-world phenomena.[52] In formal languages, these rules are embedded in a proof theory, which consists of a set of inference rules.[53] These inference rules prescribe how new combinations of symbols can be derived from existing combinations of symbols. Consequently, a proof theory, together with the syntax and semantic mapping, permits a mathematical evaluation of a grammar's correspondence with the semantic domain.[54,55] In the ideal scenario, the set of all valid models generated from a modeling grammar's symbols and its (inference) rules covers the entire domain and nothing but the domain (i.e., every real-world phenomenon from the semantic domain can be modeled, and it is impossible to create a model that does not belong to the set of intended models).

Semantic mappings can also be applied to validate and integrate ontologies. When two or more ontologies that cover the same semantic domain share the same concept, the concept is more likely to belong to the semantic domain. When a concept occurs in only one of several ontologies that share the same domain, the concept is more likely to be redundant. The LEADing Practice community has applied semantic mappings to validate its ontology and integrate it with the ontologies of other frameworks and methods (e.g., The Open Group Architecture Framework (TOGAF), Control

Objectives for Information and Related Technology (COBIT), Information Technology Infrastructure Library (ITIL), Layered Enterprise Architecture Development (LEAD)).[56] However, most semantic mappings are applied in data management for the purpose of enterprise application integration[57] or database integration,[58] or to build a semantic[59,60] or pragmatic web.[61] Additionally, the semantic mappings allow for an automated translation of a concept from one ontology (e.g., applied in database A) to another equivalent ontology (e.g., applied in database B).

A lot of corporate knowledge is documented using diagrammatic languages (e.g., BPMN). An ontological evaluation of such languages through a semantic mapping of their symbols has been observed to improve their expressiveness and clarity. Consequently, semantic mappings between domain ontologies and domain-specific modeling languages[62,63] would allow organizations to improve these languages for the purpose of interorganizational communication. Semantic mapping might also allow organizations to develop unique intraorganizational languages based on an organization's application ontology for strategic information. Such an intraorganizational language might be defined as an extension of BPMN (e.g., extended business process modeling notation (X-BPMN)[64]) or as a completely independent language, which might need to respect the "physics of notation."[65]

Markup languages such as the Ontology Web Language (OWL), Resource Description Framework (RDF) and Knowledge Interchange Format (KIF) allow ontologies to be processed and distributed by computers, which allows for an automated combination and evaluation of (inter)organizational ontological knowledge.[66-68] Although some efforts have been made to formalize enterprise ontologies (e.g., REA (economic Resources, economic Events, and economic Agents)[69]) or best practices,[70] most applications of ontology in an organizational context are currently limited to building less formal ontologies (e.g., folksonomies). Therefore, organizations should invest in formalizing shared knowledge (e.g., big data).

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

This chapter defined ontology engineering as a discipline that can support corporate knowledge creation through the definition of fundamental concepts, as well as semantic relations and correlations between these concepts. Such definitions are not incorporated in contemporary BPM practice in an integrated and standardized way. Therefore, it would be advisable to develop an ontology for BPM.

A BPM ontology could include, among others, the following:

- It should state the primary concepts,[71] such as the entities/objects involved in BPM.
- It should define each of these primary involved concepts.
- It should define the relationships between these concepts.
    - It should preferably describe these relationships using class hierarchies.
    - These class hierarchies should preferably be based on existing classifications.
- It should describe the properties of the concepts and relationships above.

- It should define a set of value restrictions, such as how and where can the process objects be related (and where not).
- It should be supported by as large a user community as possible.
- It should be vendor neutral and agnostic, therefore allowing it to be used with most existing frameworks, methods, and/or approaches that have some of its mentioned meta-objects.
- It should be practical.
- It should have fully integrated and standardized relationship attributes.

Within the context of a BPM ontology, what are the properties of process (meta) objects and how do they relate to other (meta) objects?

- It should define how to organize and structure viewpoints and concept associations.
- It should structure process knowledge.
- It should establish guiding principles for creating, interpreting, analyzing, and using process knowledge within a particular (sub) domain of business and/or layers of an enterprise or an organization.

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