A SEMANTIC-RELATIONS TAXONOMY FOR KNOWLEDGE REPRESENTATION

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Abstract

Concepts are units of knowledge and, the relationships link these units, which gives the meaning as represented. Semantic relations in knowledge representation characterizes the association between the concepts of a domain. In this way, semantic relations allow users to assimilate the association between concepts in a domain. These relationships are essential because they serve as a basis for representing and structuring a domain of knowledge. Thus, the studies on semantic relations have been accomplished by several researchers from different areas of knowledge, approaching a different point of view, which resulted in a terminological variation. The objective of this proposal of the taxonomy of semantic relations arose precisely to solve this problem. In this sense, exploratory research was carried out using the methodological procedure literature research following criteria that pointed out the most relevant approaches to types of semantic relations. As result, a taxonomy was arrived at of sixty-three semantic relations, including the new relationships found from this study, nicknamed here "subordinate agent".

Keywords: Semantic Relations; Knowledge Representation; Knowledge Organization; Semantic-Relations Taxonomy

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1 Introduction

Knowledge is created at all times; without organization, however, it becomes unusable by people (or machines) (Soergel 2009). The use of techniques, methods and processes for creating Knowledge Organization Systems (KOS) codifies knowledge so that users can find and utilize it.

"The term 'knowledge organization' implies that what is being organized is knowledge", according to a recent definition Broughton et al. (2005); that may be broken down into units called "concepts". A concept is a compilation of true statements about an object, fixed by a linguistic symbol (Dahlberg 1978). Therefore, true propositions about an object may be elaborated, eliciting the object's characteristics. For example, the object "glass" may have the propositions that it is made of glass, it serves the drinking of liquid, and it is a kitchen utensil. The combination of these propositions are the characteristics observed about the object and form the object's concept. However, a symbol is required to associate the characteristics with it. In this example, the symbol for this concept is the word "glass".

The concepts do not occur in isolation since they belong to a domain and, therefore, they relate to other concepts in that domain. Thus, knowing the domain is important since the characteristics that make up a concept can vary according to context, as different domains have different needs. In the example of the "glass" object presented above, the characteristics mentioned speak to the domain of household utensils. In the domain of 'supermarket', the features that matter are the glass's price and brand, for example.

A concept in a domain connects to other concepts making a semantic structure of knowledge. Thus, through the semantic relations between concepts, it becomes possible to understand the context of the concept in a structure. To continue with the example of the concept of "glass", the following relationship can be made in the domain of household items in a home: a person uses a glass. In the supermarket context, the relationship would be: a person buys a glass. In these examples, it can be seen that the relation between "person" and "glass" has changed according to the domain in which these two concepts were inserted and according to the purpose of the representation.

Beyond the domain, the specifications of semantic relations are influenced by language/culture and knowledge about the world. According to Khoo and Na (2006), linguistic aspects are fundamental for the understanding of knowledge structures that involve concepts and semantic relations. For the authors, it is difficult to analyze the meaning of concepts and their relations apart from language, since each language has its idiom and is tied into the culture.

As mentioned, the other factor that affects semantic relations is human knowledge about things, that is, knowledge of the world. Without this type of knowledge, a semantic relation between things cannot be established. For example, without the knowledge that Copenhagen is the capital of Denmark, it is impossible to determine a relation between Copenhagen and Denmark (Hjørland 2007).

Specifically, on the LIS (Library and Information Science), semantic relations are important elements in the construction of KOS. Depending on the nature of these instruments, sometimes the semantic relations are represented implicitly and other times explicitly. Likewise, for Green (2001), the relationships involved in KOS are numerous and generally complex. This magnitude and complexity get in the way of its consistent use by professionals as well as by the end-users of information. According to the author, sometimes there is a lack of consensus about how to treat certain relationships, therefore, the users cannot understand what is being communicated by the relationship or by the relationship notation standard.

Hjørland (2007) also states that the number of semantic relations can be infinite and different domains develop new types of relations. Furthermore, according to the author, contributions about semantic relations are difficult to present coherently because they are not related to each other or systematically related to broader views.

So, the research problem of this paper refers to the lack of a current classification that accommodates the types of semantic relations commonly used in LIS. Recent studies about semantic relations were carried out (like Almeida and Emygdio (2019), Maculan (2019), Hasan et al. (2020), Koeva (2020), and Hosseini et al. (2021)), but, no one none of them proposed a classification of semantic relations.

This study is justified because of (1) the importance of semantic relations for understanding the connections between concepts in the domain; (2) the considering nuances for the establishment of relations for knowledge organization and representation, and (3) the given the numerous types of semantic relations spread on the literature. Therefore, the objective of this paper is to analyze and compile the types of semantic relations discussed in the work of several authors, active mainly in the field of LIS (Library and Information Science).

This research is exploratory since it aims to understand the point of view of several authors about the types of semantic relations. The methodological procedure is the bibliographic research, based Pradonov and Freitas (2013) with the following stages: (1) choice of the theme; (2) preliminary bibliographic survey; (3) formulation of the problem; (4) elaboration of the provisional plan of the matter; (5) search for sources; (6) reading the material; (7) filing; (8) logical organization of the subject and; (9) writing the text.

The choice of theme, stage (1), was based on the research problem and objective: “The types of semantic relations in LIS”. Stage (2), a preliminary bibliographic survey, involved an exploratory search in Google Scholar based on the theme. Among the retrieved references, the book by Green and Bean (2001) “Relationships in the Organization of Knowledge”. The question that drove the search is: What are the types of semantic relations of the LIS and how are they classified?”. In stage (4), it was an elaboration of the provisional plan of the matter, with the determination of queries: "Q1: 'Semantic Relation' OR 'Semantic Relationship' AND 'Information Science'"; "Q2: 'Semantic Relation' OR 'Semantic Relationship' AND 'Knowledge Organization' OR 'Organization of Knowledge'. Also, in This stage, defines the bibliographic databases: Library, Information Science & Technology Abstracts with Full Text (EBSCO), Information Science & Technology Abstracts – ISTA (EBSCO), Library and Information Science Abstracts – LISA (ProQuest), Web of Science, and Scopus.

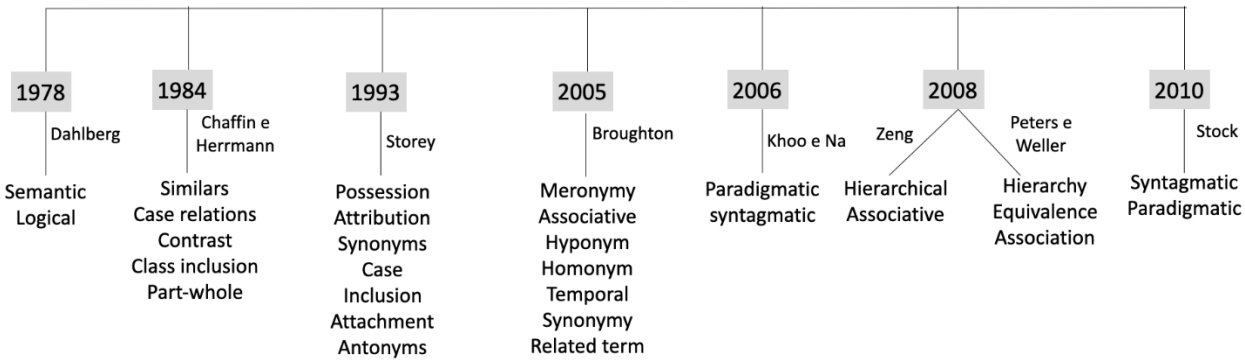
In stage (5) of bibliographic research, search for sources, the queries were performed with the necessary adjustments in the databases. From the results retrieved, those whose titles explicitly dealt with the subject were selected, in addition, the relevance of the publications was analyzed based on the abstracts. In stage (6), reading of the material, an exploratory reading of the publications and their categorization based on the sub-topics they addressed was carried out. This

categorization further refined the results found. In stage (7), filing, the types of semantic relationships found in each publication were registered. At this stage, it was perceived through repeated citations the need to read other publications that did not necessarily address semantic relationships in the title, in addition, it was noted that it was necessary to explore sources from other areas besides LIS. Furthermore, at this stage, was returned to the stage (4) with queries that addressed the specific types of semantic relations. Then, in stage (8), of logical organization of the subject, the classifications of semantic relations by authors were organized in chronological order of publication, as presented in the next chapter.

2 Approaches to semantic relations in the literature

Distinct types of semantic-relation arrangements were suggested by different authors, each one classifying semantic relations according to their perspective, as codified in their systems, studies and researches. Figure 1 shows a timeline of the authors to be reviewed in this paper and the respective classes of relationships pointed out by them.

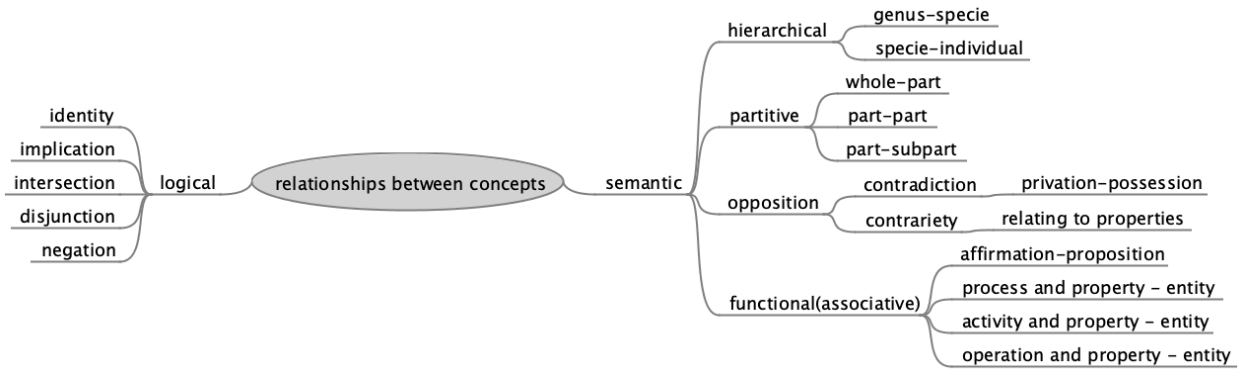
Figure 1 - Timeline of semantic-relation classifications



Source: Translated of Maia (2018)

Dahlberg (1978) classifies relations as logical and semantic (figure 2). The logical relations (identity, implication, intersection, disjunction and negation) are based on common characteristics between concepts. According to the author, this is important for comparison of the concepts and then to organize and relate them semantically. The semantic relations by Dahlberg (1978) are grouped in hierarchical, partitive, oppositional and functional categories, as shown in figure 2.

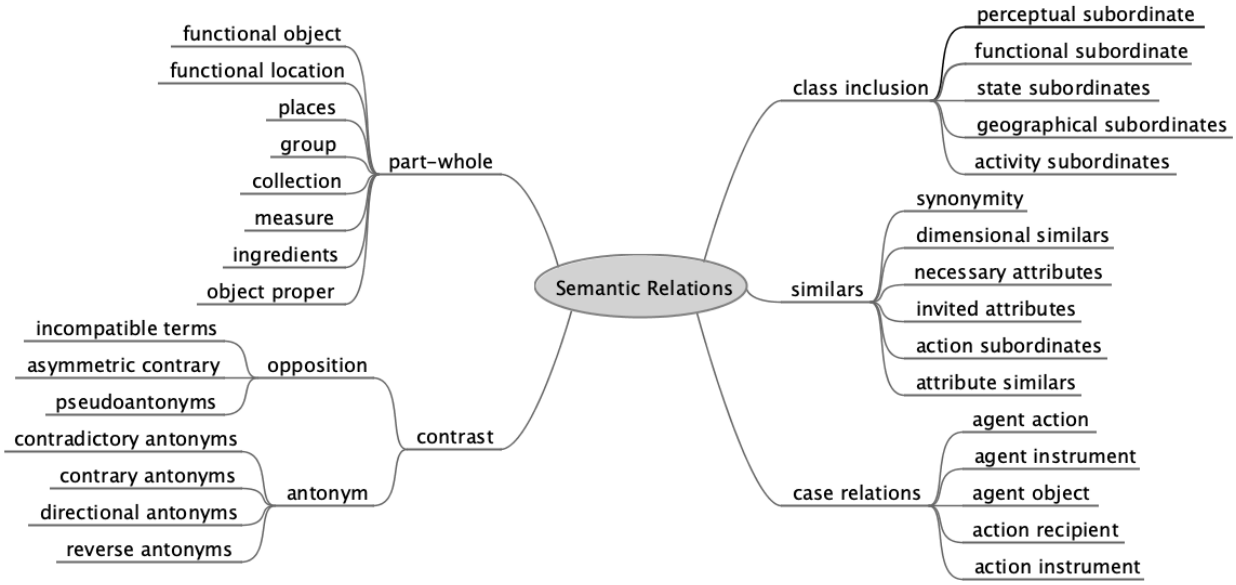
Figure 2 - Relationships between concepts according to Dahlberg



Source: Translated of Maia (2018)

Figure 3 shows the semantic-relations taxonomy of Chaffin and Herrmann (1984) who arrange the relationships differently to Dahlberg (1978). They present partitive relations in the same way as Dahlberg (1978), but name them as "part-whole", and they create other peculiarities for this relationship. The opposition relation, also pointed out by Dahlberg (1978), was introduced as a type of contrast relation in Chaffin and Herrmann (1984). In the contrast class, besides opposition relation, Chaffin and Herrmann (1984) also included antonym relations. In addition, they expanded the types of semantic relations, creating "class inclusion", "similars" and "case relations". Briefly, class inclusion relations are "type of" relations, in similar relations the meanings of terms converge, and case relations involve attribution.

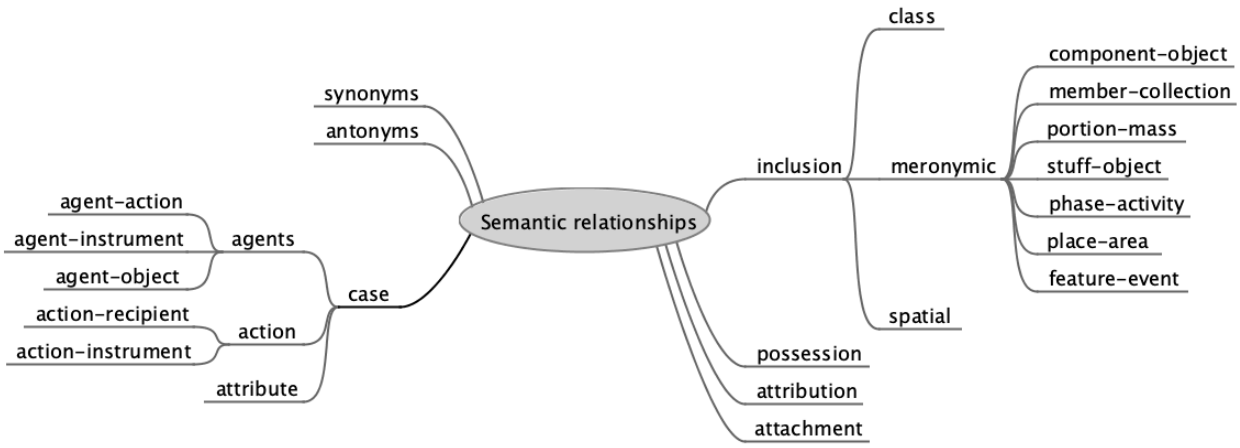
Figure 3 - Semantic relations according to Chaffin and Herrmann



Source: Translated of Maia (2018)

Storey (1993) based her work on Chaffin and Herrmann (1984), but gave her taxonomy a different configuration (see figure 4). Of the similar-relations class understood by Chaffin and Herrmann (1984), only the category of synonyms was considered by Storey (1993). Likewise, antonym, of the contrast relations of Chaffin and Herrmann (1984), was accepted by Storey (1993). Again, the case relations as cited by Chaffin and Herrmann (1984) were subdivided into agents and actions and were joined by “attribute relation”. Storey (1993) created “inclusion relation” and subdivided that into class inclusion, spatial inclusion and meronymic (named by Chaffin and Herrmann (1984) as “part-whole” and Dahlberg (1978) as “partitive”). In addition, Storey (1993) established “possession relations” as those to indicate ownership, “attribution relations” to refer to an object and its attribute, and “attachment relations” to indicate that one object is connected to another.

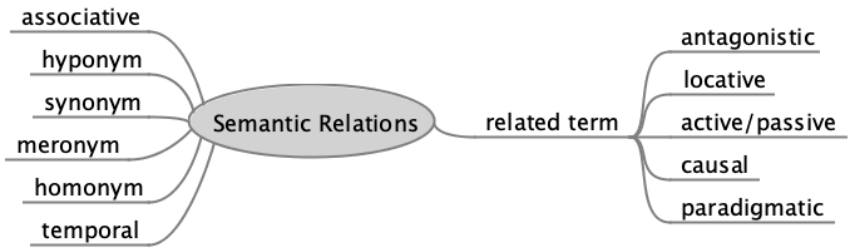
Figure 4 - Semantic relationships according to Storey



Source: Translated of Maia (2018)

Broughton et al. (2005) presented a set of semantic relations (figure 5) considered important to Knowledge Organization System (KOS), exemplified mainly in the making of a thesaurus. The authors suggested the term "associative relation" for what was treated by Dahlberg (1978) as "functional relation", and "hyponym", considered by Dahlberg (1978) as "hierarchical relation". Synonym and meronym were considered by them in the same terms as Storey (1993), however without further specifying types of meronyms. Furthermore, Broughton et al. (2005) introduced the "homonym relation" (when two concepts are expressed by same symbol), "temporal relations" (when "a concept indicates a time or period of an event designated by another concept") and "Related Terms" (RT), frequently used in a thesaurus when a term is related to another term in some way. Broughton et al. (2005) determine five types of RT relations.

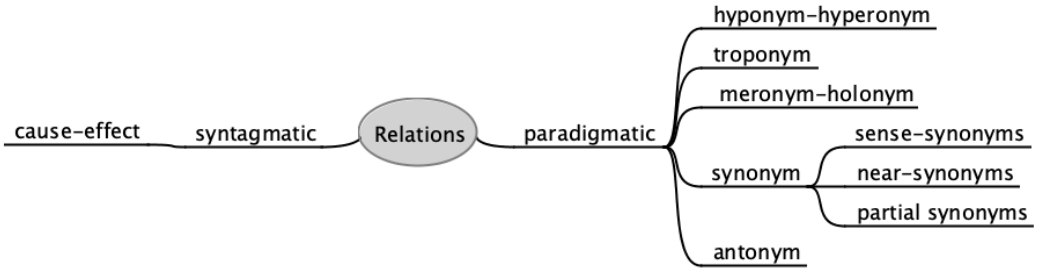
Figure 5 - Semantic relationships according to Broughton Hansson, Hjørland and López-Huertas



Source: Translated of Maia (2018)

Khoo and Na (2006) separate relations into “paradigmatic” (also called “semantic relations” or “lexical relations”) and “syntagmatic” (see figure 6). With the exception of Dahlberg (1978), who does not consider the cause-effect relation, the other authors cited so far Chaffin and Herrmann (1984); Storey (1993); Broughton et al. (2005) addressed the case (or casual) relations in their classifications; however, they classed it as a semantic relationship, unlike Khoo and Na (2006), who classified the relation as “syntagmatic”. In paradigmatic relations, Khoo and Na (2006) termed the relation called “hierarchical” by Dahlberg (1978) and “hyponym” by Broughton et al. (2005) as a “hyponym-hypernym” relation. According to Khoo and Na (2006), “hyponym” indicates the specific term and “hypernym” the generic term. For them, this relation is usually denoted by the expressions “is-a” and “type- of”. The “troponym”, included by Khoo and Na (2006), is attributed to relations between verbs. Moreover, the synonyms presented by Khoo and Na (2006) are subdivided into: “sense-synonyms” (terms that share the same meaning), “near-synonyms” (terms in which the meanings are close) and “partial synonyms” (terms that share the same meaning but are different in some aspect or aspects). Finally, the “antonym” was considered by Khoo and Na (2006), as also Chaffin and Herrmann (1984) and Storey (1993).

Figure 6 - Relations according to Khoo and Na

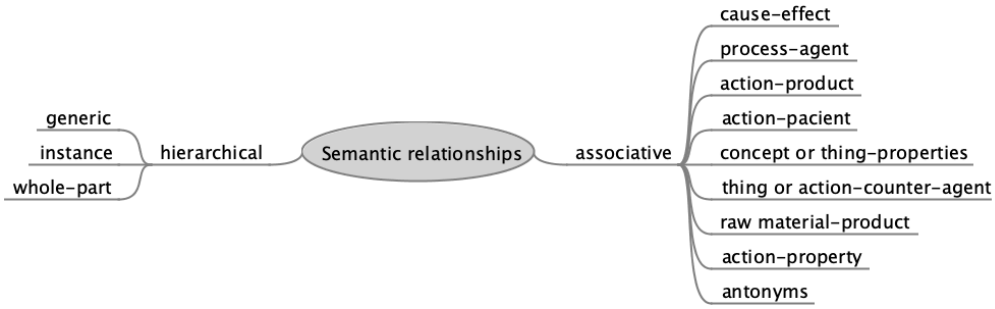


Source: Translated of Maia (2018)

Zeng (2008) presents a set of semantic relations used in KOS. The semantic relationships suggested by Zeng (2008) are divided into: hierarchical and associative, as may be seen in figure 7. While Dahlberg (1978) separates the hierarchical and partitive relations, Zeng (2008) points out that the partitive relation (whole-part) is a hierarchical relation. The hierarchical relations indicated by Zeng (2008) are “whole-part”, “generic”, and “instance”. The instance relation is a concrete relation between an entity and an individual Green et al. (2013). The cause-effect relation was

considered by Zeng (2008) as associative, unlike Khoo and Na (2006) who classified it as a syntagmatic relation. Furthermore, antonyms were pointed to as a type of associative relation.

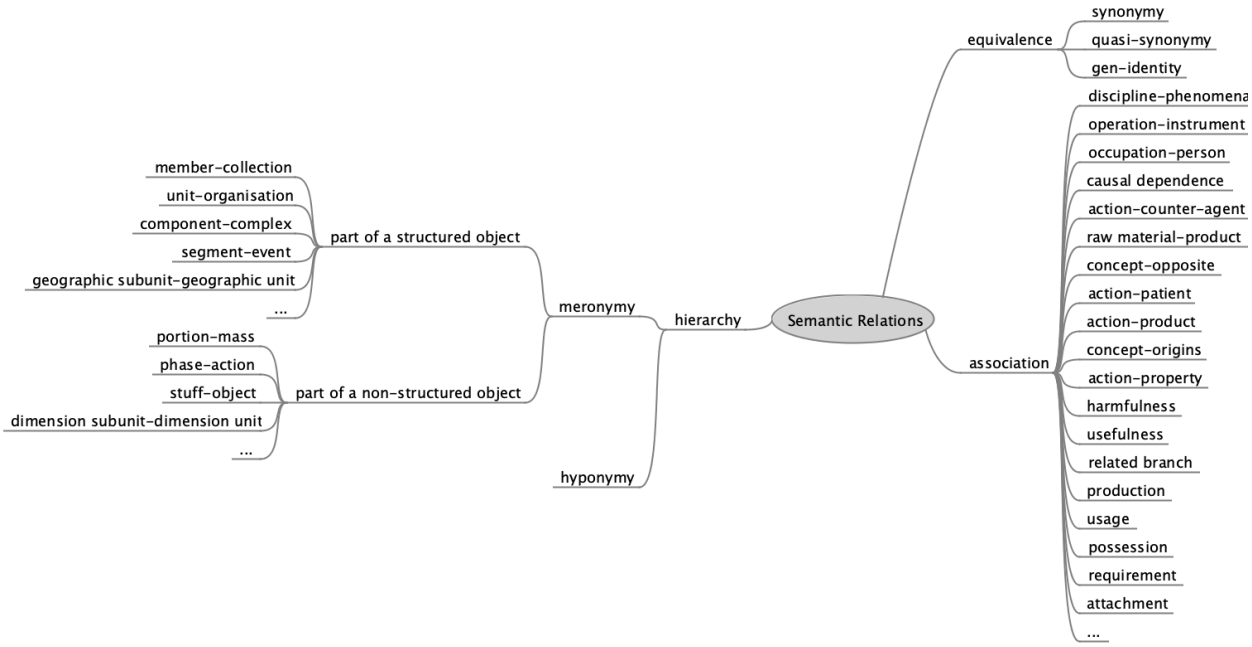
Figure 7 - Semantic relationships according to Zeng



Source: Translated of Maia (2018)

Peters and Weller (2008) treat relations in KOS, especially in the context of folksonomy and ontology. Like Zeng (2008), they also group semantic relations into hierarchical and associative categories, but they add equivalence relations to gather synonyms, quasi-synonyms and a gen-identity relation, based on Gene Ontology. In respect of meronym relations, the authors divided that into relations in which the parts refer to a structured object and parts to a non-structured object. As to the taxonomy set out by Peters and Weller (2008), association relations group all other relations that are neither hierarchical nor equivalence. It is important to observe of Peters and Weller (2008)'s taxonomy that the meronymy and association relations are infinite, that is, the authors do not exhaust the possibilities for including new subtypes of these types of relations. Figure 8 shows the semantic relations pointed out by the authors.

Figure 8 - Semantic relations according to Peters and Weller

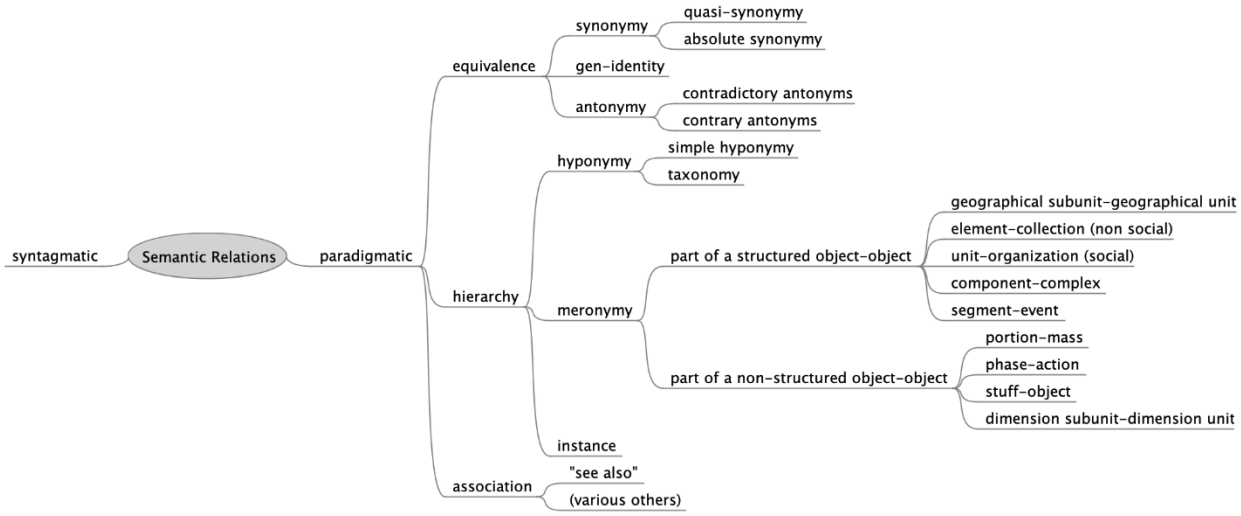


Source: Translated of Maia (2018)

Stock (2010) addresses semantic relations in the context of Library and Information Science (LIS). As seen in figure 9, semantic relations are divided into "syntagmatic" and "paradigmatic", a different solution to that of other authors discussed in this section. For Stock (2010), the syntagmatic relation occurs only in folksonomy. On the other hand, paradigmatic relations are grouped into "equivalence", "hierarchy", and "associative". Observing the Peters and Weller (2008) in figure 8, these relations are semantic relations, but Stock (2010) adds one level before semantic relations, that is to say, "paradigmatic relations". Another distinction separating this from the classifications presented hitherto, are antonyms indicated as an equivalence relation, unlike Zeng (2008) and Broughton et al. (2005). Furthermore, antonyms are separated into two types: "contradictory antonym" and "contrary antonym". According to the author, contradictory antonyms occur when there are two opposite extremes with nothing in between, e.g. a woman is pregnant or not pregnant. Contrary antonyms, on the other hand, allow for other values between the extremes, e.g. between love and hate, indifference can reside. In hierarchical relations Stock (2010), as well as Zeng (2008), makes reference to "instance relations". In hyponym relations, Stock (2010) separates two groups: "simple hyponym" and "taxonomy". In this case, the simple hyponym is the "is-one" relation and taxonomy is the "type-of" relation. As with Peters and Weller

(2008), Stock (2010) distinguishes meronyms into structured and non-structured objects. Finally, associative relations are “see-also” relations, used in thesauri and all other relations that are neither hierarchical nor equivalent, as defined by Peters and Weller (2008).

Figure 9 - Semantic relations according to Stock



Source: Translated of Maia (2018)

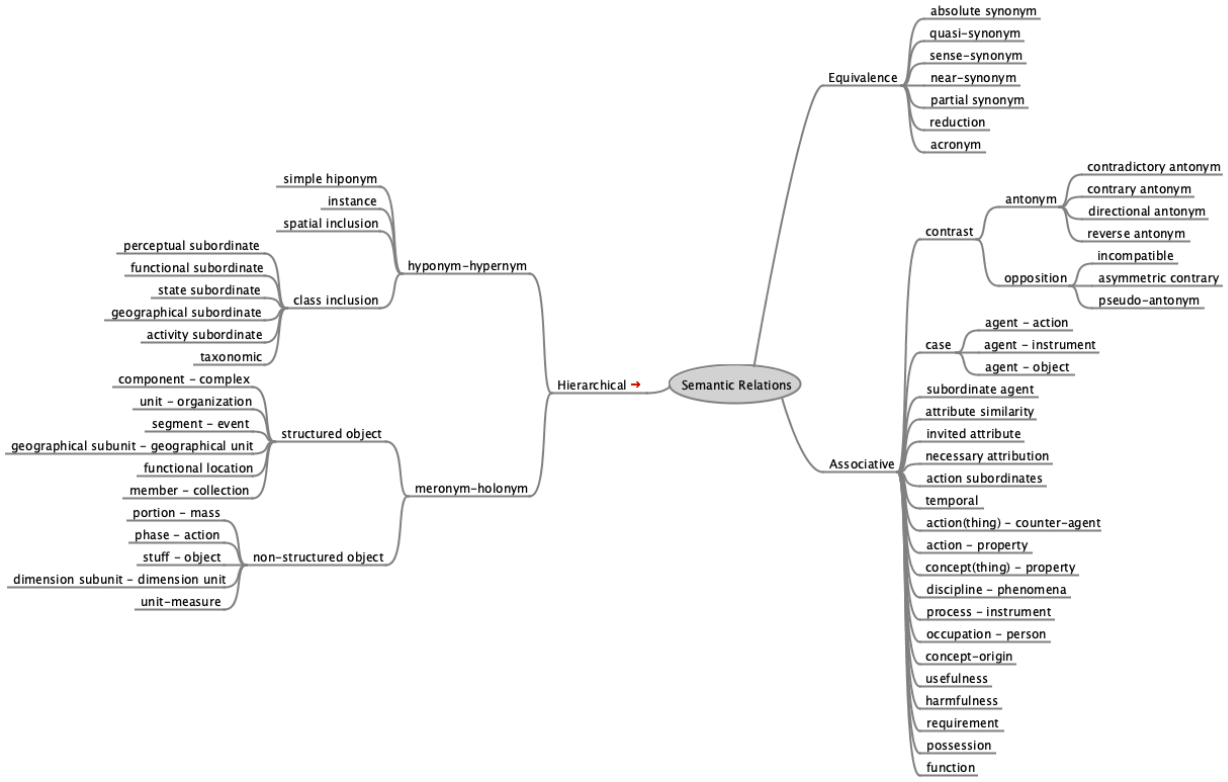
This section has explored the classifications of semantic relations as set out by the authors included in this review and listed in the bibliography below. The next section will present a taxonomy that unifies the classifications of semantic relations presented by these authors.

3 Proposal of Semantic Relations Taxonomy for Knowledge Representation

Peters and Weller (2008) state their belief that it is necessary to rethink semantic relations in respect of classification and generalization for use in Knowledge Representation and Information Retrieval. In the same way, Hjørland (2007) has given some consideration to the fact that consensus on semantic relations has been lacking. This being the case, and based on the classifications of semantic relations by the authors considered in this study Broughton et al. (2005); Dahlberg (1978); Khoo and Na (2006); Chaffin and Herrmann (1984); Storey (1993); Zeng (2008); Peters and Weller (2008); Stock (2010), a taxonomy is proposed that aggregates all the proposals presented in the literature under review. Thus, the suggested taxonomy is subdivided into

hierarchical, equivalence and associative relations, as shown in figure 10. These types will be explained in the following sub-sections.

Figure 10 - Semantic relations taxonomy



Source: Translated of Maia (2018)

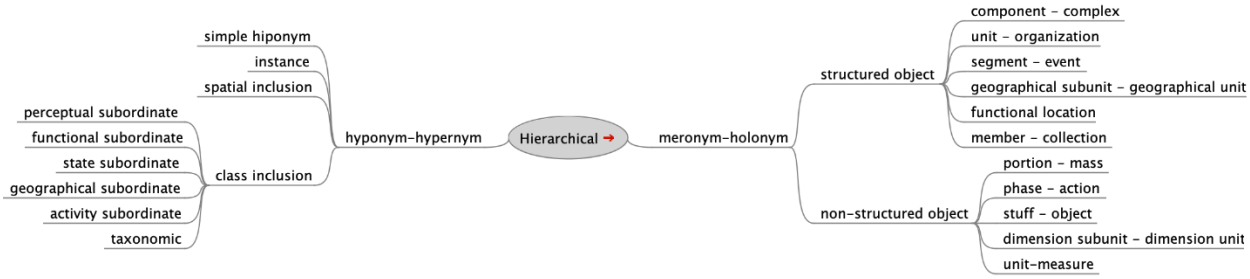
3.1 Hierarchical relations

According to Stock (2010), the hierarchical relation is the most important relationship in a KOS, because the process of classification starts with this relation, in which concepts are grouped into classes. As corroborated by Campos (2004), "The hierarchical relationship is one of the main relationships in any classification structure. It forms the backbone of a structure. [...] it is essential, and from it the first element of a definition is established".

The hierarchical relations proposed in this taxonomy are separated into two classes: "hyponym-hypernym" and "meronym-holonym", as Zeng (2008); Peters and Weller (2008); Stock (2010). The hyponym-hypernym relations are subdivided into: "simple hyponym", "instance", "spatial inclusion", and "class inclusion". In the other case, the meronym-holonym relations are

determined in light of the structure of the analyzed object: relations in which the object is structured and when the object is unstructured, as can be seen in figure 11

Figure 11 - Hierarchical relationships



Source: Translated of Maia (2018)

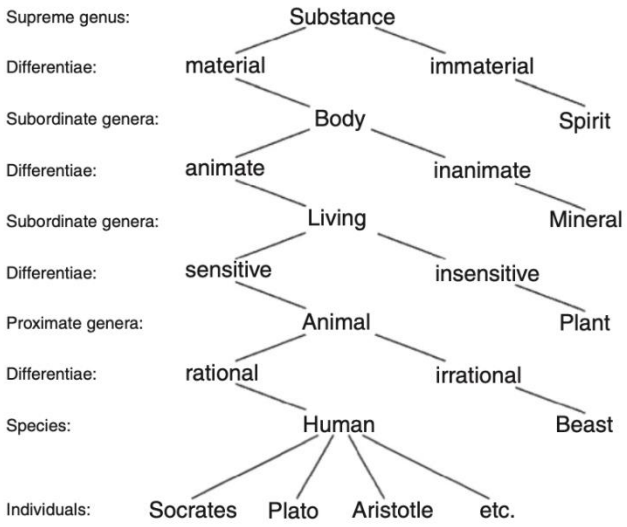
3.1.1 Hyponym-hypernym relations

In the hyponym-hypernym relationships, the hypernym is the most generic term and hyponym is the most specific term. In this sense, the hyponym inherits characteristics from the hypernym Stock (2010). In Dahlberg (1978), it is understood that the definition of hierarchical relationships refers specifically to hyponym-hypernym relations. According to the author, in the hierarchy (that is, in the hyponym-hypernym), the members of a class possess some characteristics common to the general class and some specific characteristics. At the concept level, characteristics are the attributes or elements of the concepts. For Mazzocchi (2017), the hyponym-hypernym relationship corresponds to the genus- species relation. According to him, this relation links a genus with its species or a class with its subclasses. Like Dahlberg (1978), for him, an important property of these relationships is the inheritance of characteristics: any attribute of the genus (hypernym) must also be attributed to the species (hyponym).

According to Mazzocchi (2017), hyponym- hypernym relations have historically been portrayed using the Porphyry Tree (Figure 12). Porphyry, a Neoplatonic philosopher of the third century, followed this method to carry out the correct division of the supreme genera (or categories) for individual species. The branched tree that results therefore reflects the hierarchical order, obtained by a series of bifurcations that begin with the supreme genus of the substance, in which essential differential characteristics are added to a species. According to Mazzocchi, this is the main element for distinguishing one species from all other species that share the same genus.

Finally, for Mazzocchi (2017), the genus-species relationship is seen as truly definitive and independent of the context.

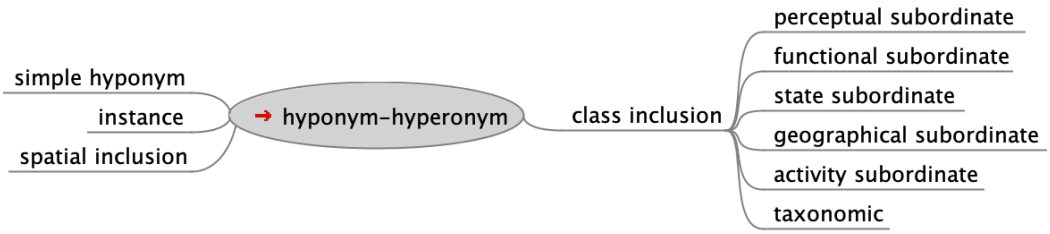
Figure 12 - Prophyry Tree



Source: Mazzocchi (2017, p. 372)

Besides the genus-species naming of hyponym-hypernym relation, the review of the literature found other names for this relationship, such as “is-a” and “type -of” relationship, generic, taxonomic, class/subclass, inclusion relations, class inclusion, subordinate hierarchically, and superordinate/subordinate (Hjørland 2007; Khoo and Na 2006). Some of these terms are defined in this taxonomy as types of hyponym-hypernym relation, as seen in figure 13.

Figure 13 - Hyponym-hypernym relations



Source: Translated of Maia (2018)

The **simple hyponym** relation was proposed by Stock (2010); Cruse (2002). According to the authors, this relationship is denoted by the standard “is a”, for example: “The queen *is a*

woman". In this case, as Stock (2010) observes, it would be strange to say that "The queen *is a type of* woman".

The **instance** relation was indicated by Zeng (2008); Stock (2010) as a type of hierarchical relationship. For Green (2001), the instance relation is a concrete relation, in that the instance is a name for an object of an entity, or an exemplar of an entity. As may be seen in table 1, some instance relations can be denoted as *geographical subordinate* or *geographical sub-unit - geographical unit* when the concepts of instance relation refer to geographical spaces.

Table 1 – Examples of instance relations

Entidade	**Instância**
Person	João
User	Maria
Book	Relationships in the Organization of Knowledge
Paper	Semantic Relations in Knowledge Organization Systems
Country	Brazil
City	Belo Horizonte
Author	Gercina Lima

Source: Translated of Maia (2018)

The classifications of semantic relations presented by the authors of LIS did not consider class inclusion and spatial inclusion. However, Cruse (2002) pointed out that a hyponym-hypernym never occurs in isolation. According to this author, the hyponym relation naturally involves inclusion. In this sense, a class of *apple*, for example, is included in the *fruit* class, which allows one to conclude that the meaning of *fruit* is included in the meaning of *apple*. Therefore, it was decided to incorporate the class-inclusion and spatial-inclusion relations into the hyponym-hypernym relations of this taxonomy.

The **spatial-inclusion** relation describes situations in which an object is located in a place but is not part of the place in which it is located (Storey 1993; Kuczora and Cosby 1989; Winston

et al. 1987). Storey (1993) exemplifies the relation with the following sentence: “The customer is at the reception”. In this context, the customer is at the reception, but is not a part of it.

According to Winston et al. (1987), class-inclusion relations may be labeled “is a” or “is a type of”. Chaffin and Herrmann (1984) classify these relationships as: (1) **perceptual subordinate**: objects characterized mainly by their visible physical features (e.g. horse *is an* animal); (2) **functional subordinate**: involves objects characterized by their functions (e.g. car *is a type of* vehicle); (3) **subordinate state**: involves a state of affairs (e.g. fear *is an* emotion); (4) **geographical subordinate**: involves places (e.g. America *is a* continent) and (5) a**ctivity subordinate**: involves activities (e.g. chess *is a type of* game).

Into the class-inclusion relations of the taxonomy proposed in this paper are inserted **taxonomic** relations. The rule for classifying a pair of concepts as a taxonomic relation is: if the relation in the pair of concepts denotes class inclusion and if it cannot be classified into sub-types— perceptual subordinate, functional subordinate, state subordinate, geographical subordinate or activity subordinate — then it is a taxonomic relation. In the classifications of semantic relations in the review of the literature, Stock (2010) refers to the taxonomic relationship based on Cruse (2002). In addition, there is a correlation between taxonomic relation and species-individual relation proposed by Dahlberg (1978). In this case, the species are a set of individuals that have common characteristics (such as morphological, anatomical, biochemical and physiological), similarities between them, and which belong to the same family or genus. Cruse (2002) pointed out that in the taxonomic relation it is important to consider the nature of the resulting subcategories and their relations with each other in the light of the proposed taxonomization. One example of taxonomic relation is: “Spaghetti is a type of mass”.

3.1.2 Meronym-holonym relations

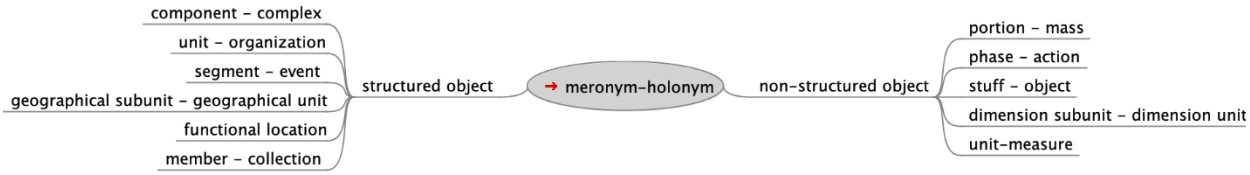
In the literature, several terms can be found for the meronym-holonym relationship, such as: part-whole, whole-part, partition, partitive, mereological, meronym and partonym (Beghtol 2001). The terms adopted in the proposed taxonomy follow Khoo and Na (2006).

In the meronym-holonym relation, complex concepts are subdivided into smaller units. This subdivision presents a hierarchical structure in which the concept that represents the whole

(holonym) is the higher class and the concepts that denote the parts of this whole (meronym) are lower classes (Beghtol 2001; Weller and Stock 2008).

The organization of meronym-holonym relations in the taxonomy of semantic relations proposed in this paper is based on the grouping carried out by Peters and Weller (2008); Stock (2010); Weller and Stock (2008) (see figure 14), which considers the constructive aspect of the object as suggested by Gerstl and Pribbenow (1996). In this approach, "Each part-whole relation represents a different way of partitioning a whole into parts". Thus, the ways of partitioning objects are divided into two categories: partitions based on the compositional structure of the whole and partitions aimed at internal features or external criteria.

Figure 14 - Meronym-holonym relations



Source: Translated of Maia (2018)

In the partitions based on the compositional structure of the whole, the internal structure of the object (the whole) can be broken down into dependent and permanent structures (parts) Gerstl and Pribbenow (1996). These partitions were described by Peters and Weller (2008); Weller and Stock (2008); Stock (2010) as part of a **structured object**.

On the other hand, for partitions whose parts relate to unstructured objects, the resulting parts are temporary constructs and may not belong to the domain of knowledge Gerstl and Pribbenow (1996). In this case, Peters and Weller (2008); Weller and Stock (2008); Stock (2010) described this type of partition as part of a **non-structured object**.

Starting with structured-object relations, the **component-complex** relationship – so named by Peters and Weller (2008); Weller and Stock (2008); Stock (2010) –, is also termed as "functional object" by Chaffin and Herrmann (1984) and "component-integral object" by Winston et al. (1987). In this relation, the object can be segmented into its components, for example: roof

is part of house (the house is the complex and the roof is one of the components of a house) (Stock 2010).

The **unit-organization** relation comprises a person or a group of people who belong to an organized group. For example: Department *is part of* University, researcher *is part of* Department (Stock 2010; Weller and Stock 2008).

In the **segment-event** relation, an event is composed and may be divided into sections. Events differ from objects (as in the component-complex relationship), since an event can have parts that occur at different moments in time, while the parts of an object usually occur at the same time. Chaffin and Herrmann (1984) and Storey (1993) named this relation as ”feature-event” and exemplified it with the following sentence: ”Trapeze *is part of* circus”. In this context, the circus spectacle is the biggest event, composed of acts (segments), such as clowns, the dancers and the trapeze artists.

The **geographical sub-unit - geographical unit** relation as termed by Peters and Weller (2008); Weller and Stock (2008); Stock (2010), is also known as “place-area” by Winston et al. (1987) and as ”location” by Chaffin and Herrmann (1984); Broughton et al. (2005). It encompasses relationships where geographic spaces may have divisions, administrative or not. Examples: Minas Gerais *is part of* Brazil, Hamburg *is part of* Germany; China *is part of* Asia.

On the other hand, **functional location** concerns place that can be separated from a larger location. Example: dining room *is part of* house, refrigerator *is part of* kitchen, reception *is part of* library, cash-register *is part of* store Chaffin and Herrmann (1984).

Finally, in the **member-collection** or element-collection (non-social) relation, the members in a collection can differ from the components, because members do not need to perform a function or have a particular structural arrangement in relation to the other and its totality (Winston et al. 1987). According to Storey (1993), this relationship may also be expressed as “belong to”. Examples: A ship *belongs to* a fleet, a tree *is part of* a forest, the card *belongs to* a deck, a juror *is part of* a jury (Winston et al. 1987; Stock 2010).

Of the relations that concern the parts of non-structured object, the **portion-mass** relationship refers to a totality divided into portions Stock (2010). According to Winston et al.

(1987), in this type of relation, the parts are similar to each other and to the whole. Examples are: Slice-pie, grain-salt.

The **phase-action** relation is characterized by the division of a continuous activity into simple phases Stock (2010). For Winston et al. (1987), it can be used to refer to stages, phases, discrete periods or sub- activities. Examples: payment-purchase, dating-adolescence, ovulation-menstrual cycle.

In the **stuff-object** relation, the raw material cannot be, theoretically, physically separated from the object. Examples: steel-car, hydrogen-water, aluminum-bicycle (Winston et al. 1987).

In the **dimension sub-unit - dimension unit** relation, a homogeneous unit can be divided into sub-units. For example: a litre of wine *is part of* a wine cask (Stock 2010).

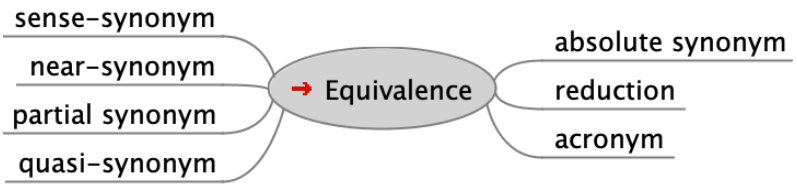
Finally, the **unit-measure** relation, defined by Chaffin and Herrmann (1984), denotes relations of measures broken down into units, such as minute-hour and cent-dollar.

3.2 Equivalence relations

Equivalence relations concern words whose meanings or senses (concepts behind words) are the same or are considered equivalent in a given context. In the review of the literature, this type of relation was found to have been first developed by Peters and Weller (2008), in 2008, although it had earlier been suggested by Vickery (1960) in 1960, in discussion of thesauri.

Figure 15 shows equivalence relationships as proposed for the taxonomy of semantic relations. As will be seen, equivalence relations refer to synonyms, as determined by Peters and Weller (2008); Stock (2010). Others authors, such as Khoo and Na (2006); Chaffin and Herrmann (1984), cited some types of synonyms in their classifications but without classifying them as equivalence relations.

Figure 15 - Equivalence relations



Source: Translated of Maia (2018)

The synonyms include words that have the same relevant properties in context, but that differ in the shape of the sign. Relevant properties must include, at least, the meaning of the word (Murphy 2003). The type of synonyms that compose the equivalent relations are presented below.

The **sense-synonym** relation refers to words that share one or more senses, such as "sugar" and "sucrose". The **near-synonym** type has meanings that approximate, for example, "city" and "municipality". The **partial synonym** indicates that two words share many meanings but differ in some particulars, for example "car" and "vehicle". **Quasi-synonym** relations occur when two words have more or less similar concepts in terms of extension and intention, for example, "discussion" and "quarrel". This relation was called by Chaffin and Herrmann (1984) "dimensional similarity", in which there is a denotative meaning that is not sufficient for synonymy, but which occurs at adjacent points in a common dimension, that is, there is a degree of dimension that indicates how two concepts differ. Examples: "laughter" and "smile"; "gross" and "unpleasant", "tormented" and "angry". Finally, the **absolute-synonym** type; in this case, the meaning is the same in its entirety, so this type of synonym is rare (Khoo and Na 2006; Cruse 1986; Lyons 1995; Murphy and Koskela 2010).

In the proposed equivalent relations, it was decided to add reductions and acronym. In **reductions**, lexically complex words are reduced to their first element, for instance: "photo" (from "photograph"). The **acronym** is a set of initial letters of words that represent a given name, for example "NY" (for "New York").

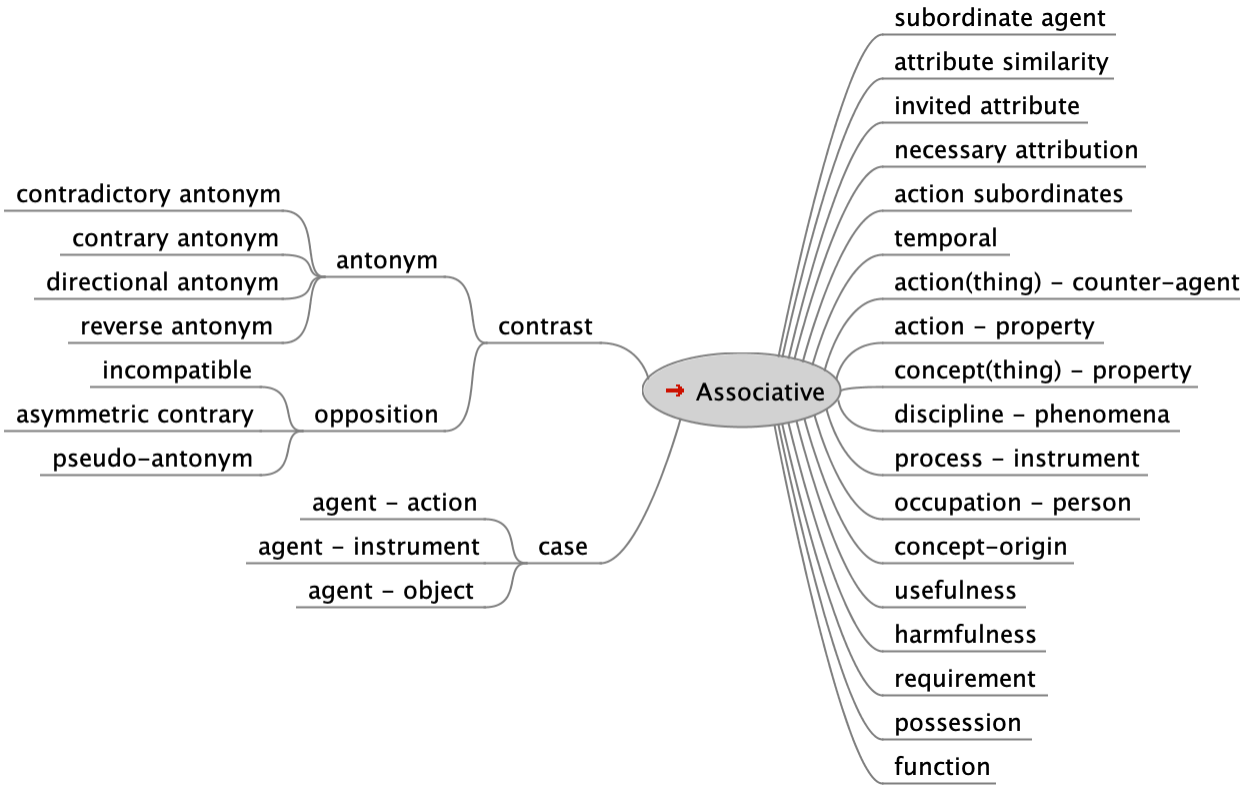
3.3 Associative Relations

According to Hjørland (2007), associative relation is defined as a mental association of the concepts. In this context, if *A* is mentally associated with *B*, there is an associative relation between

them. In classification structures, the associative relation applies to sibling terms, that is, those that are at the same level of hierarchy. It also applies to terms in which there is a clear connection, both conceptual and linguistic, but in which the relationship does not meet the criteria necessary for a hierarchical relation (Broughton 2008). In fact, as stated by ISO (2011), the associative relation occurs between a pair of concepts that are not hierarchically related, but which share a strong semantic connection. Further, for Zeng (2008) an associative relation is one that is neither hierarchical nor equivalent. According to Green (2008), specifically in thesaurus compilation, these relationships are usually specified by RT (Related Term).

Figure 16 shows the associative relations that are covered in this section. In this case, contrast relations are proposed, which, according to Chaffin and Herrmann (1984), are opposed terms, that is, they contradict each other. **Contrast** relations are subdivided into **antonym** and **opposition** types. According to Hjørland (2007), specifically in thesaurus compilation, antonyms are not usually specified, but can be listed with other terms as an associative relationship. Likewise, Zeng (2008) also proposes that antonyms are a type of associative relation.

Figure 16 - Associative relations



Source: Translated of Maia (2018)

The antonyms presented in this paper follow Chaffin and Herrmann (1984). They can be: **contradictory antonym**, those that are dichotomous opposites (living- dead); **contrary antonym**, those that are symmetrically opposed, for example, “hot” and ”cold” are equally opposite temperatures; **directional antonym**, which are opposed in time or space (”before-after”, ”top-down”); and, finally, **reverse antonym**, which denote opposite actions (”sell- buy”).

Relations grouped as oppositional are those that are contrary but not necessarily antonymic. In this group of relations may be found **incompatible**, a type of relation that occurs when one meaning is opposite to part of the meaning of another. For example, “frank” is incompatible with “hypocritical”, for hypocrisy involves dishonesty while frankness involves honesty and sincerity. In **asymmetrically contrary** relations, the concepts are opposed in a continuous dimension, such as, for example, the *dry* and *moist* concepts. As is well known, the opposite of “dry” is “wet”, and that “moist” is wet to a certain degree. In this case, imperfect symmetry is the reason why the relationship is generally not considered antonymic. The *pseudo-antonym* is so called because its

opposition is based on a connotative meaning of a term; for example, “popular” and “shy” are opposed because popularity connotes extroversion, which is opposed to shyness (Chaffin and Herrmann 1984).

Another group of associative relation is *case relationships*. In the case relation, *A* is a cause of *B* (Broughton et al. 2005). The term, **case** relations, follows Chaffin and Herrmann (1984); Storey (1993). However, these relations were treated by Broughton et al. (2005) as “causal relation”; and “cause-effect” by Khoo and Na (2006); Zeng (2008). Case relations were further considered by Khoo and Na (2006) as “syntagmatic”, and as “associative” by Zeng (2008), followed by the present paper.

The taxonomy presented by Storey (1993) grouped case relations into two types: “agents” and ”actions”. However, in this proposed taxonomy, we have decided to include only the relations that refer to agents, because relations that involve actions, as noticed by Storey (1993), are unary relations and, in the scope of this taxonomy, only binary relations are being addressed. In this sense, case relations have been classified as **agent-action**: they occur between an agent and the action performed (e.g. “consultant-consulting”); **agent-instrument** relations occur between an agent and the instrument (s)he uses, for example, “programmer-computer”; and **agent-object** relations occur between the agent and the object (s)he uses or makes, for example, “carpenter-wood”.

Subordinate agent relations is a new sub-type of associative relation proposed by Maia (2018) for the relation between *author* and *indexer*. In this case, the agents perform some action in the same object, sometimes in parallel.

Attribute-similarity relation denotes terms in which the prominent attributes of one concept are similar to those of another, e.g. “rake-fork” and “rug-blanket” Chaffin and Herrmann (1984). Note that, in this case, there is an equivalence with respect to the function or some features of the objects, but it is not enough to classify it as a type of synonym because, while the concepts have things in common, they do not share meanings.

Invited attribute relation involves characteristics that do not necessarily occur in the definition of the concept, for example, “comfortable bed”, “intelligent teacher”. Also, **necessary-**

attribution (or necessary-attribute) relation "involves a term and a defining attribute of the term", e.g. "lemon-sour" (Chaffin and Herrmann 1984).

Action-subordinates relation, as the name implies, refers to two actions that relate, like "cook–fry" (Chaffin and Herrmann 1984). Chaffin and Herrmann (1984) classified this relation as a type of class inclusion relation. However, on reviewing the examples cited there, it is clear that this relationship does not concern a unit and its class as understood in the relation activity subordinate (a type of hierarchical relation in the present taxonomy), considered by them as "similars". Moreover, in the example of "cook–fry", it could be said that *fry* is part of *cook*; however, due to the fact that this relationship does not to refer to an object, it was not classified as meronym-holonym.

Temporal relation is a semantic relation in which one concept indicates a timeframe or period in relation to another concept. For example, "World War II occurred between 1939 and 1945" (Broughton et al. 2005).

As pointed out by Peters and Weller (2008); Stock (2010), associative relations can be infinite. Table 2 shows examples of other relationships found in Peters and Weller (2008); Zeng (2008). As can be seen, some relations involve actions and agents; however, based on their given examples, they do not denote cases and, therefore, were not classified as case relations. In addition, relationships that denote attributes (properties) are listed in the table, but they do not relate to necessary or invited attribute relations.

Table 2 - Others examples of associative relations

Associative Relation	**Example**
action(thing)–counter-agent	pest – pesticide
action - property	precision measurement – accuracy
concept(thing) - property	steel alloy - corrosion resistance
discipline - phenomena	seismology – earthquake
process - instrument	velocity measurement – speedometer
occupation - person	accountancy – accountant
concept - origin	water – water wells
usefulness	job creation – economic development
harmfulness	over-fertilization – diversity of species
requirement	MP3 Player - batteries
possession	MP3 Player - Sony Ericsson
function	Bluetooth - computer

Source: Translated of Maia (2018)

3.4 Unclassified Semantic Relations

Some associative relationships were not classified because in the sources and in the review literature there were not enough specifications or examples for their correct understanding and classification. They are: **production**, **usage**, and **attachment**, as proposed by Peters and Weller (2008).

The **raw-material - product** relationship, suggested by Peters and Weller (2008); Zeng (2008), was classified as an associative relationship; however, the authors' own examples ("skin–leather", "grape–wine") show that this is a partitive relation of the stuff-object, proposed by Winston et al. (1987), explained above.

The **see-also** relationship, proposed by Stock (2010) as a type of associative relationship, has been understood in the present paper to be a relation that encompasses all associative

relationships, so it has not been classified. The same thing applies to the **related-branch** relation, described by Peters and Weller (2008).

The **causal-dependence** relation, suggested by Peters and Weller (2008), involves the causal relationships already mentioned. Other unclassified relations were the **active-passive** relationships proposed by Hjørland (2007); detailing these relations, the active expresses the execution of an operation or process in another; the inverse is the passive relationship. These relationships were not exemplified in the literature to permit a proper understanding, so it was decided not to classify them in the proposed taxonomy.

4 Conclusion

This paper has pointed out certain classifications of semantic-relation types as discussed by LIS authors. To this end, a literature review explored the approaches of these various authors in order to understand how semantic relations have been treated in this area.

Differences were found in the authors' classifications, some structural, others of nomenclature. An example of structural difference was the placing of the meronym-holonym relation. In the first approaches presented by Dahlberg (1978); Broughton et al. (2005); Khoo and Na (2006), this relationship was not specified as a type of hierarchical relationship. As of 2008, relations were divided into three major groups: hierarchical, equivalent, and associative. And, therefore, only in that same year, meronym-holonym relationships started to be classified as a type of hierarchical relationship.

On the other hand, differences around naming also indicated the absence of a standard nomenclature. An example of this is the meronym-holonym relation. Dahlberg (1978) named this relationship as "partitive", and Zeng (2008) as "whole-part". Broughton et al. (2005); Peters and Weller (2008) identified it as only "meronym".

The result of this paper is a taxonomy that compiles all types of semantic relations, according to the selected literature review, taking the author's point of view related to each other. In this study, the semantic relationships are not exhausted, others studies continue carried out in different contexts of all subjects. However, in recent scientific literature, there were no new types

of semantic relations to add to the proposed taxonomy, there was no need for changes in the taxonomy structure.

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