Parallel Hierarchies in the Verb Lexicon

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Abstract

We discuss semantically heterogeneous manner-relations in the verb component of a lexical database. To make verb hierarchies more consistent while at the same time including instances of links among verbs that are based on expectancy instead of logical necessity, we propose to augment the lexical database with a parallel relation among hierarchically organized verbs. Possibilities for identifying instances of para-troponymy in corpora are outlined and the advantages of an enriched lexical database for NLP are briefly discussed.

1. Introduction and Background

It has been pointed out that the noun hierarchies in WordNet are built on heterogeneous subsumption relations (Gangemi et al., 2001; Gangemi et al., 2002; Guarino and Welty, 2001). The most common violation of the subsumption relation is the failure to distinguish Types and Roles (Guarino and Welty, 2002). Thus, WordNet lists as subordinates of the synset *dog, domestic_dog, Canis_familiaris* such synsets as *poodle, poodle_dog, Newfoundland*, and *corgi, Welsh_corgi* along with synsets like *cur, mongrel, mutt, lapdog, hunting_dog,* and *working_dog*. (Gangemi et al., 2001; Gangemi et al., 2002) propose eliminating from WordNet violations of strict subsumption (Type) relations and moving Roles like *student* to lower levels of the taxonomy.

Some of WordNet's verb hierarchies exhibit heterogeneous kinds of subordinates that seem intuitively similar to the Type/Role distinction among the nouns. For example, among the manner-subordinates of *clean*, we find *steam-clean* along with *brush, sweep*, and *wipe*. One of our goals here is to examine the heterogeneous manner-of relations in WordNet's verb component. Referring to work in progress, (Gangemi et al., 2002) briefly outline a clean ontology of events, categorizing them on the basis of criteria such as aspect and intentionality. Their examples are all complex events, such as *conducting a symphony* and *running a 100-meter race*. The number and nature of the event's participants as well as its spatial and temporal parts provide criteria for the ontological status of the events.

WordNet's verb entries are for the most part simple lexical items and do not include the kinds of complex events cited in (Gangemi et al., 2002). To the extent that WordNet is an ontology, it is a strictly lexical ontology whose entries are limited to concepts that are lexicalized in English[1]. WordNet resembles a traditional dictionary or thesaurus in that it does not explicitly account for aspectual or argument-taking properties of verbs (though verbs that are hierarchically related frequently share the same valency and aspectual properties). Therefore, the criteria for a clean ontology of events outlined by (Gangemi et al., 2002) are not applicable, and, indeed, may be complementary to the present discussion. Our treatment of simple verbs must necessarily be less ambitious, though we hope, no less interesting.

Besides offering some theroretical reflections, this paper attempts to outline how the different manner relations among the verbs could be constructively exploited and how corresponding links might be added to WordNet. Distinguishing and introducing a second manner relation parallel to the existing one would not only ensure semantically consistent relations but also yield a richer and more tighly interconnected network with a greater potential for NLP applications.

2. Hierarchies in WordNet's Verb Lexicon

In WordNet (Fellbaum, 1998), a word's meaning is represented by its membership in a group of cognitively synonymous words (a synset), and labelled pointers among the synsets that stand for semantic relations such as hyponymy, meronymy, and opposition.

The semantic relation that organizes most of the verbs in WordNet is the manner relation, or troponymy (Fellbaum, 1998). This relation allows one to build hierarchical structures akin to those found in the noun lexicon. Similar to the hyponymy relation expressable by the formula "X is a kind of Y", the formula for troponymically related verbs is (1):

(1) to X is to Y in some manner/way

For example, *stammer*, *lisp*, and *whisper* are among the many manner subordinates of *speak*, as the statement "to stammmer/lisp/whisper is to speak in some manner" shows.

Thus, WordNet expresses (part of) the meaning of verb X in terms of the meaning of its superordinate, Y. And the meaning of verb Y is expressed, in part, as the sum of the meaning of its subordinates (troponyms), such as X.

The manner relation is highly polysemous, as (Fellbaum, 1998) notes. Depending on the semantic domain, the differentiae distinguishing the superordinate from the more specific subordinate may be dimensions like speed (*walk-run*), direction (*move-rise*), volume (*talk-scream*), or intensity (*persuade-brainwash*). Despite these differences, the formula given in (1) seems to fit thousands of English verb senses and could be used to construct WordNet's extensive net, which currently includes well over 13,000 verb synsets.

3. Heterogenous Troponymy Relations

Most verbs fit neatly into a given hierarchy and can be assigned to a clearly identifiable superordinate (following

[1] WordNet's verb component contains a few non-lexicalized nodes that are arguably occupied by lexical gaps. See (Fellbaum and Kegl, 1989) for discussion.

an initial stage of identifying and coding top-level concepts, WordNet was constructed bottom-up). But if one examines specific hierarchies, it becomes clear that the relation is not just polysemous along the dimensions referred to above, but semantically heterogeneous.[2]

For example, *exercise* has subordinates like *jog*, *swim*, and *bike*. But these are clearly also manners of *moving/travelling*[3]. Both the following statements are true:

(2) to jog/swim/bike is to exercise in some manner

(3) to jog/swim/bike is to move in some manner

But clearly, there is a difference. The relation between *jog*, *swim*, *bike* and *exercise* is defeasible: Not every jogging/swimming/biking event is necessarily an exercising event. By contrast, every jogging/swimming/biking event is necessarily a moving event:

(4) She jogged/swam/biked but did not exercise

(5) *She jogged/swam/biked but did not move

The concept *exercise* is definable only by means of subordinates like *swim*, *jog*, and *bike* that are shared with another subordinate, *move*. But *move* has many subordinates that are not shared with *exercise*, such as *fly* and *drive*.

The relation of *jog*, *swim* and *bike* to their superordinates *move* and *exercise* is similar to that between, e.g., *dog*, *cat*, and *goldfish* to *animal* on the one hand and to *pet* on the other hand:

(6) A dog/cat/goldfish is a kind of pet.

(7) A dog/cat/goldfish is a kind of animal.

(8) That's my dog/cat/goldfish, but it is not a pet.

(9) *That's my dog/cat/goldfish, but it is not an animal.

Just as one can recognize dogs, cats, and goldfish as animals, but not (necessarily) as pets (Guarino, 1999), so one can recognize instances of biking, swimming, jogging as moving events, but not (necessarily) as exercising events. Unlike moving, the exercise component of biking, swimming, and jogging does not supply an identity criterion and is notionally dependent. Applying the terminology of (Guarino and Welty, 2001; Guarino and Welty, 2002) for nouns to verbs, we could say that *moving* is a rigid property, and *exercising* is an anti-rigid property of a biking/swimming/jogging event. Thus, verbs like *exercise* are similar to role nouns like *pet*, and *move* is similar to type nouns like *animal*.

[2]Some of the examples discussed here are not in fact coded in the current version WordNet, 1.7.

[3]For the sake simplification, we omit other nodes that may intervene; e.g., *jog* is linked to *move* via *run*.

3.1. Consequences for a Lexical Database

(Gangemi et al., 2002) propose an important criteria for "cleaning up" an ontology like WordNet: An anti-feature cannot subsume a feature. Thus, anti-rigidity cannot subsume rigidity. (Gangemi et al., 2002) advocate eliminating all violations of this principle found among WordNet's nouns. This would cut out hierarchical links between synset pairs like *animal* and *fictitious_animal*, while leaving intact the relation between pairs like *animal* and *horse*.

3.2. Arguments for Including Heterogeneous Troponymy Relations

The verb component of WordNet contains (perhaps many) cases of heterogeneous subsumption relations, and these must be recognized and distinguished. But we argue for retaining the corresponding pointers and, in fact, for coding more instances. Our arguments are grounded largely in a pragmatic view of WordNet as an NLP tool, rather than as an ontology that is perfectly consistent with strict logical principles.

First, if links between verbs like *bike* and *exercise* were eliminated in favor of links such as between *bike* and *move, travel*, important and potentially valuable information would be lost. In some cases, the semantic relation between words that are not conforming to strict subsumption principles is more salient than between words that are properly linked. This point will be discussed further later on.

Second, lexical databases that are useful for NLP gain from a tight network of relations. Word sense disambiguation, anaphor resolution, and applications relying on measures of textual cohesion can benefit from links such as between *bike* and *exercise*.

Finally, a random search in the WordNet shows up a fair number of subsumption violations of the *jog/swim/bike* as a manner of *exercise* kind. They are not simple lexicographic errors, as demonstrated by the goodness of the formula *to jog/bike/swim is to exercise in some manner*. But at present, we don't know how common such relations are, nor whether they are distributed evenly throughout the lexicon. Eliminating them when found would preclude a systematic study of the range, variety, and distribution of these relations and a better understanding of the structure of the lexicon.

4. Representing Different Kinds of Verb Hyponymy

Various possibilities exists for representing links between *bike, swim, jog* and superordinates like *move* on the one hand and *exercise* on the other hand.

First, each verb could be linked to multiple parents by means of the same labelled "manner" pointer. However, this "tangled hierarchy" approach is clearly unsatisfactory, as it implies that every jogging/swimming/biking event is both an exercising and a moving event, when in fact only the latter is true.

The second possibility is to posit two distinct senses each for verbs like *swim*, *bike* and *jog*, each sense with a different superordinate, here *move* and *exercise*. Some traditional dictionaries take this route; for exampe, *jog* is

represented in the *American Heritage Dictionary* as having distinct *running* and *exercising* senses. But this solution has the undesirable effect of increasing polysemy. More seriously, positing two distinct senses misses the fact that is every instance of jogging-as-exercise is necessarily also an instance of moving.

A better way to capture the relevant semantic facts is to introduce two distinct kinds of super-/subordinate relation linking a single verb to two superordinates. In addition to strict hyponymy, there would be a parallel hyponymy relation with the appropriate properties.

4.1. Para-troponymy

(Cruse, 1986) proposes a relation dubbed *para-hyponymy* for organizing nouns like *dog* and *pet* hierarchically. Like regular hyponymy, para-hyponymy admits the formula *Xs and other Ys*, where X is the subordinate and Y the superordinate: Both *roses and other flowers* and *dogs and other pets* are good. This formula can easily be adopted for verbs, and fits both strict hyponymy and para-hyponymy:

(10) Biking/swimming/jogging and other manners of moving/travelling

(11) Biking/swimming/jogging and other manners of exercising

To distinguish strict hyponymy from para-hyponymy among nouns, (Cruse, 1986) cites the *but*-test:

(12) It's a dog, but it's not a pet

This test shows that the hyponymy relation between *pet* and *dog* is first, expected, and second, defeasible.

Para-hyponymy can easily be applied to concepts expressed by verbs. The pairs *walk* and *exercise*, *jog* and *exercise*, *bike* and *exercise* etc. are all good in the *but not* frame:

(13) It's a walking/jogging/biking event but it's not an exercising event.

To distinguish this relation in the verb lexicon from para-hyponymy among nouns, we will call it para-troponymy. Our proposal for WordNet or a similar lexical database designed for NLP applications then is to include among the verb relations both strict troponymy and para-troponymy.

Other examples of verbs related by para-troponymy are listed below[4]. *Brush, wipe, sweep* are para-troponyms of *clean* and troponyms of *rub*; by contrast, *steam-clean, dry-clean* are strict troponyms of *clean*. *Nod, wink, scowl, frown, pout* are para-troponyms of *gesture*, *communicate* and troponyms of *move [a specific bodypart]* (omitting several intervening nodes).

[4]The examples of para-troponyms that we have found so far intuitively suggest a similarity to the telicity of Role nouns in para-hyponymic hierarchies; para-troponyms refer to events with a specific purpose or goal, as noted in (Fellbaum, 2002)

5. Expectation

(Cruse, 1986) notes that para-hyponymy is defined not by logical necessity but by "expectation." While intuitively convincing, this notion immediately raises several questions. How can expectation be characterized? Can it be quantified? How can pairs of verbs related by para-troponymy identified in the lexicon? And how do we know whether, say, a verb token *jog* in a corpus refers to an exercising event or (merely) to a running event?

To begin with, expectation is often context-dependent rather than inherent in the concept. In some contexts, a given verb's interpretation as a para-troponym is more salient, whereas in other context, its reading as a strict troponym of another superordinate is more appropriate:

For example, *move* is more salient in (14), but *exercise* is more salient in (15):

(14) a. The boat capsized and we had to swim to the shore.

(14) b. My car is in the repair shop so I'll bike to work.

(14) c. It started to rain heavily so she ran into the library.

(15) He swims/bikes/runs 3 miles every morning before work.

Some contexts allow for an underspecified reading:

(16) He jogged to the store.

More specifically, the nature of the verb's argument projection may play a role in setting up the expectation and the appropriate reading in some cases. *Clear dishes from the table*, where the Locatum entity is the direct object, seems to favor the *remove* reading (the strict superordinate) rather than the *clean* reading (the para-superordinate); *clear the table of dishes*, with the Location entity in direct object position, appears to favor the *clean* interpretation.

Second, the degree of expectation may differ across verbs independently of specific contexts. For some verbs, the para-relation is stronger than the strict relation, and the reverse may be true for other verbs. For example, *jog* intuitively is more strongly associated with its para-superordinate *exercise* than with its logical superordinate *run, move*. This is reflected in the fact that some dictionaries have distinct running and exercising senses for *jog*, as noted earlier. Conversely, *walk* seems be more strongly associated with *move* that with *exercise*. *Walk* seems like a less canonical form of exercise than *jog*, and thus exhibits a weaker association with its para-hypernym and a correspondingly stronger link to its strict superordinate.

The relative frequency of one reading as compared to another presumably influences expectation. Just as, say, hawks as pets may be more conventional in certain cultures than in others, there are probably cultures where jogging is not done for exercise purposes but, say, for pursuing game in a hunt.

Of course, the higher frequency of one reading as compared to the other makes the former more expected and thus stronger. It would therefore be desirable to firm up intuitions about the relative strength or weakness of the (para)troponymy relation with the aid of corpus data.

Almost any verb that is a hyponym of *move* could be made a para-troponym of *exercise*, just as any animal can be called a pet. If one wants to code para-relations in the database, it is important to avoid flooding it with links that reflect readings with very low expectancy. Here, too, corpus data would be useful to identify genuine from spurious para-links.

6. Para-tronomymy in the Lexicon

This paper has cited only a handful of examples of para-troponymy. At this point, we don't know how prevalent this relation is in the lexicon, or how many cases of concepts that exist merely by virtue of contingent subordinates are lexicalized in English. To find them, we need characteristic syntactic frames and a tool to search a corpus for appropriate occurrences of such patterns[5]. This section merely offers some thoughts and suggestions for future work.

We saw that para-troponyms pass the tests adapted from the one for para-hyponymy; in this respect, para-troponyms are indistinguishable from strict troponyms:

(17) X-ing and other manners/ways/methods of Y-ing.

(18) To X is to Y in some way/manner.

Using Google to search the Web for the string *and other manners/ways of*, we turned up quite a few examples of para-troponymy and para-hyponymy, as well as some cases of regular troponymy and noun hyponymy, in addition to cases of verbs co-occurring with nominalizations. Here are some cases of para-troponymy:

(19) Flirtation, courting and other manners of getting the attention of the opposite sex is certainly a form of manipulation ... www.mothersmagic.net/Goddess/maiden.html

(20) Befriending, listening and other ways of helping.... www.britishcouncil.org/sudan/science/ - 17k

(21) volunteering and other ways to help www.fcs-sf.org/page5.html

(22) Home Cooking and other ways to save Money. www.geocities.com/ dvsclothing/cooking.html

(23) Walking and other exercise use many muscles. www.lungusa.org/diseases/exercise.html

(24) activities that repeatedly flex the knee (ie, jumping, squatting, running and other exercise). orthoinfo.aaos.org/fact/thr_report.cfm? Thread_ID=252&topcategory=Knee

(25) Swimming, running, biking, walking and other exercise that are at a time length of over 20 minutes.. www.pmssolutions.com/Hiddentruth.html

To limit the search to para-troponyms, we searched for instances where the expected relation is negated, as in the pattern in (26):

(26) It's X-ing but not Y-ing
(e.g., it's swimming but not exercising)

We found:

(27) ...and then spraying the action with a little WD-40 is not cleaning. It is a slow methodical destruction of a considerable investment. Like everything ... www.doubleought.com/cleaning.html

(28) No, this is not "cleaning for the cleaning lady", it's picking up so that the cleaning lady can clean ... www.bitchypoo.com/2000/May/11.html - 7k

Similarly, on can search for cases where the para-hyponymy is asserted, possibly over a negative presupposition, as in the pattern in (29):

(29) This X-ing is Y-ing
(e.g., This swimming is exercising)

A web search turned up examples like these:

(30) Shotblasting is a way of cleaning or preparing surfaces for recoating, using an abrasive material forced through a jet nozzle... www.westshotblasting.co.uk/

(31) ... shake hands, using the right hand, and explain that this is a way of greeting one another. Pair up children and allow them to practice shaking hands. www.atozkidsstuff.com/math.html

(32) Tipping-leaving a gratuity-is a way of thanking people for their service. www.istudentcity.com/stages/3mannerstipping.asp

Another possibility is to examine co-occurrences of verbs in contexts for cases of (defeated) para-troponymy, without using any specific patterns. The following are actual examples:

(33) really get the job done. If the goal is to have clean sidewalks, they're going to have to be swept and bagged, not just blown. www.heartlight.org/two_minute/2min_971015.html

(34) will be swept by City crews. Residential streets are now swept once a month, while downtown streets are cleaned three times a week... www.ci.walnut-creek.ca.us/street

(35) These sociologists think that interrupting is a way of exercising power. They say, "Here we are dealing with a class of speakers ... www.glc.k12.ga.us/qstd-int/ancill/guidance/schoices/sc-f20.htm

We hope to develop more sophisticated and efficient ways for finding para-relations in the lexicon in the near future and to test their usefulness in applications.

[5]Resnik, Fellbaum, and Olsen are currently developing a tool to search the Web for specific syntactic patterns.

7. Summary and Conclusions

We have argued for retaining instances of paratroponymy in a lexical database like WordNet. Furthermore, we advocate collecting and adding naturally attested cases of this relation. Semantic relations that are not based on logical necessity but on expectations grounded in pragmatics or world knowledge are an interesting area for research in lexical semantics. Enriching a lexical database with para-relations can not only shed light on the organization of the lexicon, but may yield benefits for NLP applications relying on this database.

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