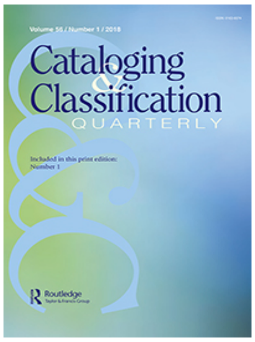

Cataloging & Classification Quarterly

ISSN: 0163-9374 (Print) 1544-4554 (Online) Journal homepage: https://www.tandfonline.com/loi/wccq20

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To cite this article: Walter Moreira & Daniel Martínez-Ávila (2018) Concept Relationships in Knowledge Organization Systems: Elements for Analysis and Common Research Among Fields, Cataloging & Classification Quarterly, 56:1, 19-39, DOI: 10.1080/01639374.2017.1357157

To link to this article: https://doi.org/10.1080/01639374.2017.1357157

Published online: 13 Sep 2017.

CATALOGING & CLASSIFICATION QUARTERLY
2018, VOL. 56, NO. 1, 19–39
https://doi.org/10.1080/01639374.2017.1357157

Routledge
Taylor & Francis Group

Concept Relationships in Knowledge Organization Systems: Elements for Analysis and Common Research Among Fields

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ABSTRACT

Knowledge organization systems have been studied in several fields and for different and complementary aspects. Among the aspects that concentrate common interests, in this article we highlight those related to the terminological and conceptual relationships among the components of any knowledge organization system. This research aims to contribute to the critical analysis of knowledge organization systems, especially ontologies, thesauri, and classification systems, by the comprehension of its similarities and differences when dealing with concepts and their ways of relating to each other as well as to the conceptual design that is adopted.

ARTICLE HISTORY

Received August 2016
Revised June 2017
Accepted July 2017

KEYWORDS

Concept relationships; knowledge organization systems; ontologies; thesauri

Introduction

Knowledge Organization Systems (KOS) and their relationships have been studied in a great variety of fields, including Library and Information Science (LIS), Knowledge Organization (KO), Documentation, Computer Science, Artificial Intelligence, software engineering, language engineering, and more. In LIS, the study of KOS usually considers these systems as tools that are potentially capable of facilitating and making the organization and representation of information more efficient in information retrieval systems, such as in digital libraries and, in the broadest sense, the Semantic Web.

The ubiquity of information and the explosion of technologies in which KOS can be applied have increased the number of fields that study KOS. Some KOS such as classification systems have a long tradition of study in LIS, and newer fields have considered that tradition to a certain point. However, the study of other KOS such as ontologies has been abruptly redefined by cutting-edge research in fields such as artificial intelligence and software development (commonly ignoring the theories and research of the LIS field even within the LIS community). In this sense, authors such as Barry Smith[1] have made a distinction between ontologies created by "engineers" and ontologies created by "scientists" (presumably

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philosophers developing "scientific ontologies"). It has also been suggested elsewhere that LIS scholars often embrace the tenets and assumptions of those engineers rather than looking to LIS research and knowledge organization theory.[2]

Although the ontological understanding of classification systems has been the object of several studies in LIS[3] (usually these consider the similarity of purpose as the fundamental link between ontologies and classification systems), there does not seem to be a consolidated recognition of the contributions of the research on classification and other traditional KOS to the development of ontologies, especially outside the LIS field. Thus, our research question involves the ways in which the discussion and literature on concept relationships in KOS, especially in the LIS context, contribute to the research of new trends and more sophisticated systems such as ontologies. Our hypothesis is that, given all the gathered knowledge and advances in classification theory, particularly regarding its principles and methodologies applied to knowledge organization and representation, as well as in the library practice and use of KOS, such as thesauri and bibliographic classification systems, the fundamental principles regarding concept relationships are present and could be further developed in a possible ontology theory in LIS. A better understanding of the exchanges and dialogs between different KOS and their relationships will improve and strengthen the interrelations between ontologies and other tools regarding the organization and representation of knowledge for access and use. This research can contribute to a critical analysis of the effectiveness of knowledge organization tools in documentation and information systems, suggesting the application of methodological features of ontologies in their development.

Methodology

This article uses a text-based method and a theoretical approach to analyze the concept relationships in KOS. In this sense, it is a conceptual and critical analysis of concept relationships in KOS. We survey and examine ideas and arguments from LIS and the classification traditions that are relevant to ontologies.

The sections of the article include a presentation of preliminary concepts related to the topics that are important for the analysis, namely knowledge organization and representation, classification theory, and ontology theory, followed by the results of the analysis and a critical discussion. In the Results section, we present the characteristics and different concept relationships found in standards and in the literature. Finally, we address and discuss our hypothesis in relation to the ideas of other authors in the literature. Overall, we acknowledge the influence of Hjørland's pragmatism, which considers the information about the goals and values and consequences of both the researcher and the object of research, as a theoretical framework for the analysis and discussion of results.[4]

Preliminary concepts: Knowledge organization and representation

Knowledge Organization is "a field of research, teaching and practice, which is mostly affiliated with library and information science."[5] The practical side of knowledge organization and representation is based on the development of tools for organizing and representing knowledge, such as classification systems, subject headings, thesauri, taxonomies, and ontologies. A common goal of these tools is to systematize the organization of knowledge through the use of identification, description, and the control of terms and concept relationships.

Thus, the organization of knowledge can be seen as a scientific and applied discipline that, in the words of García Marco, "aims to improve the flow of information within and through mediating systems—selection, storage, retrieval, and dissemination of information centers—to produce new knowledge and/or facilitate the access to the existing one" (in translation, originally in Spanish "La Organización del Conocimiento constituye una disciplina científico-aplicada cuyo objetivo es mejorar la circulación de la información dentro y a través de sistemas mediadores -los centros de selección, almacenamiento, recuperación y difusión de la información-para producir nuevo conocimiento y/o facilitar el acceso al existente.").[6]

According to Hjørland, knowledge organization can be understood both in a broad and in a narrow sense.[7] In a broader sense, KO is about "how knowledge is organized in different domains and how this can be used for IR [Information Retrieval]." This broader sense can also refer to the social organization of knowledge, how knowledge is structured in disciplines and professions, etc. On the other hand, "KO in the narrow sense is about the design of bibliographic records and systems of controlled vocabularies,"[8] about "activities such as document description, indexing and classification performed in libraries, bibliographic databases, archives, and other kinds of "memory institutions" by librarians, archivists, information specialists, subject specialists, as well as by computer algorithms and laymen."[9]

Considering the representational aspects that can be drawn from the expression "document description, indexing and classification," we have opted to use "knowledge organization and representation" to further develop Hjørland's sense of knowledge organization related to KOS in order to expand and highlight the importance of the theories in LIS, and subject knowledge to facilitate IR. Following Kiel's literal meaning of knowledge organization,[10] knowledge organization entails making knowledge an "*organum*" (in Greek an instrument, an aid) for particular purposes.

Provided the cumulative effect and exponential growth of knowledge, and considering that there must be free conditions for its production (and circulation), it is essential to record knowledge and organize its resources. Among the various meanings of "knowledge" that are used in LIS we take the one that refers to objective (or objectivized) knowledge, recorded in documents, in the sense of Popper's

"World 3."[11] David Bawden and Lyn Robinson have summarized these Worlds as follows: "World I is the physical world, of people, books, computers, buildings, etc World 2 is the internal, subjective mental state of an individual, including their personal knowledge; World 3 is the world of objective knowledge, which may be communicated between people by means of information stored in documents."[12] Of course, these three worlds interact with each other and the relation between subjective and objective knowledge is complex. Although some authors, such as Rafael Capurro,[13] have criticized this model, in LIS, it is commonly accepted in the cognitive paradigm that knowledge produced in "World 2" is organized in the "World 3", while "World 3" feeds the production of knowledge in "World 1". According to Brookes, one of the most enthusiastic advocates of this theory, it is "World 3" that offers a rationale for the professional activities of librarians.[14]

Classification theory and traditional KOS

Classification, together with indexing, document description, and metadata assignment, is considered one of the core activities of knowledge organization.[15] In a different sense, classification is also one of the general processes that condition a user's understanding of any fact or phenomenon. The cognitive ability to grasp the meaning of something requires activities of identification and sorting, regarding individual actions, and collective and social spaces of knowledge production that are not neutral.

The advances and growth of public and academic libraries during the late nineteenth century contributed to the emergence of new techniques of knowledge organization and representation, especially for the improvement of access and circulation. The organization of scientific knowledge allowed and preceded the emergence of a set of theories and methodologies for the organization and representation of recorded knowledge (and also of scientific knowledge in some cases, as the categories are not mutually exclusive). Thus, bibliographical classifications are the offspring, "more or less legitimate, more or less bastard" (in translation, originally in Portuguese "mais ou menos legítimas, mais ou menos bastardas"),[16] of scientific classifications, as the arrangement of books in the systems reproduces and legitimates the importance of the disciplines in the curricula of universities.[17]

In the context of LIS, classification theory has been developed in a constant dialog with practice, identifying gaps and implications in the practical application of KOS in libraries and drawing on theories to propose advancements in the field. Indeed, some of the most prominent proponents of theoretical research on classification of the last decades, such as Birger Hjørland and Hope Olson, acquired a valuable knowledge and practical experience working as librarians before their tenure as scholars. *Grosso modo*, a theory can be understood as a logically organized set of different "knowledges" that relate to each other and act as a "general reference framework" to explain some fact or phenomenon. In this sense, classification theory can also relate to the determination of the formal conditions that any bibliographic classification must meet. This is consistent with Gregor's suggestion[18] (discussed specifically in the area of knowledge organization by Hjørland[19]) of theories having four primary goals: analysis and description, explanation, prediction, and prescription.

Considering the specific case of bibliographic classifications in their applied dimension, linked to Popper's World 3, it can be said that the classification principles and theories that underlie classification systems are more concerned with the organization of classes in a logical and systematized way, ruled by principles that aim to gather and distinguish the relationships established between concepts.

On the other hand, classification systems can be typified according to different aspects and criteria. Vanda Broughton,[20] for instance, illustrates the variety of systems and structures listing scientific classifications, taxonomies, tree structures, folk classifications, bibliographic classifications, and aspects classifications. As for the way classifications are developed, Broughton also provides a further typology: enumerative classifications, "top-down" classifications, analytico-synthetic classifications, faceted classifications, and "bottom-up" classifications. A bibliographic classification can be faceted or enumerative. Enumerative classifications list all possible subclasses of interest for each class, faceted classifications break up subject areas into different aspects or "facets" of interest and numbers are synthesized from these facets. While systems can be more or less faceted or enumerative, pure enumerative bibliographic classifications are becoming less common. Even the DDC, which is commonly used as an example of an enumerative system, has become more flexible with each new edition and now offers impressive functions of analysis/synthesis, especially in the online edition. Modern classification theory, mainly after the contributions of Bliss and Ranganathan, has harshly criticized purely enumerative systems,[21] especially because their representational limitations make them unable to deal with the complexity and the dynamics of the knowledge representation processes.

Bibliographic classifications are usually understood in a narrow sense, burdened by their practical purpose of arranging physical documents according to subjects. Thesauri, on the other hand, are regarded for other "higher" functions, such as indexing by professionals and information retrieval by users. However, one must remember the complexity of the cognitive aspects involved in the classification process as a whole and the epistemological foundations that underlie the seemingly naive task of determining the subject and the class to which the document will "belong."

Decisions following criteria, underlying assumptions, unstated or stated theoretical foundations, and pragmatic interests always play an important role in classification, both at the classificationist and the classifier level. While bibliographic classifications are linear systems that develop the facets of the subjects in a linear way (either by design in enumerative classifications or at the moment of classification in faceted systems), the order of the facets will inevitably privilege some facets over others and thus create exclusions.[22] This brings positive or negative consequences for different groups. The factors that drive the development of classification systems are always specific and pragmatically oriented, either in *ad hoc* classifications, pragmatist classifications, or scientific classifications.[23] In the same way that Melvil Dewey's epistemic stance, based on Cartesian logic, influenced and determined the DDC system's pretense to be a universal classification,[24] it can be stated that the epistemological stance and the epistemological approach always precede and determine the ontological approach in classification.[25]

Ontology theory

Going back to Hjørland's concept of KOS, he also added that "[i]n the narrow sense KOS is a synonym for semantic tools, which is understood as selections of concepts and an indication of some of their semantic relations."[26] Based on Olensky,[27] ontologies are placed above topic maps, thesauri, taxonomies, folksonomies and glossaries as the KOS with the greatest semantic richness. In this context, ontologies are "KOS in which the kinds of semantic relations are unlimited. They are produced for making logical inferences by computers and [this] puts therefore high demands on the formal specifications."[28]

However, many of the practices currently used in LIS regarding ontologies can be traced via computer science and artificial intelligence (see Martínez-Ávila & Fox's detailed analysis of the matter[29]). In this vein, a popular and commonly used definition of ontology is Borst's: "An ontology is a formal specification of a shared conceptualization."[30] This definition is based on the thesis that, similar to other KOS, ontologies also require a terminological-conceptual agreement on the development and use of the conceptual systems that they intend to represent as a precondition for communication and reuse.

Although probably not always recognized by computer scientists working with ontologies, the notion of terminological-conceptual agreement resembles the notion of Quine's "ontological commitment."[31] This concept requires the understanding of the relationships between theory, entities, and ontology as elements that are characteristic of the formulation and development of ontologies. For Quine, the ontological commitments of a theory are "the entities or kinds of entity that must exist in order for the theory to be true," while theory refers to: "a set of sentences (or a single sentence) of some language."[32] In the Quinean conception, a theory would need a language, such as a first-order predicate logic, to specify the truth conditions and therefore the ontological commitments. Quine wrote, "A theory is committed to those and only those entities to which the bound variables of the theory must be capable of referring in order that the affirmations made in the theory be true."[33]

In KOS, the ontological commitment is assumed as a convention or agreement (implicitly established according to the epistemological views of the classificationists) that also demands a formal expression through the use of logic. The logical formalization is also a condition for the conceptual organization of "informational ontologies,"[34] and the ontologies used as computational tools. In those cases, formalization becomes a necessary condition for the "inferences," as machines, unlike humans, are not able to always fully understand the context and create new inference rules using implicit elements.

Despite the necessity of identifying and describing the concept relationships in ontologies, they do not need, as a logical necessary condition, to adhere to the classical conception of KOS and their types of hierarchical relationships. Relationships are indeed richer in ontologies and, given the characteristics of this type of KOS, are not required to present the universalizing enumerative intentions of some bibliographic classification systems. In domain or task ontologies, for instance, the concept relationships can be customized, that is, different ontologies can define different types of relationships.

Results: Term and concept relationships in KOS

There are two types of important relationships necessary for effective terminological control in KOS: relationships between terms and relationships between concepts. Although it is difficult to differentiate these two types of relationships in practice, since the concepts are represented by terms, and the concepts and terms establish a relationship of interdependence between themselves, it is important to understand the different characteristics of these relationships according to the literature.

A relationship between terms exists at the level of the expression and is controlled by equivalence relationships. In this type of relationship, a link between the sets of preferred terms and non-preferred terms is established in the KOS, following specific criteria that were previously adopted.

In addition to the relationships that are established between preferred terms and non-preferred terms, a network of relationships between concepts that are semiotically related can be established, in a way that such relationships work only with the preferred term. Considering that the concepts have no concrete existence, the display of the concept relationships is possible using the terms that represent them. Thus, the relationships identified as BT (Broader Term), NT (Narrower Term), and RT (Related Term) in a thesaurus also represent the notions of broader concept, narrower concept, and related concept, respectively.

Concept relationships can be classified differently according to the perspective or standard used. Table 1 shows the different typologies of concepts in the ISO 704 "Terminology work – principles and methods,"[35] ISO 25964-1 "Information and documentation – Thesauri and interoperability with other vocabularies – part 1: Thesauri for information retrieval,"[36] ANSI-NISO Z39.19 "Guidelines for the construction, format and management of monolingual controlled vocabularies,"[37] Wüster's classification (as discussed by Anita Nuopponen[38]), and Arnzt and Pitch.[39]

There are other authors who have also presented or discussed different typologies of concept relations, usually based on, or overlapping the aforementioned classifications. One example is Morville and Rosenville's typology for information

Table 1. Different typologies of concept relations found in the literature.

Author	Concept relations
ISO 704	– hierarchical relations — generic relations — partitive relations – associative relations
ISO 25964-1	– hierarchical relationships — generic relationships — instance relationships — whole-part relationships — polyhierarchical relationships – associative relationships
ANSI-NISO Z39.19	– equivalence relationships – hierarchical relationships — generic relationships — instance relationships — whole-part relationships — polyhierarchical relationships – associative relationships — relationships between terms belonging to the same hierarchy — relationships between terms belonging to different hierarchies
Wüster (in translation, as discussed by Nuopponen)	– logical concept relations – ontological concept relations — contiquity —— spatial contact —— temporal contact — relationship of effect —— causality —— tooling —— descent ——— genealogical descent ——— phylogenetic descent ——— ontogenetic descent ——— stages of substances
Arntz & Picht (in translation)	– hierarchical relations — abstract (also called logical or generic) — ontological (also called partitive or whole part) – non-hierarquical — sequential — pragmatic

architecture,[40] a subset of ANSI-NISO Z39.19/ISO 25964-1. Typologies presented in Table 1 and others that are derived from them can be synthetized in two "groups" of criteria: hierarchy and association relationships.

Hierarchical relationships are established between two concepts when the semantic spectrum of one of them fits completely in the semantic spectrum of the other. Depending on the position of the concepts in the hierarchical relationship, in theory the level of generality or specificity of concepts assumes relations of superordination (the class) and subordination (the member, part or instance).

Compared to an associative relationship, a hierarchical relation (generic or partitive) is easier to be displayed in a tree structure (see Figure 1).[41]

With the appropriate notation, it is even possible to differentiate types of hierarchical relationships, such as generic relationships (see Figure 2), instance relationships (see Figure 3), and partitive relationships (see Figure 4).[42,43]

mammals
BT vertebrates
vertebrates
NT mammals

Figure 1. Example of hierarchical relationship.

rats
BTG rodents
rodents
NTG rats

Figure 2. Example of generic relationship.

Fairy tales
NTI Cinderella
NTI Rumpelstiltskin

Figure 3. Example of instance relationship.

The associative relationship, more dependent on contextual situations and thus more unstable than hierarchical relationships, is not an easy concept. The ANSI/NISO Z39.19-2005 (R2010) defines it by exclusion: "This relationship covers association between terms that are neither equivalent nor hierarchical, yet the terms are semantically or conceptually associated to such an extent that the link between them ***should*** be made explicit in the controlled vocabulary, on the grounds that it ***may*** suggest additional terms for use in indexing or retrieval"[44] (emphasis in original). A similar definition is also included in the ISO 25964-1: "The associative relationship covers associations between pairs of concepts that are not related hierarchically, but are semantically or conceptually associated to such an extent that the link between them needs to be made explicit in the thesaurus, on the grounds that it may suggest additional or alternative terms for use in indexing or retrieval."[45]

The identification and establishment of associative relationships in a system depend on the system's policies and the types of "semantic connections" that are useful for the system. Although there are different typologies and models of

central nervous system
BTP nervous system
nervous system
NTP central nervous system

Figure 4. Eample of whole-part relationship.

Table 2. Examples of associative relationships.

Relationship type	Example
Cause / Effect	accident / injury
Process / Agent	velocity measurement / speedometer
Process / Counter-agent	fire / flame retardant
Action / Product	writing / publication
Action / Property	communication / communication skills
Action / Target	teaching / student
Concept or Object / Property	steel alloy / corrosion resistance
Concept or Object/ Origins	water / well
Concept or Object / Measurement Unit or Mechanism	chronometer / minute
Raw material / Product	grapes / wine
Discipline or Field / Object or Practitioner	neonatology / infant

associative relationships reported in the literature,[46] the most common associative relationships found in practice include those summarized in Table 2.

Generic relationships are always grounded on theoretical or epistemological views. For instance, there are scientific arguments and convention in zoology to consider "lion" as a subordinated species to the genus "mammal." Such a relationship can be only verified at the conceptual plane though, as there is not such a class as "mammals" in reality. However, in some views, such as in the Wusterian conception (see Table 1), ontological relationships refer to properties of the objects in the empirical world. In this sense, concepts would be related to their whole and their parts, such as in "cardiovascular system" and "blood vessels."

In thesauri and bibliographic classifications the relationships between concepts can be indicated just by visual features such as indentation leaving the inference process to the user of the system (although this is not desirable), but all relationships in ontologies must be detailed and formalized in relation to their nature and ontological commitment. Related to this, Marcondes and Campos[47] comment on the partitive relations: "in ontologies we should identify what type of part and whole the terms represent, for example, if it is a full object/component, such as a wheel is a part of the car; if it is a member/collection, such as a tree is part of a forest, but maintains its own identity; if it is mass/portion, such as the piece of a pie" (in translation, originally in Portuguese: "nas ontologias devemos identificar que tipo de parte e de todo esses termos representam, por exemplo: se é um objeto integral/componente, como: roda é uma parte do carro; se é um membro/coleção, como: uma árvore é parte de uma floresta, mas mantém uma identidade própria; se é massa/porção, como: o pedaço de uma torta.").

In the case of the generic relationships (also called "IsA" relationships as in the case of instance relationships), there is the possibility of applying the logical "all-and-some test" to confirm their logical validity (see Figures 5 and 6).[48] In the example in Figure 5 there is a genuine and valid generic hierarchical relationship because it is truly possible to say that some members of the class "birds" are known as "parrots" and that all the "parrots" are by definition, and irrespective of the context, regarded as "birds." Figure 6 illustrates an opposite example of a generic

Figure 5. Relationship that satisfies the "all-and-some test."

hierarchical relationship that is not correctly and logically established, as while some members of the class "pets" are "parrots," only some (not all) "parrots" are regarded as "pets."

Hierarchical relationships, given their more clearly identifiable characteristics and criteria for description, can be adapted more easily to the automatic processes of inference of ontologies. In these processes, the greatest difficulty in the treatment of the conceptual relationships lies in the identification and formalization of associative relationships. This is also true for thesauri, as noted earlier. In this regard, Marcondes and Campos state that "the associative relationships (functional relationships), that in the thesaurus are only identified by symbolism (RT/RT [related term]), […] in the ontologies are more explicit and express the kind of relationship that exists between the two terms, that is, it is useless to just indicate, as in the case of thesauri, that in the context of Health Science there is an associative relationship between a "Barber" and "Chagas disease," i.e., between an entity and a process, rather that the relationship that is established between these two elements is one in which an "entity" "transmits" a "disease""[49] (in translation, originally in Portuguese "as relações associativas (relações funcionais) que no tesauro somente são identificadas pelo simbolismo (TA/TA), […] nas ontologias elas são mais explicitadas e expressam o tipo de relacionamento que existe entre os dois termos, ou seja, não adianta, como nos tesauros, somente indicar que no âmbito da Ciência da Saúde existe uma relação associativa entre um "Barbeiro" e a "Doença de Chagas", ou seja entre uma entidade e um processo, mas que o relacionamento que se coloca entre esses dois elementos é aquele onde uma "entidade" "transmite" uma "doença"").

The notion of system in computer science implies that the relationships between the concepts are ordered by a logical-semantic principle that must be absolutely consistent. Therefore, the consistency and quality of the system can be determined by the quality of these relationships.

Some authors have argued a possible superiority of ontologies over thesauri and classification systems in the processes of knowledge organization and representation.[50] One of the main reasons for this "superiority" would be the greater diversity

Figure 6. Relationship that does not satisfy the "all-and-some test."

and quality in the identification (as in the process of making explicit) and description of the conceptual relationships, seen as inherent to the detail required to formalize these relationships. Other arguments for this superiority include the possibility of reusing ontologies and the capability of this tool to operate in heterogeneous systems.

Given the current state of the methodological and theoretical frameworks, it can be said that we still need more effective contributions in information science to understand the problem of the organization of logical-semantic relationships between concepts in regards to the construction and maintenance of ontologies. While we recognize the progress and efforts achieved in the field of computer science, we concur with Marcondes and Campos[51] when they say that despite the proposal of languages and tools for the representation and construction of ontologies in the computer science domain, these proposals generally do not include satisfactory guidelines for identifying concepts and relationships between them, to create consistent definitions, or even for modeling associated domains.[52] As a result, these tools have little to contribute to guidelines for the process of ontology construction by users, or to guidelines for the construction of quality ontologies.

In this vein, Barry Smith also claimed in his "Why computer science needs philosophy" that "Ontologies have become core components of many large applications yet the training material has not kept pace with the growing interest."[53] Although there have not been specific methodologies for the construction of ontologies in the information science literature, as pointed out by Sales,[54] it is common to find in the knowledge organization field some references and concerns regarding this aspect.

Discussion on concept relations in KOS

In the 1970s, thesauri were still perceived as a relatively new thing (in spite of their emergence in the 1950s) and they were often compared to classification systems. As an example, Eric de Grolier[55] stated that thesauri were classifications that did not dare to say their name, and saw the proliferation of them as a symptom of disordered and anarchic growth of undercover classifications. In the same vein, other contemporary authors such as Campos[56] also claimed not to understand "why [thesauri] are not called classifications" (in translation, originally in Portuguese "por que [os tesauros] não são chamados de classificações"). More recently, authors such as Soergel have also equated thesauri to classifications in the following terms: "But a classification by any other name is still a classification. The use of a different term is symptomatic of the lack of communication between scientific communities. The vast body of knowledge on classification structure and on ways to display classifications developed around library classification and in information science more generally, and the huge intellectual capital embodied in many classification schemes and thesauri is largely ignored."[57]

Considered in any of their aspects, either as a discipline of philosophy or as a new discipline whose main product is the computational tool known as "ontologies," they function as categorization systems that enable the organization and representation of knowledge. Usually, the concepts of philosophical ontology and computational ontology are distinguished in the literature with the use of a capital "O" for the philosophical ontology (Ontology) and lower case for computational ontologies. In our article, we generally chose not to follow this typographical distinction, as we believe that this disambiguation can be resolved by context and, when necessary, by the use of qualifiers.

Ontology emerged as a philosophical concern with Aristotelian metaphysics. In the educational divisions of philosophy, ontology (the theory of being) takes place next to aesthetics (the theory of beauty), ethics (the theory of morals), epistemology (the theory of knowledge), and logic (the theory of reasoning). The Aristotelian model distinguishes being, 'what really is,' from appearance, or "what seems to be." Ontology would be the study or knowledge of beings, that is, of things as they really and truly are in themselves. Ontology is thus the philosophy itself and knowledge of being, as it represents the passage from opinions about objects of the senses to thoughts about those objects' immutable essences.

Given their condition as computational tools, ontologies have been understood differently in philosophy from the way they are understood in information science and computer science in particular. The key element of the distinction lies in its application. While the philosophical Ontology aims to establish big concepts of immediate application, the computational ontology includes micro-worlds with a limited number of concepts that are aimed at solving specific problems. While philosophy focuses its ontological concerns on the description of the things that exist in the world, the application of ontologies in the domain of computational representation of knowledge is more modest, basically because it pragmatically understands that what exists is what can be represented.[58] In this case, the ontological concerns are restricted to specific domains, as they aim to understand the concept in the context of a specific domain, task or application, even being able to choose just one of its facets according to the particular ontological commitment.

Barry Smith has argued that, given the state of computational ontologies, there is a risk of holding a non-prolific use of the term "ontology" that is disengaged from its philosophical meaning.[59] As bibliographic classifications are indebted to philosophical classifications, seeking or inheriting from these the logical and epistemological bases for the organization of knowledge, the development of computational ontologies should not be alien to the contributions of philosophical ontology either, and probably even to the advances in classification theory.

The ontological approach of philosophical classifications offers methodological tools which can ensure that the bibliographic classification process is conducted consistently. This also applies to computational ontologies.[60] The inconsistency of enumerative classification systems that have no philosophical basis is something to be considered too. In this regard, discussions on the relationship between computational ontologies and philosophical ontologies are rare, some examples being the works of Sowa,[61] Smith,[62] Marcondes,[63] and Martínez-Ávila and Fox.[64]

Ontologies and classification systems are different types of systems that have different purposes. However, both can benefit from each other's implementations and theoretical and methodological models to organize knowledge. Ontologies can be used as a basis for the construction of more complex and cohesive classification systems (including thesauri), because of their richer treatment of conceptual relationships that can be likened to the faceted approach in classification. It should be noted, however, that the epistemological framework of the developers will define the way ontologies and classification systems address a given phenomenon. As conceptual modeling tools, ontologies are designed to provide a simplified representation of knowledge of particular phenomena, while classification systems present a division of classes in order to arrange objects.[65]

Even if we do not consider ontologies "undercover classifications"—to paraphrase Grolier —it is essential to expand beyond the confines of the most traditional taxonomy of semantic relationships that classification systems such as the DDC express, basically understood as hierarchical. The expansion and effective understanding of the types of semantic relationships expressed by these tools for knowledge organization, together with their formal representation, can allow classification systems to be brought closer to ontologies as well as enable effective synergies at that intersection.

According to Mitchell, the types of relationships in the DDC include hierarchical relationships (generic, whole-part, instance relationships, and polyhierarchical relationships), equivalence relationships, and associative relationships, all of them expressed through notation and structure.[66] These relationships are present in the schedules and tables, in the relative index, and in the manual of the DDC.

One of the most common criticisms of the DDC is related to the limitations of enumerative systems. However, it should be noted that although the number of entries listed in the system is finite (40,920 explicit assignable numbers in schedules, including built numbers[67]), it also has the potential of building new conceptual relations by synthesis, which gives the system an analytic-synthetic approach.[68] Another common criticism of the DDC and other bibliographic classifications is the inconsistencies of their hierarchical relations.[69]

On the other hand, ontologies are not free of inconsistencies either, as pointed out by Smith *et al.* for the case of the Open Biomedical Ontologies (OBO): "The problem is that when OBO and similar ontologies incorporate such relations they typically do so in informal ways, often providing no definitions at all, so that the logical interconnections between the various relations employed are unclear, and even the relations *is_a* and *part_of* are not always used in consistent fashion both within and between ontologies"[70] (emphasis in original). In both cases, this would be understandable given the difficulty of representing reality in a rigorously logical model.

Although it is possible to find several examples of instance relationships in the DDC ("Yellowstone National Park" as an instance of national parks, for example), their use seems to be awkward, especially when comparing a classification system to a thesaurus. In this tool, instances are rarely used (considering the admissibility of their use), because it cannot be safely said that an instance represents a class or subclass. In the DDC, a system that is organized by classes, the hierarchical nature of this type of relationship is at least questionable. An instance, in this type of organization, questions the systematics of the structure, as the concept does not work as a concentrated unit of knowledge forming a class, i.e., it does not have, in that sense, representative power.

However, instance relationships are indeed considered hierarchical relationships in the standards. The ANSI/NISO Z39.19-2005 (R2010) states that this relationship "identifies the link between a general category of things or events, expressed by a common noun, and an individual instance of that category, often a proper name."[71] This relationship is shown in Figure 7.

As also indicated in the standard, although the concepts "Alps" and "Himalayas" are hierarchically subordinated to "mountain regions" in the example, they do not represent types or parts of mountainous regions (as in the generic relationships and partitive relationships). Both concepts in the example represent individual instances, occurrences that can be taken as individual objects related to a general object that subsumes the two concepts.

A study of hierarchical relationships in the DDC and in the Universal Decimal Classification (UDC) by Marilda Lara[72] shows that it is very common, although not necessarily acceptable, to assign an entity a subordinate position in two or more hierarchies, something that violates the principle of logical disjunction. Having more than one characteristic for division enables the coordination of terms of different natures and (logically) invalidates the principle of hierarchical force that is claimed by both systems. On the other hand, according to Lara, in addition to the hierarchical generic and partitive relationships, there are other types of conceptual relationships in the DDC, such as associative relationships; this makes the popular claim that DDC is based on Aristotelian logic questionable.

In a slightly different way, instances in ontologies are not exempt from controversy either. Ontologies are considered tools for the organization and representation of knowledge, and as such, the very notion of representation is in conflict with the representational or definitory potential of instances in relation to a class or a category. On the other hand, ontologies, considering their variety of typologies and applications (from the description of more delimited and specific semantic

Mountain regions
  Alps
  Himalayas

Figure 7. Example of instance relationship.

fields such as in task ontologies to the inclusion of general and universal concepts of foundational ontologies), are not always defined within a specific knowledge domain, and therefore they cannot always benefit from the apparent notional integrity that characterizes a given conceptual or semantic field. If we assume, just as a rhetorical experiment, that some kind of concept relationship independent of context was possible, the indication of the instance, which represents individual objects or occurrences, would be less precise and with less potential to be universalized than the relations that can be established between groups of concepts formed by generic or whole-part relations.

Conclusion

If we study ontologies in relation to the philosophical aspects that they inherit from classification systems, even when that heritage is not always recognized, we can say that traditional KOS, such as classification systems and thesauri, no doubt can contribute theories and methodologies to solve the problems that are related to knowledge organization, especially in the context of libraries and databases. We must be skeptical, however, about the accuracy of this statement in a scenario involving complex digital resources and hybrid forms of documents that has been dominated by computer scientists.

While classification theory, in the LIS tradition, is based on recognized philosophical principles, these principles are not necessarily recognized in the computer science literature on ontologies. Computer scientists working on computational ontologies seem to look to LIS even less than in the case of classifications. However, because the development of ontologies is a rich field of application for knowledge organization with great potential for theoretical research, we believe that it is important for our field to invest in classification research and link this research to both the applications of ontologies and the development of an ontology theory.

Finally, considering the modernity of the classification theory in light of the new questions, notably those raised by ontologies and other ways to organize information in digital contexts, it is necessary to invest in a new understanding of bibliographic classification systems and classification theory that considers their necessary intersections with computational ontologies.

Acknowledgments

We would like to thank the anonymous reviewers for their helpful comments.

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