

The Study of Thesaural Relationships from a Semantic Point of View

J. Mehrad, Ph.D.

President of Regional Information Center
for Science and Technology, I. R. of Iran
email: dean@srlst.com

F. Ahmadasab, Ph.D.

Regional Information Center
for Science and Technology, I. R. of Iran
Corresponding author: ahmadasab@ricest.ac.ir

Abstract

Thesaurus is one, out of many, precious tool in information technology by which information specialists can optimize storage and retrieval of documents in scientific databases and on the web. In recent years, there has been a shift from thesaurus to ontology by downgrading thesaurus in favor of ontology. It is because thesaurus cannot meet the needs of information management because it cannot create a rich knowledge-based description of documents. It is claimed that the thesaural relationships are restricted and insufficient. The writers in this paper show that thesaural relationships are not inadequate and restricted as they are said to be but quite the opposite they cover all semantic relations and can increase the possibility of successful storage and retrieval of documents. This study shows that thesauri are semantically optimal and they cover all lexical relations; therefore, thesauri can continue as suitable tools for knowledge management.

Keywords: Thesaurus, Thesaural Relationships, Lexical Relations, Semantic Relations, Information Storage and Retrieval.

Introduction

In the era of information explosion with the emergence of computers and internet and their important role in the storage and retrieval of information, every researcher has to do her/his scientific queries through scientific databases or the web. There are two common ways of query, one is free search which is done by keywords and the other is applying controlled vocabularies. The reason for the use of controlled vocabularies is that query by keywords is full and free text search and this kind of search leads to errors which arise from lexical peculiarities (Miller, 1997), while controlled vocabularies turn out to provide a consistent tool for the increase of the precision and recall of information storage and retrieval. Here, by information we mean every kind of information in the form of any documents such as papers, books, tables, programs, handbooks, manuals, etc. and recently even graphs and pictures. One of these controlled vocabularies is thesaurus. Thesaurus is a controlled vocabulary designed to improve information storage and retrieval in information management. Thesaurus is viewed as a semantic tool representing three different semantic relationships with the purpose of

guiding librarians and researchers to the most suitable terms for indexing and searching the concepts of a subject field (Dextre Clarke, 2001). Thesaurus construction and use serve as fundamental functions within the fields of text mining and information retrieval (Losee, 2007). Although thesaurus is a very important tool in information technology, in recent years, it is claimed that thesaurus is not a perfect tool for indexing and searching because its semantic relationships are restricted and it does not cover all semantic relationships (San'atjoo, 2005). It is argued that ontology is a good replacement for thesaurus (Lauser, 2001; Wielinga, Schreiber, Wielemaker & Sandberg, 2001; Fischer, 1998). Ontology is a specification of the kinds of entities that exist or may exist in some domain or subject area. It is claimed that time for thesaurus is over and studies of ontology are flourishing. In recent years, ontologies are on the agenda, but it should be reminded that sometimes it is very difficult to distinct between ontology and thesaurus. Their border is so fuzzy that a researcher working on ontology sometimes finds herself/himself addressing thesaurus and vice versa (Kless & Milton, 2010). There is not a clear cut between ontology and thesaurus. In some literatures, thesaurus is considered to be a type of ontology and in some ontology is believed to be an enriched thesaurus (Fischer, 1998; Brewster & Wilks, 2004; Losee, 2007). In this paper, semantics of thesaurus will be addressed. The writers show that semantic relationships of thesaurus are not limited and they cover all basic lexical relationships; therefore, thesauri can continue their life as semantic tools for information management.

Lexical Semantics and Basic Lexical Relations

In order to evaluate the semantic relationships of a typical thesaurus, the writers will study lexical relations in semantics. Semantics is a part of linguistics. Linguistics, in simple words, is the study of the linguistic competence (or knowledge) of human beings. The major parts of linguistics are syntax, morphology, phonology and finally semantics. Semantics is the study of meaning (Safavi, 2000). Lexical semantics is the study of word meaning. One of the interests of this kind of semantics is lexical relations. A lexical relation is a semantic relation in which two or more words have some aspect of meaning in common (Murphy & Koskela, 2010). We decided to switch to lexical relations for the evaluation of thesaural relations because in thesaurus words (or terms, to be more exact) are the core of focus. So, to study the semantics of thesaural relations, there is no way but to study lexical relations. In this section we will introduce a number of notions that have been used to describe the meaning relations of lexical items and in the next section the semantic relationships of thesaurus will be studied. The crucial lexical semantic relations are as follows:

Hyponymy

Hyponymy is the lexical relation that shows a relation of inclusion between two words or concepts. The more general word is the hyperonym and the more specific one is called

hyponym (Murphy & Koskela, 2010). Hyponym always entails hyperonym unilaterally. A very simple example is:

John ate an *apple*.

John ate a *fruit*.

The first sentence unilaterally entails the second sentence but not vice versa (Krifka, 1998). Therefore, entailment in hyponymy is a downward entailing. Concepts or terms that are hyponyms of the same hyperonym at the same level, semantic sisters, are called co-hyponyms. For example, *apple*, *banana* and *peach* are co-hyponyms of the hyperonym fruit (Safavi, 2000).

Antonyms & complementaries

If two or more terms cannot apply to the same entity, they are called incompatible. One reason for this incompatibility is represented by antonymy (Krifka, 1998).

Antonymy is the paradigmatic lexical relation between two terms that are opposite in meaning like *male/ female*, *down/ up* and *closed/ open*. Antonymy has several types with regard to their logical and referential features (Murphy & Koskela, 2010) as follows:

- Simple antonyms

In this kind of antonymy, negative of a term implies the positive of another one. Examples include *dead/ alive*, *pass/ fail* and *hit/ miss*. This pairs of words are also called complementary/ binary pairs (Saeed, 2009).

- Gradable antonyms

Another kind of antonymy is called gradable antonymy. This is a relationship in which the positive of one term does not necessarily imply the negative of the other such as *rich/ poor* and *young/ old* (the same). Actually such antonyms are often adjectives that can be intensified with adverbs like very, so, too, etc.

- Heteronymy

Heteronymy is an antonymy relation between more than two expressions. A typical example is the set of terms for the days of the week. Heteronyms are not opposite extremes of a scale. They are just members of a set of terms which often have a common hyperonym (Lobner, 2002). Heteronyms are taxonomic sisters. It means that the words in heteronymy are sister-members of the same taxonomy and therefore incompatible with each other, for example, *Sunday* and *Monday* are taxonomic sisters and hence heteronyms (Saeed, 2009).

- Converse antonyms

Converse antonyms describe the same relation or activity from different perspectives and have a pattern such as: if X is p to Y, then Y is q to X. We can refer to *child/ parent* and *buy/ sell* as examples of converse antonyms (Murphy & Koskela, 2010). This relation is a part of a speaker's semantic knowledge and explains why the following two sentences are paraphrases:

John *sold* the car to Mary.

Mary *bought* the car from John (Saeed, 2009).

Converse antonymy is also called symmetrical antonymy (Safavi, 2000).

- Reversive antonymy

Another kind of antonymy is reversive antonymy. It involves undoing of an action like *lock/unlock* and *embark/disembark*. In some literature converse and reversive antonymies are grouped under a general category called directional antonymy (Murphy & Koskela, 2010).

In this paper we do not need a sharp distinction among different kinds of antonymy and we can group them under a single category.

Homonymy

A homonym is a term that shares the same form as another term without any semantic or paradigmatic relationship. An example is *tattoo* and *tattoo*. One means '*an ink drawing in the skin*' and the other one means '*a military drum signal*' (Murphy & Koskela, 2010). *Tattoo* and *tattoo* are an example of total homonymy because all properties of them such as grammatical category, form and spelling are the same. Partial homonymy exists in the case of terms that have unrelated meanings and they are ideal in some but not all of their grammatical forms. Verbs *lie* (*lay, lain*) and *lie* (*lied, lied*) are good examples of partial homonymy (Lobner, 2002). Some authors make a distinction between homographs, words with the same written forms, and homophones, words of the same spoken forms. The verb *keep* and the noun *keep* are homographs and *not* and *knot* are homophones (Saeed, 2009). Homonymy is one of the sources of linguistic ambiguity (Murphy & Koskela, 2010).

Meronymy

Meronymy is a term used to describe a part-whole relation between words (Saeed, 2009). Meronymy or paronymy (Lobner, 2002) reflects hierarchical classification in the lexicon. A system based on meronymy relation is mereology. In this system if X is a meronym of Y then Y is a holonym of X; for example *hand* is a holonym of *finger* and *finger* is a meronym of *hand* (the same). Meronymy is an important relation especially for determining definition of words; for example, it is difficult to give the definition of *yolk* without reference to *egg*. We can distinguish different types of meronymy on the basis of is-a-part-of or has-a relation (Murphy & Koskela, 2010).

Portion-Mass

This relation holds between a mass noun and the usual unit of measurement. The result will be a count nominal; for example, a *sheet* of *paper* and a *drop* of *liquid* (Saeed, 2009; Safavi, 2000).

Member-Collection

This relation is between the word for a unit and the word for the collection of that unit (Saeed, 2009). The relation between *bird* and *flock* is an example of member-collection relation (Saeed, 2009; Safavi, 2000).

Synonymy

Synonyms are different phonological forms that mean the same although true synonyms are rare (Krifka, 1998; Saeed, 2009). Sameness of meaning can be tested by a substitution test; if two words can be replaced in the same sentence without causing any change in the meaning of the sentence then they are said to be synonyms (Murphy & Koskela, 2010). However, most of the synonyms which are considered to be total synonyms and have identical denotation or similar truth conditions have at least a very small difference at stylistic level, context, connotation or in other respects (Krifka, 1998). It is better to talk about near-synonyms than true synonyms. They show crucial meaning differences in their selectional restrictions. *Kill, murder, execute* and *assassinate* are synonyms or near-synonyms in strict sense (the same). These examples are called partial synonyms by some authors (Lobner, 2002). Analytic synonymy is a type of synonymy. In analytic synonymy, a word is synonymous with a set of its necessary and sufficient conditions of its sense such as *sister* and *one's parents' daughter* (Safavi, 2000).

Polysemy

Polysemy is a phenomenon in which a single word is associated with multiple distinct but related meanings (Saeed, 2009; Safavi, 2001; Lobner, 2002). While homonymy is a rare phenomenon, polysemy is abundant. Polysemy is another source of ambiguity (Murphy & Koskela, 2010). A good example of polysemy is *cousin*. Polysemy is a natural economic tendency of language. Rather than inventing new words for new entities or phenomena, the existing words will be used for similar things (Lobner, 2002). Polysemy should not be confused with homonymy. In homonymy, a single word has two or more related meanings but polysemous words are different words with different meanings but one single form (Murphy & Koskela 2010).

Semantic relationships in a typical thesaurus

Thesaurus is a controlled vocabulary which its unit of study, naturally, is word. It should be mentioned that in thesaurus technical word for *word* is term.

The basic semantic relationships of a thesaurus are three relations: equivalency, hierarchy and association (ANSI, 2005). In the following, these three relations will be dealt in depth:

Equivalency

Equivalence relationship holds between preferred and non-preferred terms (ANSI, 2005). Preferred term or descriptor is one of two or more synonyms selected as a term for inclusion in the thesaurus (Broughton, 2006) and non-preferred term is the term that only refers to the relative preferred term. Four basic equivalence relationships, relevant here, are: synonymy, near-synonymy, lexical variants and generic posting. The two that need explanations are lexical variants and generic postings.

- Lexical variants

Lexical variants are different word forms for the same expression. They are often different spellings, grammatical variations or abbreviated forms of the same word (ANSI, 2005). Some examples are *color/ colour*, *online/ on-line* and *United Nations/ UN*.

- Generic posting

Generic posting is a technique in which the name of a class and the names of its members are treated as equivalents with the broader class name functioning as the preferred term (the same, 45). For example, *furniture* is the preferred term for non-preferred terms, *chair*, *bed* and *sofa*. Now the question is how thesaurus constructors show equivalence relationship in thesauri? The relationship indicators are paired operators, USE and UF used to show this relationship. USE is used to refer from non-preferred term to preferred one and UF is used to show the vice versa relation. An example is:

beds USE *furniture*
furniture UF *beds*

In the above example *beds* is the non-preferred term and *furniture* is the preferred term.

- Synonymy

In thesaurus, synonymy is not treated in the strict sense of sameness and interchangeability and it covers various classes:

Synonyms of different linguistic origins	<i>sweat/ perspiration</i>
Synonyms of popular and scientific names	<i>salt/ sodium chloride</i>
Synonyms of generic and trade names	<i>tissues/ Kleenex</i>
Synonyms of favored and outdated names	<i>poliomyelitis/ infantile paralysis</i>
Synonyms of slang and jargons	<i>helicopters/ whirlybirds</i>
Synonyms of dialectical variants	<i>subways/ undergrounds</i>

As you see, synonymy in thesaurus covers any possible synonymy derived of different sources (the same, 44).

- Near-synonyms

Near-synonyms are words which generally have different meanings, but they are treated as equivalents for the purpose of thesaurus construction. The reader may find it strange that even antonyms are considered to be near-synonyms in some standards like ANSI (2005). The reason for including antonyms in near-synonyms has a psycholinguistic reason. Speakers

of all languages find a close connection between antonyms. For example, given the word *warm*, they easily remember the word *cold*. Maybe this is the reason why some standards treat antonyms as associative terms.

Hierarchy

Hierarchical relationship is a relation based on levels of superordination and subordination. The superordinate word represents a class or a whole and the subordinate word is a member or a part of that class (Broughton, 2006; ANSI, 2005). In thesaurus the superordinate word is called Broader Term (BT) and the subordinate word is called Narrower Term (NT). In linguistic terms, BT is the mother node and NT is the sister node. They are also called parent and child terms respectively (the same).

Hierarchical relationship covers three different relationships: generic, instance and finally whole-part relationship.

- Generic relation

Generic relationship is a relation based on the relationship between a class and its members. A test for evaluating the validity of this relation is ISA. It means that the narrower term is a broader term. An example is *cacti* and *desert plants*. Our test for validity of this relation is the sentence: Cacti are desert plants. This sentence is logical, therefore, the generic relation holds between *cacti* and *desert plants*.

- Instance relation

Another type of hierarchical relationship is instance relationship. Instance relation holds between a general category and individual instances of that category. The general category is often a common noun and individual instances are proper nouns. *Country* and *Iran* are an example of instance relationship (ANSI, 2005).

- Whole-part relation

The third type of hierarchical relationship and the last is whole-part relationship. This relationship covers situations in which a word is a logical part of another one. This relation holds between any two or more words that can be included in a whole-part system. It is not necessary for them to be physically in whole-part relation. Three crucial types of whole-part relation are parts of things, geographical locations and finally organizational structures.

Examples are *spinal cord/ brain*, *Amsterdam/ the Netherlands* and *soldiers/ armies* (the same, 49).

It is necessary to mention that we can add to these subcategories with any relation that cognitively can be regarded a whole-part relation.

Association

Association from the three semantic relations of thesaurus is the most difficult one to define. It is a relation that is not hierarchy or equivalency. Association is a relation that

expresses a link or semantic closeness between two or more terms. Associative words are conceptually, semantically or cognitively related; therefore, including them in thesauri can optimize indexing and retrieval (Broughton, 2006; ANSI, 2005). Unfortunately, the nature and definition of this relation is not completely agreed upon, so it can lead to subjective judgments and therefore inconsistency in associative relations (the same). Some guidelines are given for determining the associative relation as following:

This relation should be established between two or more terms that are sisters with the same parent in a hierarchy; for example, *boats* and *ships* are in association relation in a thesaurus of sailing. It should be kept in mind that it is not necessary to associate two sibling terms that are mutually exclusive in a hierarchy. An example is *roses* and *tulips*. They share the broader term *flowers*, but they are not associative because the meaning of the two words does not overlap, that is to say, they are mutually exclusive (the same, 52). Some of the sources of association relation between two terms are as follows:

Process/ agent	<i>hunting /hunters</i>
Process/ counteragent	<i>fire/ flame retardants</i>
Action/ property	<i>polling/ public opinion</i>
Action/ product	<i>cloth/ weaving</i>
Action/ target	<i>crops/ harvesting</i>
Cause/ effect	<i>pathogens /infections</i>
Concept or object/ property	<i>liquids/ surface tension</i>
Concept or object/ origin	<i>Caspian Sea/ beluga caviar</i>
Concept or object/ unit of measurement	<i>temperature/ thermometers</i>
Raw material/ product	<i>wheat/ flour</i>
Discipline or field/ object or practitioner	<i>linguistics/ language</i>
Antonyms	<i>height/ depth</i>

As it was said before, it is also possible to include antonyms in equivalency relation (the same, 53-56). The abbreviation for associated or related terms is RT.

Discussion

In sections 1 and 2, lexical relations and thesaural relationships are addressed. In this section, in a comparative study, it will be shown that all lexical relations are covered by thesaural relationships. It is interesting to know that there are some relations which are regarded as association relation in thesaurus, but they are not addressed by lexical relations. They are process/ agent, process/ counteragent, action/ property, action/ product, action/ target, cause/ effect, concept or object/ property, concept or object/ origin, concept or object/ unit of measurement, raw material/ product and finally discipline or field/ object or practitioner. This list of relations can be expanded by any other relation that has some logical base and is cognitively acceptable. In the following table, you can find all basic lexical

relations and their relevant thesaural relations which cover them. It is necessary to mention that we have not mentioned different subtypes of lexical relations, because these differences are irrelevant here.

Table 1

A Comparison of Lexical Relations and Thesaural Relations

Lexical relations	Thesaural relations
Hyponymy	Hierarchy
Antonymy	Equivalency/ Association
Synonymy	Equivalency
Polysemy	?
Meronymy	Hierarchy
Homonymy	?
Member-collection	Hierarchy
Portion-mass	Association

As you can find in the above table, all lexical relations are covered with thesaural relations except polysemy and homonymy. Does it mean that thesaurus has ignored them? The answer is no. Polysemy and homonymy are two important lexical relations. Thesaurus has addressed these two relations but not with equivalency, hierarchical or association relations. Polysemy and homonymy are treated in a different way. As it was said in section 1 and 2, homonymy and polysemy are two sources of ambiguity. Ambiguity is a situation in which an expression can have more than one sense or meaning. This linguistic ambiguity can be structural or lexical. Structural ambiguity arises from a complex expression like phrase or sentence. This kind of ambiguity is not our concern here, because in thesaurus we are addressing words, simple or compound, not phrases or sentences. In thesaurus construction, lexical ambiguity is a common phenomenon. Lexical ambiguity involves a word form having more than one sense because of homonymy or polysemy (Murphy & Koskela, 2010).

As it was said in section 1, homonymy has two types, total homonymy and partial homonymy. Homonymy can be encountered in the form of homophony or homography. Thesauri are provided in print, screen and web format (ANSI, 2005), therefore, in thesaurus construction, providers often encounter homonymy in the form of homography. Homographs are words that have the same spelling, but different meanings. In thesauri, homographs are shown by qualifiers. A qualifier is a word that is used to disambiguate a preferred term. Qualifiers are separated from main terms by punctuation especially parentheses (the same, 8).

Mercury (metal)

Mercury (planet)

In the above examples, Mercury is a homograph. As these words are not in a sentence and there exists no context, there is no way to disambiguate these words but qualifiers; therefore, qualifiers are used to clarify the relevant meaning. In the case of polysemy, the situation is the same as homography, again qualifiers are used to clarify the meaning of polysemous words. We think it is a strong point of thesauri that they solve the problem of ambiguity arisen from polysemy and homonymy by the same technique, qualifiers; because, in many cases, the distinction between these two relations is impossible and having two different techniques can be confusing, at least very time-consuming.

Besides a qualifier, a scope note is another possibility for thesaurus constructor to give any explanation following a term, explaining its coverage, usage, etc. (ANSI, 2005) necessary

All basic lexical relations are covered by three thesaural relationships and qualifiers. There are two necessary points to address here about equivalency relationship. As it was mentioned in section 2, lexical variants are also covered in equivalency relationship. Lexical variants are different word forms or spellings of a single word. This relation is not dealt with in lexical relations in semantics.

Another point is about generic posting. In the discussion about generic posting, it was seen that the name of a class and the names of its members are treated as equivalents with the broader class name functioning as the preferred term. On the other hand, under the subject of hierarchy and generic relation, it was said that generic relationship is a relation based on the relationship between a class and its members. Apparently, here, there is an inconsistency about coverage of generic relation under equivalency or association relationship. But the truth is that the decision over the generic relation depends on the subject domain of the thesaurus and how specific the thesaurus is. In other words, generic posting will be employed in the peripheral areas of the subject field and generic relation will be used in the main area of the thesaurus (ANSI, 2005). For example, in a thesaurus on linguistics, the semantic relation of the pair *consonants/ phonemes* will surely be a hierarchical relation, because these terms are two basic technical terms in the area of linguistics. But these words in a thesaurus on education will most probably be regarded as examples of generic posting and hence equivalency relation. The reason is that words *consonants* and *phonemes* are not central to the subject field of education and they are peripheral to this area. The result is that the semantic relations of the thesaurus, equivalency, hierarchy and association are not limited and they cover all lexical relations.

One may claim that it is a shortcoming of the thesaurus that its semantic relations are limited to three and they are not detailed and specific. Although we accept that both indexers and users would be given a more perfect and complete picture of the relevant subject area if all lexical relations were addressed in their specific and detailed categories, the purposes of thesauri will be fulfilled even by these three thesaural relations and more semantic relations are redundant. The primary purpose of thesauri is to improve the effectiveness of information

storage and retrieval systems and to achieve consistency in this operation. The ultimate goal of the thesauri is to improve precision and recall of the queries. This goal can be achieved by limiting and expanding our queries by the use of these thesaural relations. Regardless of their subtypes, there are eight basic lexical relations in semantics covered by three thesaural relationships. Equivalency, hierarchy and association relations are adequate for storage and retrieval of information and adding more semantic relations cannot help to optimize storing and retrieving information.

Let's examine our claim by providing an example of hierarchical relation. Hierarchical relationship can be of three types: generic, instance and whole-part. *Cacti/ desert plants*, *Cinderella/ fairy tales* and *Tehran/ Iran* are respectively generic, instance and whole-part. We use BTG and NTG to show generic broader and narrower terms, BTI and NTI for instance relation and, BTP and NTP for whole-part relationship. As it was said before, they all are covered by hierarchical relation. The user can narrow down her queries by using narrower terms (NT) and broaden her queries by applying broader terms (BT) regardless of their different types. It means that awareness of the types of hierarchical relation, generic, instance or whole-part or any other kind of relation cannot help optimizing retrieval of information. In other words, the hierarchical relation itself is very important and the *typeness* of the relation is irrelevant here. The situation is the same as hierarchical relation for the other two relations.

The irrelevance of the specificity of thesaural relations is due to the purpose of thesaurus construction and use. Thesauri are controlled vocabularies for information modeling. Their purpose is to describe documents in a consistent way for both the indexer and the user to improve storage and retrieval of information. This goal is achieved by three relations of equivalency, hierarchy and association and removal of ambiguity by the use of qualifiers and scope notes. The thesaural relations cover all lexical relations and they are optimal. Adding to these three relations not only cannot optimize storage and retrieval of information, but will also make thesaurus construction very difficult and confusing. It is possible to find and define many more lexical relations than what we have introduced in the above sections but there is no guarantee that the implementation of enriched thesauri will lead to the better and more consistent query results. If we decide to add to the degree of the complexity of thesaural relations, not only we cannot improve our knowledge management purposes, but also we will put an unnecessary burden on the process of thesaurus construction. It should be mentioned that some researchers recommend the implementation of more specific semantic relations, but they think that users will not need to be aware of all kinds of relationships (Mazzocchi, De Santis & Plini, 2007). We think that the hidden message of this recommendation is that *"the implementation of more semantic relations in thesauri is unnecessary"*.

Conclusion

This paper described and contrasted lexical relations and thesaural relations. The study

revealed that thesauri cover all lexical relations. The ultimate goal of thesauri is the improvement of information storage and retrieval. The thesaural relationships can satisfy the information management needs. The implementation of more specific lexical relations other than thesaural relations in thesaurus construction and use cannot increase the degree of information storage and retrieval. It also cannot decrease false drops in information management. The writers believe that despite the increasing researches oriented from thesauri towards ontologies, thesauri will continue in the future as a crucial semantic tool in information management. The implementation of more lexical relations cannot help to improve information storage and retrieval. Besides, determining the semantic relation between two terms are not often as easy as typical examples given in the relevant literature and it can be controversial. Of course, along with daily advancements in information technology it is possible that further studies into the nature of thesaural relations can reveal the effectiveness of some refinements in thesaurus structure.

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