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Automatic Sense Clustering in EuroWordNet

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Abstract

This paper addresses ways in which we envisage to reduce the fine-grainedness of WordNet and express in a more systematic way the relations between its numerous sense distinctions. In the EuroWordNet project, we have distinguished various automatic methods for grouping senses into more coarse-grained sense groups. These resulting clusters reflect aspects of lexical organization, displaying a variety of semantic regularities or generalizations. In this way, the compatibility of the language-specific wordnets in the EuroWordNet multilingual knowledge base is increased.

1. Introduction

EuroWordNet[1] is a European funded project (LE2-4003) that aims to build a multilingual database consisting of wordnets in several European languages. Currently, resources are being included for English, Dutch, Italian, Spanish, German, French, Czech and Estonian. Each language specific wordnet is structured along the same lines as WordNet (Miller et al. 1990), i.e. synonyms are grouped in synsets, which in their turn are related by means of basic semantic relations such as hyponymy, antonymy and meronymy. WordNet is a fairly fine-grained semantic resource (Fellbaum, 1997), and this is not always an advantage. There are several reasons for reducing the rather high level of ambiguity in Wordnet, such as the sometimes disappointing performance when it is used for NLP applications. In the EuroWordNet project, ambiguity reduction is accomplished by clustering word senses into coarser-grained sense groups that display a variety of semantic regularities or generalizations. We have examined various methods to be used for the automatic clustering of senses. These are listed and discussed in section 3.2, preceded by an introduction into an initial typology for cluster types. Finally, section 4 illustrates a practical application of the structured reduction of the WordNet 1.5 sense granularity in order to optimize compatibility of the language-specific wordnets.

2. Motivations for Sense Clustering

2.1 Lexicographic practice

It is a recognized fact that sense distinctions vary widely across lexical resources. Different dictionaries divide the semantic space a word occupies in different ways along the broad lines of homonymy and polysemy. The level of lumping and splitting (Evens 1988), i.e. where the cut-off point is determined between fine-grained and coarse-grained sense distinctions, is strongly influenced by the purpose of the resource, its authoritative character and users (Kilgarriff, to appear). Resulting sense distinctions are often arbitrary (Atkins, 1991) and the many fine-grained sense distinctions that are made in resources are related (Kilgarriff, 1991).

This high level of polysemy is often the result of the expertise of professional lexicographers, who are trained in recognizing fine-grained sense distinctions. Jorgensen (1990) found that subjects unfamiliar with lexicographical practices generally distinguish around 3 senses for very polysemous dictionary entries. Therefore, we argue that clustering related senses in WordNet will yield a more structured lexicon exhibiting a higher degree of psychological reality.

2.2 NLP Applications and WordNet

Although WordNet is used as a resource for semantic information in many NLP applications, the sense distinctions in WordNet are too fine-grained for a number of NLP tasks (Kilgarriff, 1997). For instance, in multilingual information retrieval, which is the envisaged application area of EuroWordNet, the amount of noise in query results rises exponentially when the original set of polysemous search words is being extended with synonyms from the synsets to which they belong in WordNet. It is expected that precision and recall will benefit from a reduced level of ambiguity, resulting in more sensible query expansion techniques. By clustering senses into

For an extensive introduction to EuroWordNet see (Vossen, forthcoming) For a detailed description of the overall architecture of the EuroWordNet database see (Peters et al., forthcoming).

groups the semantic search space is reduced. Moreover, if these coarser sense distinctions follow systematic semantic patterns in the lexicon, it will be possible to apply selective query expansion by solely including synset members from semantically related senses of the original search word. In this way, only relevant word senses are being used as a supplement to word-based indexing, which is in line with the recommendation of Krovetz (1997).
Another area of potential benefit is word sense disambiguation, where algorithms are frequently faced with multiple correct choices, or with a difficult choice between highly related senses (Dolan, 1994). Disambiguation tasks will also benefit from a reduced number of sense candidates resulting from sense clustering.

2.3 Compatibility of Language-Specific Wordnets within EuroWordNet

The wordnets in EuroWordNet are treated as autonomous language-specific systems. This makes it possible to build the wordnets relatively independently, which is necessary because the construction takes place at different sites with very different starting points in terms of available resources and tools. Each wordnet is a unique, language-specific structure. To create a multilingual knowledge base, we store the language-specific wordnets in a central lexical database while the equivalent word meanings across the languages are linked to each other in the Interlingual Index (ILI). The ILI forms the superset of all concepts encountered in all the languages involved and started off as an unstructured list of concepts represented by all WordNetl.5 synsets. Each synset in the monolingual wordnets has at least one equivalence relation with a record in this ILI. Language-specific synsets linked to the same ILI-record should thus be conceptually equivalent across the languages.

Because of the independence of the language specific wordnets in the development stage we need mechanisms to ensure compatibility when the wordnets are integrated. It is here that we find the third, very practical reason for clustering word senses. Typically, many mismatches between the language specific wordnets result from differences in the sense differentiation across the resources. Because of the high level of sense differentiation in WordNetl.5 there is a danger that conceptual equivalences across the wordnets are not linked to exactly the same sense of the English translational equivalent but are instead connected to distinct ILI concepts reflecting different senses of the same word. For example, where two project partners selected the verbal concept *break, damage* (inflict damage upon) as the translational and conceptual equivalent of their local concept, a third project partner selected both *break* ("He broke the glass") and *break, bust, cause to break* (which has no gloss in WordNetl.5). All three senses are so similar that each matching is equally probable, and any selection must be regarded as arbitrary. In order to account for these diverging mappings from local wordnets onto ILI concepts, composite ILI records are introduced that constitute a grouping of ILI concepts. These more global concepts are subsequently used to overcome mismatches. The experiment discussed in section 4 investigates this claim that clustering increases compatibility between the various wordnets.

3. Automatically Extracting Sense Clusters: Types and Methods

Before going into the various methods for extracting sense clusters in section 3.2, we want to briefly look at the different types of semantic relations between clustered senses. Section 3.1 discusses three general types of sense relations that are being used as an initial typology of the cluster groups in WordNet.

3.1 Types of Sense Relations

We have so far distinguished three types of semantic clustering. The first is generalization. As mentioned in section 1, WordNet sense distinctions are fairly fine-grained, which leads to a proliferation of sense distinctions having a high level of similarity. This overlap in semantic coverage makes it possible to postulate a semantic generalization over a group of senses which constitutes an underspecified, lowest common denominator that all senses share. The case *of break* (discussed in section 2.3), where the different senses are very similar, is an example of a possible cluster based on generalization.

The second cluster type is metonymy. This type covers instances of regular or systematic polysemy (Apresjan, 1973; Nunberg & Zaenen, 1992; Pustejovsky, 1995). Recurrent systematic patterns occur where the relation between the senses is not based on coarse similarity but reflects denotational alternations such as *organization-building, person-social group, tree-wood, material-product, container quantity* and grinding types such as *animal-body covering* and *foodstuff-flora.* Often a metonymic sense extension can be regarded as a derivation of a more basic sense (Ostler and Atkins 1991). The phenomenon of metonymy can be considered as an underlying structuring principle of the lexicon that can be expressed by lexical rules (Copestake and Briscoe 1991).

A third type of semantic regularity is related to the phenomenon of diathesis alternation, which we have not yet included in our investigation. Semantic characteristics of verbs are often systematically reflected in the syntactic configurations they engage in (Levin, 1993). In many cases distinctions between e.g. transitive/intransitive or causative/inchoative usage highlight different aspects of the predication, and the conceptual core remains essentially the same. It will be possible to postulate potential semantic links between non-English verb synsets on the basis of English diathesis patterns, regardless of whether the language-specific verbs in question display similar alternation patterns or not. Also, where non-English verbs have a number of linked ILI alternations concentrated into a single sense, the systematic semantic relation expressed in the ILI may yield valuable information for a possible refinement of the sense distinctions of these verbs.

3.2 Clustering Methods

Various clustering methods have been examined within EuroWordNet, but the work is still ongoing. Most of these methods rely on the internal hierarchical organization of WordNet and, except for autohyponymy (see section 3.2.2), they are all used in the WordNet interface to compute semantic similarity. With respect to using external resources to aid clustering, we have only looked at CoreLex (section 3.2.5). However, we envisage using other existing lexical resources, such as machine-readable dictionaries and ontological classifications.

Thus far, we have limited ourselves to homographs of the same part of speech. The methods are described in the following paragraphs.

3.2.1 Sisters

Word senses that share the same hypernym are called sisters[2]. In the example below, both senses of *table* have *furniture* as their direct hypernnym:

table-2
'a piece of furniture having a smooth flat top supported by one or more vertical legs; "it was a sturdy table"'
table-3
'a piece of furniture with tableware for a meal laid out on it; "I reserved a table at my favorite restaurant"'

Using the sister criterion generates patterns of generalization. In the example above, the given senses can be used to refer to the same object, highlighting different aspects of it. However, in some cases the clustered senses refer to different objects in the real world. This is illustrated by the following example, where all three senses share the direct hypernym *vine.*

butterfly pea

- 'vine of tropical Asia having pinnate leaves and bright blue yellow-centered flowers'
- 'large-flowered wild twining vine of SE and C US having pale blue flowers'
- 'large-flowered weakly twining or prostrate vine of NJ to tropical E N America, sometimes cultivated for its purple and white flowers'

[2] The sister relation is not limited to two senses, but can also occur between three or more senses of the same word. Sometimes, a particular word exhibits more than one type of sister relation.

As these senses denote different species, they are not near-synonyms. However, they are very similar in nature, and can be clustered on that basis. It must be taken into account that, and this is true for all generalizations, the meanings cannot be used interchangeably. The most specific semantic content these particular senses share is the meaning of the direct hypernym.

3.2.2 Autohyponymy

The term *autohyponymy* is used to refer to words whose senses are each others direct hypernnyms or hyponyms (Cruse, 1986). Sharing the same hypernymic chain (except for the first node) provides us with a number of combinations where the meanings are very similar and clustering results in homogenous groups. Look at the following examples, where the first sense is the most specific one:

- *variety-3, species*
  'a specific kind of something: "a species of molecule" or "a species of villainy"'
- *variety-6, kind, sort, form*
  'a category of things distinguished by some common characteristic or quality; "sculpture is a form of art"; "what kinds of desserts are there?"

- *understand-3, read, interpret, translate*
  'make sense of a language; "She understands French"; "Can you read Greek?"'
- *understand-1*
  'know and comprehend the nature or meaning of; "She did not understand her husband"; "I understand what she means"'

As this method also leads to generalization clusters it is the meaning of the hypernym synset that can be used to characterize the resulting sense cluster. The specific sense is subsumed by the general one; the hyponym carries extra meaning which is not shared by its parent and/or is typically used in a specific domain.

3.2.3 Twins

Twins are synsets that have at least three members in common as the example below illustrates. Their meanings are defined by 'of rules or patterns' and 'act in disregard of laws and rules', respectively.

- *violate, fail to agree with, go against, break-13, be in violation of*
- *violate, go against, breach, break-6, be in violation of*

This example seems to validate clustering on the basis of the twin criterium. However, some of the twin groupings are more problematic. The synsets below have the following incompatible glosses: 'motion that does not entail a change of location; "the reflex movements of his eyebrows revealed his surprise"' and 'the act of changing your location from one place to another'.

- *change of position, motion, movement, move-3*
- *change of location, motion, movement, move-4*

A number of synsets are linked by a twin relation only because they contain spelling variants, such as *sestet, sextet, sextette.* As we have not yet examined the twin relation in great detail, we cannot fully assess the validity of this method. However, it seems that even in cases where synsets only share two members, this can also be an indication that clustering is possible. An example is *travel-4, journey* and *travel-2, journey,* where the meanings are very closely related.

3.2.4 Cousins

WordNetl.5 contains a list of 105 node top pairs whose hyponyms exhibit a specific relation to each other (see WordNet database documentation on groups, file groups.7[3]). These pairs have been identified and listed by lexicographers. The treatment of these so-called cousins is still in its experimental stage; the resulting list is incomplete and does not offer a consistent and structured list of recurrent patterns between sets of words. Examples of cousin relations are *container-containerful* and *food-tableware,* listed below.

container-1
'something that holds things, especially for transport or storage'
containerful-1
'the quantity that a container will hold'

food-1, nutrient
'any substance that can be metabolized by an organism to give energy and build tissue'
tableware-1
'articles for use at the table'

Looking at the first pair, there are a large number of words that occur both as hyponyms of the *container* node and the *containerful* node, such as *bag, can, cup, glass, shovel, spoon* and *thimble.* These are all good examples of the regular polysemic pattern that exists between *container* and *containerful.* On further investigation, we find that the cousin relation is not limited to senses sharing a word form. For example, WordNet contains no words that have both a *food* and a *tableware* meaning. While words such as *silver plate, gold plate, crockery* and *chop sticks* all occur as hyponyms of *tableware,* they are not found in a *food* sense. Cousin relations, thus, do not necessarily generate regular polysemous patterns, but sometimes capture semantic relations between words of a more schema-like nature. Within the scope of the present research we are only interested in sense distinctions of individual words and can only use those cousin relations generating clusters that share word forms.

3.2.5 CoreLex

An attempt at making systematic polysemic patterns in WordNet explicit has been made by Buitelaar (1998). The CoreLex database[4] contains 126 semantic types, covering 39,937 nouns in 317 systematic polysemous classes. Three steps were taken to derive CoreLex from WordNet. Firstly, all polysemous nouns in WordNet were reduced to a set of Basic Types, corresponding largely to WordNet's 'unique beginners' and 'top nodes', such as *artifact, causal agent, shape* and *act.* Subsequently, systematic groupings of nouns were created on the basis of their Basic Types distributions. For example, the noun *banana,* occurring both in a *food* and a *plant* sense, was put in a group with other nouns exhibiting the same pattern, such as *coriander, grapefruit, plantain* and *mulberry.* The final step consists of integration into the Core Lexical Engine (Pustejovsky, 1995).

On examining the polysemous classes, we found a number of disadvantages to the CoreLex system. Firstly, 19 of them consist of only one Basic Type and therefore do not display systematic polysemy. More importantly, the generated classes are not always homogeneous in nature; particularly the larger groups do not necessarily exhibit regular polysemic patterns and occurrences of 'monsters' are not infrequent. Often there is scope for further subclustering. For example, we find *bundle, package, packet, ragbag, deck, edition, library, menagerie, repertory* belonging to the same CoreLex type (*arg,* a combination of the Basic Types *artifact* and *group)* where we find the first 4 words covered by the more specific hypernymic nodes *collection-1* and *container-l* and the last three by *collection-1 and facility-1.* For our purposes, the main problems with CoreLex are caused by the fact that the Basic Types are largely based on very high-level nodes in the WordNet hierarchy. In order to obtain more homogeneous classes, we propose to examine recurrent distributional patterns at a more specific level in the hierarchy (see also (Peters &Peters, forthcoming)).

4. Evaluating the Effect of Sense Clustering on Wordnets.

We carried out an experiment in which different fragments of the Dutch and Spanish wordnets were compared, both before and after extending the ILI with composite ILI records. First we generated composite ILI records, which are listed in table 1 and 2, and discussed in section 4.1. In section 4.2 we then go on to measure the effect of some of the clustering methods on the compatibility of the local wordnets.

[3] This documentation is included in the WordNet database, downloadable from http://www.princeton.edu/~wn/

[4] Available from http://www.cs.brandeis.edu/~paulb/CoreLex/overview.html

Metonymy	Descendant Intersections
animal/food	81
organization/construction	25
plant/food	100
move/sound	8
Total	214

Table 1: Metonymic clusters

Generalization	Total no Descendants	Generalization Clusters	Metonymic Clusters	Total Composites	Percentual Coverage of all Senses
animal[5]	3842	80	81	161	4.19%
plant	4750	48	100	148	3.11%
food	2123	64	181	245	11.54%
organization	846	31	25	56	6.61%
construction	1210	81	25	106	8.76%
move	708	176	8	184	25.98%
sound	192	6	8	14	7.29%
Total	13671	486	428	914	6.68%

Table 2: Generalization clusters and cluster coverage

4.1 Adding composite ILI records

For the experiment, composite ILIs have been generated automatically on the basis of two methods:

- We selected a number of metonymic relations (see table 1) and subsequently extracted all words that have one sense occurring as a (sub)hyponym of one element of the relation and another sense as a (sub)hyponym of the other element. Some of these relations feature in the cousin table, discussed in section 3.2.4. As suggested in section 3.2.5, the selected relations generally consist of hypernymic nodes that are more specific than WordNet's top nodes and unique beginners. This method generates regular polysemic patterns.
- From the words selected by the above-mentioned method, we clustered those word senses that are (sub)hyponyms of one of the members of the metonymic relations selected in this experiment (see table 2). This method extracts generalization clusters and extends the sister relation discussed in 3.2.1 to include those senses that are not direct hyponyms of the shared hypernymic node, i.e. senses that are not co-hyponyms. This method also subsumes autohyponomy.

Tables 1 and 2 give the totals for the extracted records. In total 700 new composite ILI-records have been added (214 metonymic groupings and 486 generalization pairs), involving 1557 ILI-records. Note that this method is fully automatic and can easily be extended to all senses in WordNetl.5. In general, we see here that the largest metonymic classes are *animal/food* and *plant/food.* The largest set of generalization is extracted for *move.* After extending the ILI with the new concepts, the equivalence relations of the Spanish and Dutch wordnet to the ILI have been updated. This is done automatically by the database: any synset that is related to an ILI-record included in a composite ILI will get an additional metonymy or generalization link to this composite ILI-record. For the Dutch wordnet 602 links have been added, and for the Spanish wordnet 521 links.

[5] In the case of animal and food, we have concentrated on the metonymic patterns. Because of the size of both sets, we have not investigated the instances of generalization.

		NL					ES				
		Desc. WMs	Projection		Intersection		Desc. WMs	Projection		Intersection	
			WMs	% of ES Desc.	WMs	% of NL Desc.		WMs	% of NL Desc.	WMs	% of ES Desc.
organiza-tion	ILI-0	48	47	97,92%	19	39,58%	186	41	22,04%	21	11,29%
	ILI-1	48	66	137,50%	20	41,67%	186	49	26,34%	26	13,98%
construc-tion	ILI-0	344	254	73,84%	131	38,08%	548	130	23,72%	77	14,05%
	ILI-1	344	270	78,49%	134	38,95%	548	139	25,36%	81	14,78%
food	ILI-0	154	133	86,36%	71	46,10%	533	83	15,57%	68	12,76%
	ILI-1	154	136	88,31%	71	46,10%	533	93	17,45%	69	12,95%
move	ILI-0	1183	445	37,62%	309	26,12%	384	392	102,08%	143	37,24%
	ILI-1	1183	510	43,11%	345	29,16%	384	418	108,85%	168	43,75%
sound	ILI-0	47	33	70,21%	18	38,30%	139	43	30,94%	19	13,67%
	ILI-1	47	33	70,21%	18	38,30%	139	46	33,09%	20	14,39%
Total	ILI-0	1776	912	51,35%	548	30,86%	1790	689	38,49%	328	18,32%
	ILI-1	1776	1015	57,15%	588	33,11%	1790	745	41,62%	364	20,34%
Increase			103	5,80%	40	2,25%		56	3,13%	36	2,01%

Table 3: Mapping Dutch and Spanish coverage

4.2 Evaluating the Effect of Clustering on the Compatibility of the Language-Specific Wordnets

To measure the effect, we mapped Spanish (ES) and Dutch (NL) fragments before and after extending the ILI with these records. All descendants of Dutch and Spanish representatives of the above classes were selected, e.g. all (sub)hyponyms of *bouwwerk-1 (construction)* in Dutch and *construcción-4 (construction)* in Spanish. In the EuroWordNet database, it is possible to 'project' these language-specific descendant word meanings to the other language (translate via the ILI). The result is a set of word meanings in the target language connected to the source language meanings via ILI-records. By taking the intersection of this projection in both directions we get an idea of the overlap of these semantic clusters (for further details, see (Peters et al., forthcoming)).

Table 3 gives the results of this mapping in both directions for each hierarchical node, once before the ILI-extension (rows headed by ILI-0) and once after the update (rows headed by ILI-1). For each language, the first column gives the total number of (sub)hyponyms per hierarchical node (the descendants), the second column gives the number of word meanings that have been projected to that particular language (from Spanish to Dutch and from Dutch to Spanish) and the third column lists the percentages of the projection for the total set of descendant word meanings.[6] The last two columns give, for each language, the intersection of the projected word meanings (WMs in table above and the descendant word meanings, in absolute numbers and percentages.The bottom rows list the totals.

The general tendency for the Dutch wordnet is that the projection increased by 5.8%. whereas the increase of the intersection is 2.25%. For the Spanish wordnet these figures are 3.13% and 2.01% respectively. If we compare the increase of the projection (103 word meanings for Dutch and 56 for Spanish) with the increase in intersection (40 word meanings for Dutch and 36 for Spanish), we see that between 40-65% of the extended projection is effective, i.e. leads to an increase of the intersection. We suspect that the remaining incompatibilities either reflect a real difference in coverage or are caused by diverging classifications (e.g. *milk* is classified as a *product* instead of *comestible;* a hypernym of *food).*

If we examine the figure in more detail, we see the following tendencies:

- the methodology is effective for *organization, construction* and *move;*
- the methodology is hardly effective for *food* and *sound;*

[6] In some cases, the projection extends the total set (more than 100%). This means that these words have been classified differently in the target language of the projection.

In the case of *move* (see table 2) we can expect that the effect is high because the extension (the composite ILIs) already makes up 25% of the total set of descendant senses. In the case of *organization* and *construction*, it is more remarkable because the extension only makes up 6-8% of the total of descendants. Further inspection shows that the effect for *construction* and *organization* is evenly spread over metonymy and generalization (50-70%) whereas the effect for *move* is almost exclusively due to generalization (97%). The fact that the effect is small for *sound* is in line with the low extension with composite ILI-records (6% of the total number of descendants). For *food*, the effect is more disappointing, given the much higher proportion of composite ILIs (11%).

	New Projections to NL after the ILI Extension	Metonymic Overgeneration	Genuine Errors
food	3	1	0
construction	16	3	0
organization	19	4	0
move	65	0	4

Table 4: Metonymic extension

To verify the quality of the extension, we have manually inspected the new word meanings that were projected from the Spanish wordnet to the Dutch wordnet. This inspection showed hardly any projections that are incompatible with the classifications of the projection before the extension, except for those that fall within the metonymic extension. In so far as there is a degree of variation in classification across the wordnets ((Peters et al., forthcoming), the extension is not worsening this effect. However, there is metonymic overgeneration across the wordnets (see table 4). Metonymic overgeneration was to be expected, since regular polysemy does not necessarily hold across the languages. It may be caused by a cultural difference (e.g. not all *plants* and *animals* are considered to be *food* in all language/cultures), although we did not find any examples of this type of overgeneration. Another possible reason for overgeneration is a difference in lexicalization (e.g. metonymic meanings can be lexicalized by different word forms). In the case of *plant/food*, there is only one occurrence of overgeneration: in the compound *vanilleplant* (the plant from which vanilla is extracted) the headword *plant* blocks the *spice* interpretation. The same phenomenon occurs more often with *organization/construction* , because a number of Dutch compounds can only refer to a building, such as *vestigingswerk* (defense construction), and *verenigingsgebouw* (building where the club is seated). Among the *constructions* we find several genuine cases of overgeneration: *gemeenschap* (the community), godsdienst (religion), *delegatie* (delegate), *commissie* (commission) are all groups of people without an associated building. Finally, in the case of *move*, three errors occur: *bidden* (to pray), *gelijkspelen* (to finish a game with even scores) and *verschrijven* (to make a mistake with writing). However, these are due to incorrect translations or dubious classifications which also occur within non-extended projections. Metonymic overgeneration is not problematic since it is up to the builder of the local wordnet to decide whether to include the metonymic pattern for a particular language. For example, in the cases discussed above the Dutch wordnet will only have an eq_synonym relation with one of the senses related by metonymy, while in other languages we may find the same word linked to multiple meanings.

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