New Polysemy Structures in Wordnets Induced by Vertical Polysemy

Ahti Lohk[1], Heili Orav[2], Kadri Vare[2], Francis Bond[3] and Rasmus Vaik[1]

[1]Department of Software Science, Tallinn University of Technology, Tallinn, Estonia
[2]Department of Computer Science, University of Tartu, Tartu, Estonia
[3]School of Humanities, Nanyang Technological University, Singapore

<{ahti.lohk, rasmus.vaik}@taltech.ee,
{heili.orav, kadri.vare}@ut.ee, bond@ieee.org>

Abstract

This paper aims to study auto-hyponymy and auto-troponymy relations (or vertical polysemy) in 11 wordnets uploaded into the new Open Multilingual Wordnet (OMW) webpage. We investigate how vertical polysemy forms polysemy structures (or sense clusters) in semantic hierarchies of the wordnets. Our main results and discoveries are new polysemy structures that have not previously been associated with vertical polysemy, along with some inconsistencies of semantic relations analysis in the studied wordnets, which should not be there.

In the case study, we turn attention to polysemy structures in the Estonian Wordnet (version 2.2.0), analyzing them and giving the lexicographers comments. In addition, we describe the detection algorithm of polysemy structures and an overview of the state of polysemy structures in 11 wordnets.

1 Introduction

The advantages of wordnet (Fellbaum, 1998) come from its specific design. On the one hand, it is a machine-readable dictionary, with definitions and examples of concepts, but on the other, a network of concepts in semantic relations (Fellbaum, 1998). This kind of resource makes it easy to figure out how close or far concepts are semantically from each other (semantic distance). Similarly, we can find the sub-concepts, super-concepts or synonyms of a given term. Wordnet offers a lexical-semantic background knowledge base for solving various NLP tasks, in particular for tasks that require semantic analysis.

However, one of the problems that can make wordnet usage difficult is the lexical polysemy in its semantic hierarchies (Freihat, Giunchiglia, & Dutta, 2013; Mihalcea, 2003). Furthermore, the problem is even more acute in the cases of polysemy where the context of two or more lemmas with the same spelling in a semantic network is barely distinguishable. The emergence of such a situation is facilitated by auto-hyponymy and auto-troponymy (Fellbaum, 2002), which fall within the definition of vertical polysemy (Koskela, 2011).

Auto-hyponymy and auto-troponymy in semantic hierarchies of wordnet have already been studied mainly as a criterion for grouping meanings of words (Pociello, Agirre, & Aldezabal, 2011; Pedersen, Agirrezabal, Nimb, Olsen, & Rørmann, 2018), but also for reducing polysemy (i.e. reducing the number of terms for their coarser distinction) (Mihalcea, 2003). In this paper, however, we are going to look at the possible substructures of semantic hierarchies that can only be formed by vertical polysemy.

We discovered that polysemy structures caused by vertical polysemy help us identify both the previously handled basic polysemy structures, such as chain and triangle (Jen-Yi, Yang, Tseng, & Chu-Ren, 2002), but also those that have not previously been associated with vertical polysemy. By studying such polysemy structures, we also were led to cycles and structures containing up to 20 vertical polysemy cases, which we judge are likely to be errors.

The paper is structured as follows: Section 2 gives the theoretical background to understand the main body of the article. Next, Section 3 is dedicates to the overview of polysemy structures from the perspective of previous work. Section 4 describes the algorithm to detect specific polysemy structures from wordnet semantic hierarchies. Section 5 focuses on the case study of Estonian Wordnet. Section 6 gives an overview of the 11 wordnets uploaded to the OMW environment.

Section 7 concludes the paper and presents future work.

2 Theoretical background

This section aims to give some understanding of the theoretical basis of the discussed topic. Here we define the concept of polysemy and provide an overview of different polysemy structures.

2.1 Lexical ambiguity: polysemy and homonymy

We define polysemy to be a specific type of lexical ambiguity where a word or phrase has multiple semantically related meanings (Langemets, 2009). That is to say, they share the same etymology. Every polysemous word or phrase falls into one of three polysemy sub-categories: metonymy, specialization polysemy, or metaphors (Freihat, Giunchiglia, & Dutta, 2013).

In the case of metonymy, the polysemous word *chicken* can be as *a domestic fowl* or *food*.

A specialization polysemy example is the word *programming* where its narrow meaning is *coding* but in a broader meaning, it involves many actions like *inventing and analyzing the algorithm, coding and testing the code*.

In the case of metaphors, the polysemous word *parasite* can be *an animal or a plant* but also *a person*.

Beside the polysemy, another type of lexical ambiguity is homonymy. This concept differs from polysemy in that the meanings of a word or phrase are unrelated. In other words, they do not share the same etymology. For example, the homonymous word *bank* can be a *financial institution* or *edge of a river* (Jia-Fei, 2015).

Sometimes different authors refer to homonymy as contrastive polysemy and polysemy as complimentary polysemy (Weinreich, 1964) and (Freihat, Giunchiglia, & Dutta, 2013), with polysemy being used for both.

As stated, in the case of homonymy, the meanings of a word are unrelated. It implies that homonymous words do not form specific structures in wordnet hierarchies. For that reason, homonymous relationships remain out of our scope for further investigation.

2.2 Polysemy structures

Depending on how polysemy may form substructures in wordnet hierarchies, we divide polysemy structures into three categories (Figures 1-3):

1. Polysemous words in synonym sets have IS-A or MANNER-OF relationship (Figure 1).
2. Multiple inheritance cases in IS-A or MANNER-OF hierarchies. Cases where one synonymous set as child has at least two parents. By the Figure 2, it is important to emphasize that here a sub-term ("milk") has two meanings that come from its parents ("dairy product" and "beverage").
3. Polysemous words in IS-A or MANNER-OF hierarchies are not connected. That is to say, meanings of the words are related but not related in the hierarchical structure (Figure 3).
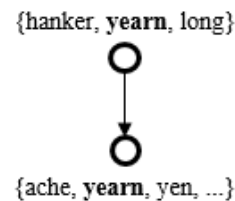

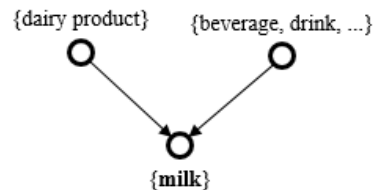**Figure 1**: IS-A relationship between polysemous words. The example originates from PrWN 3.1[1]

Figure 2: A multiple inheritance case. The example originates from PrWN 3.1
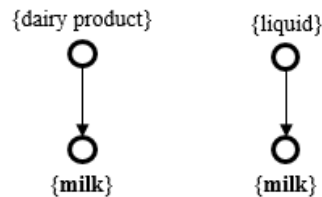

Figure 3: Not directly related polysemous words. The example has translated words and originates from EstWN 2.2.0[2]

Examples of the second (Figure 2) and third (Figure 3) categories are deliberately chosen to point to another important aspect – different wordnet developers can place different meanings of a word differently in the wordnet hierarchy. Furthermore, there are no clear guidelines on how to organize

polysemous words in the wordnet hierarchy (Verdezoto & Vieu, 2011).

2.3 Vertical polysemy

In this paper, we study only polysemy structures caused by "IS-A" (in the case of noun hierarchy) or MANNER-OF (in the case on verb hierarchies) relationships between polysemous words.

A more appropriate term for describing such a case is **auto-hyponymy** (in noun hierarchies) or **auto-troponymy** (Fellbaum, 2002) and more generally speaking **vertical polysemy** (Koskela, 2011). Auto-hyponymy (also auto-troponymy) is a subset of the hyponymy (troponymy) relation where the superordinate and subordinate synonym sets contain same term (word) as shown in Figure 1. (Koskela, 2011) referring to (Horn, 1984) who says "**auto-hyponymy**, alludes to the fact that a **vertically polysemous** word is effectively its own hyponym." Thus notions of auto-hyponymy (also auto-troponymy) and vertical polysemy are very tightly related and are used here as synonyms. However, as referred by (Koskela, 2011) in the case of vertical polysemy, a polysemous word "with a broader and a narrower sense" can "occupy different levels in a taxonomic hierarchy". That is to say, that there may be not only a parent-child relationship between the polysemic words, but also the relationship of the grandparent-grandchild. However, in our work only parent-child relationship is considered.

3 Previous work: overview of polysemy structures

Previous work in relation to auto-hyponymy (also auto-troponymy) involves finding sense clusters of polysemous words (Peters, Peters, & Vossen, 1998) (Jen-Yi, Yang, Tseng, & Chu-Ren, 2002) and reducing polysemy structures in wordnet semantic hierarchies to transform its term (word) senses from fine-grained to coarse-grained ones (Mihalcea, 2003).

The nearest work for our approach is (Jen-Yi, Yang, Tseng, & Chu-Ren, 2002). The authors' broader goal was to create a bilingual network for Chinese and English, exploring the hierarchies of verbs, since there is approximately twice as much polysemy among the verbs as among the nouns. They aimed to find semantic patterns, hoping that these are helpful in multilingual information retrieval task. In their work, they distinguish five types of patterns calling them specifically the sense clusters of polysemous verbs or polysemic patterns. Very generally, these patterns take into account cases where two or more synonym sets contain the same term in their sets and are tightly related to each other in the semantic structure. The names of these patterns are *sisters*, *twins, child, chain* and *triangle*. Next, we describe each one of them shortly (Jen-Yi, Yang, Tseng, & Chu-Ren, 2002).

3.1 Sense clusters of the polysemous words

Even though (Jen-Yi, Yang, Tseng, & Chu-Ren, 2002) work focuses only on verb sense clusters we represent examples from both verb and noun hierarchies. That is to say, all of these specific examples are about IS-A/MANNER-OF relations and have been extracted from Princeton WordNet [3] noun and verb hierarchies, first published by (Lohk, 2015), but are still present there.

- **Sisters** are co-hyponym synsets having only one common term (Figure 4). Based on verb analysis of (Jen-Yi, Yang, Tseng, & Chu-Ren, 2002), sisters is the most frequent pattern among the other ones.
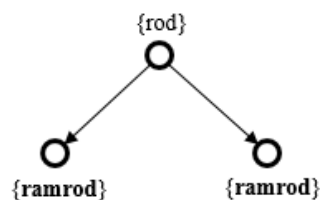

Figure 4: *Polysemic pattern – sisters*

- **Twins** are co-hyponym synsets having at least two common words (Figure 5).
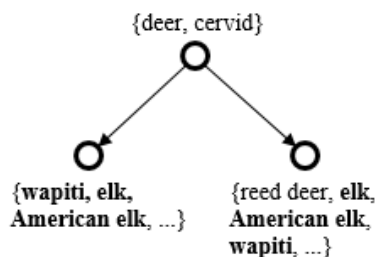

Figure 5: *Polysemic pattern – twins*

- **Child** is the polysemic pattern where the same term exists in a synset and its superordinate (Figure 6).
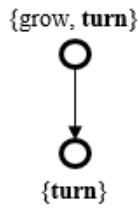
---

[3] http://wordnetweb.princeton.edu/perl/webwn

Figure 6: *Polysemic pattern – child*

- **Chain** is a polysemic pattern where the same term appears sequentially in IS-A/MANNER-OF chain three or more times (Figure 7). Based on (Jen-Yi, Yang, Tseng, & Chu-Ren, 2002) analysis, that pattern appeared the least number of times.
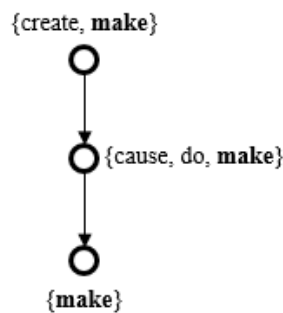

Figure 7: *Polysemic pattern – chain*

- **Triangle** is a polysemic pattern where the same term appears simultaneously in three synsets: in two co-hyponym synsets and their superordinate (Figure 8). Based on (Jen-Yi, Yang, Tseng, & Chu-Ren, 2002) this pattern is the second rarest one.
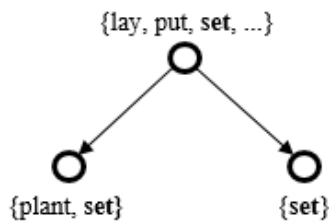

Figure 8: Polysemic pattern – triangle

Auto-troponymy relations characterize the last three patterns. That is to say, that verb term (or word) has both a more general and more specific meaning being simultaneously in troponymy (or MANNER-OF) relation(s). Here we state that these are polysemy structures caused by vertical polysemy.

4   Description of the algorithm

In our study, we find both the structures of polysemy and the statistics that describe these structures in one or another aspect. These statisticians are general enough not to pay attention to them in terms of the algorithm description. Thus, here we describe the only algorithm that finds all polysemy structures caused by vertical polysemy.

4.1   Algorithm

To get better intuition we describe that algorithm roughly through three steps:

Step 1: Separate from wordnet semantical hierarchies (IS-A and MANNER-OF) all pairs of senses (homographic pairs) with their synset id-s sharing the same lemma.

Step 2: For all pairs find equivalent classes. That is to say, find which pairs form connected components.

Step 3: Draw a graph for each connected component.

4.2   An example

To illustrate that we utilize data from Princeton WordNet. In the following example, we have separated sense pairs about "think" in **Step 1**. Even though Princeton WordNet has 13 "think" verb and one noun senses only six of them form pairs.

think-v (eng-630153) | think-v (eng-631400)
think-v (eng-630153) | think-v (eng-741087)
think-v (eng-630153) | think-v (eng-741345)
think-v (eng-691086) | think-v (eng-691551)

In **Step 2**, we find all connected pairs or connected components. As a result, two separate classes come up that are used later in separate polysemy structures.

*think-v (eng-630153) | think-v (eng-631400) - **1***
*think-v (eng-630153) | think-v (eng-741087) - **1***
*think-v (eng-630153) | think-v (eng-741345) - **1***
*think-v (eng-691086) | think-v (eng-691551) - **2***

In **Step 3**, we draw for every connected component a graph as a picture shown in Figure 9. We call these two graphs polysemy structures caused by vertical polysemy.
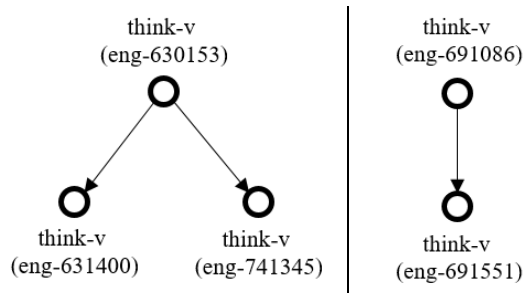
Figure 9: Two polysemy structures. Example from Princeton WordNet.

5 Case study of Estonian Wordnet

In this section, we describe one word and its senses from the Estonian Wordnet as an example of a vertical polysemy structure where it was possible to revise senses and reduce too fine-grained separation of senses.

5.1 Previous developments

In recent years, Estonian Wordnet has been mainly developed as a resource for NLP tasks. While increasing the wordnet's size also the problem of too fine-grained sense distinctions is taken into account. Different methods have been developed to reduce fine-grained senses, for example, the feedback from computer game Alias (Aller, Orav, Vare, & Zupping, 2016) feedback from NLP tasks (Kahusk & Vider, 2002) using the set of test patterns to validate wordnet's hierarchies (Lohk, Norta, Orav, & Võhandu, 2014) (Lohk, 2015) and various results from tasks given to students.

In Estonian, for example, every 10th word carries polysemous meanings. In addition, frequent words have the tendency of being highly polysemous, for example, *aasta* 'year', *asi* 'thing', *jooksma* 'run' etc. Discriminating between word senses is a problem in lexicography and it is considered as one of the hardest tasks. In wordnet, these related polysemous words should be connected via semantic relations.

5.2 An analysis example of a polysemy structure

At this point, we can say that there are 227 cases of polysemy structures in EstWN.

Here we look into one structure as an illustrative example. The word *galerii* 'gallery' in EstWN 2.2.0 has 8 different meaning. Five of them belong to the same hierarchy (Figure 10) and therefore needed attention. As follows, all senses of *gallery* are represented and explained how we tried to modify this hierarchy.

In Estonian 4 senses of the word *gallery* were changed:

- **gallery 3** - *narrow open passage on the top floor of the gallery house (on the upper floors), which is connected with an external staircase and is equipped with a balustrade.* Its synonymous with another synset *arch, arcade*, and it was possible to delete gallery 3.

- **gallery 6** - *a large, autonomous (connection) space in a building, one side of which is designed as arcade or row of windows.* We changed the hypernym from *gallery* to space, room.

- **gallery 7** - *gallery on the sidewalls in the church of Byzantine, Roman and Gothic, which opens by arcade towards the midnight robbery and forms a second high-wall balcony on the arcade.* Here we found to be reasonable delete word *gallery* from synset because others dictionaries do not show this meaning for gallery.

- **gallery 8** - *(reception)room connecting the rooms in the castles.* The hypernym was changed to *room*.

Other senses were left unchanged:

- **gallery 2** - *long, narrow room or covered gear*.

Senses which are not covered by the polysemy structure but are present in Estonian Wordnet:

- **gallery 1** - *building for the art collection, especially for paintings.*

- **gallery 4** - *pillars in the park (shaped as gallery).*

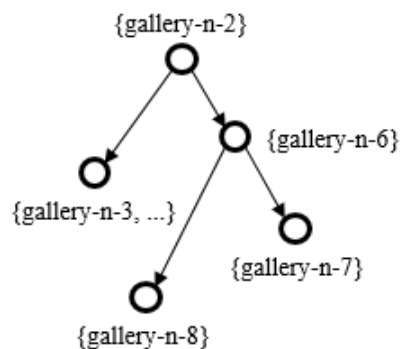- **gallery 5** - *balcony under the ceiling in the theatre halls.*

Figure 10: Example of polysemy structure in EstWN

Manual analysis of polysemy structures shows to us that generally the differences in nuance are the cause of auto-hyponomous polysemy structures in wordnets. For example:

- different function (gallery 5 used for receptions and gallery 8 used for art)

- different era (i.e gallery 4)

- different place (gallery 7 as part of theatre)

- different domain (gallery as architectural or landscape gardening or gallery in sports)

Some cases of 'gallery' can be specified, if we use another semantic relation, i.e. the domain-relation. In this case, the 'gallery1' could be associated with art and 'gallery4' with garden design etc.

These test patterns indicate possible inconsistencies, where vertical polysemy causes unjustified fine-grained senses or is otherwise problematic.

6 Polysemy structures in wordnets

In this section, we strive to capture a broader picture of the state of the wordnets in terms of vertical polysemy affected by polysemic structures. For that reason, we highlight the most specific structures caused by vertical polysemy. In addition, we provide tables for wordnets that characterize the structures of polysemy and describe the specificities that arise.

Wordnets we are using here are shown in Table 1.

6.1 Overview of the specific structures

As mentioned before, when we were making preparations to identify polysemy structures from semantic hierarchies, we expected to find structures like the **chain** and the **triangle** or their combinations. However, the results showed something different. These are structures that are not new in nature but have not previously been reflected in the context of vertical polysemy. In this light, we represent these new ones as contribution to the polysemic structures shown in Figures 7 and 8, in particular with the structures shown in Figures 11 and 12.

Next five figures originate from four different wordnets. Every node label contains here only the term common in all nodes of its substructure and synonym set id.
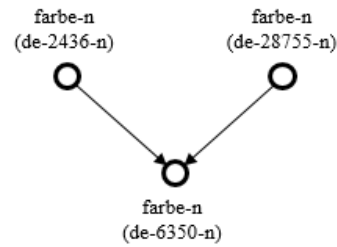

Figure 11: Multiple inheritance case caused by vertical polysemy. Example from Odenet. (*Farbe* in English is 'color')

The most basic structure here is the polysemy structure with multiple inheritance case (Figure 11). Next one (Figure 12) is known as a shortcut. Here, it seems that to multiple inheritance structure one additional link is added. Next three (Figure 13, 14, 15) are shortcut structures with an additional connection that cause the cycle. In Figure 14 purely two shortcut structures are together with an additional link that again causes the cycle.
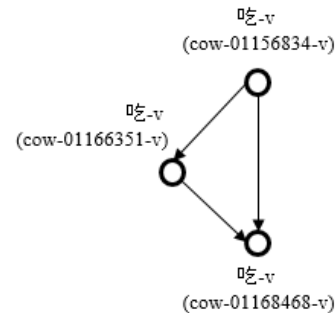

Figure 12: Shortcut structure caused by vertical polysemy. Example from Chinese Open WordNet. (吃 in English is "eat")
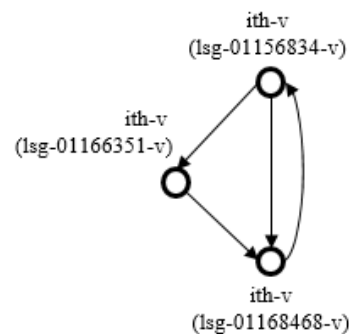

Figure 13: Shortcut structure with cycle. Example from Gaelic Wordnet. (*ith* in English is "eat")
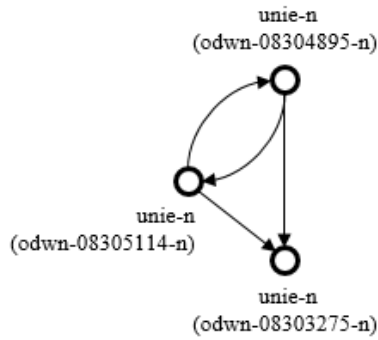
Figure 14: Shortcut structure with cycle. Example from Open Dutch Wordnet. (*unie* is "union")
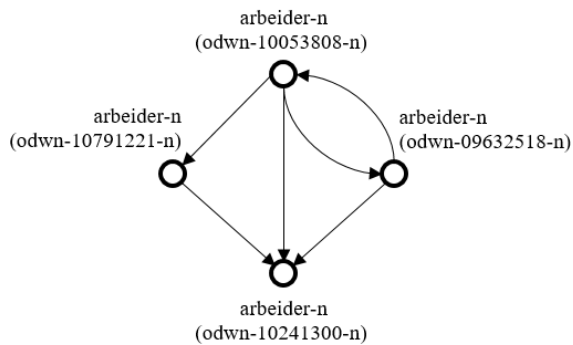

Figure 15: Two shortcut structures with a cycle. Example from Open Dutch Wordnet. (*arbeider* is "worker")

6.2   Statistics describing polysemy structures

The statistical indicators give us a better understanding of the polysemy structures in wordnets.

As mentioned before, cycles are a by-product of our results, which should be the primary goal of developers to eliminate. For this reason, we will not reflect them separately in the following tables. All rows in Tables 1 and 2 are ordered by alphabetically considering names of the wordnets. In particular columns, we represent three of the most extreme values in bold font.

To get a better comparison base, we first give the number of hyponymy relations for each wordnet (Table 1). This will make it clear which wordnets are richer in terms of vertical polysemy. Figure 16 shows the wordnets with the six highest

proportion of hyponymy relations associated with vertical polysemy. Table 1 and Figure 16 show that although LSG has a relatively small number of hyponymy relations, this wordnet also has a relatively high number of vertical polysemy relationships. Compared to the three and four columns, we can see which dictionaries have the most varied values in both columns. The more significant difference between these numbers refers to the fact that the vocabulary precedes more pairs of synonyms with more than one word with the same orthography. Here the biggest difference is between NTU-JPN numbers, after that LSG and in third position ODWN.
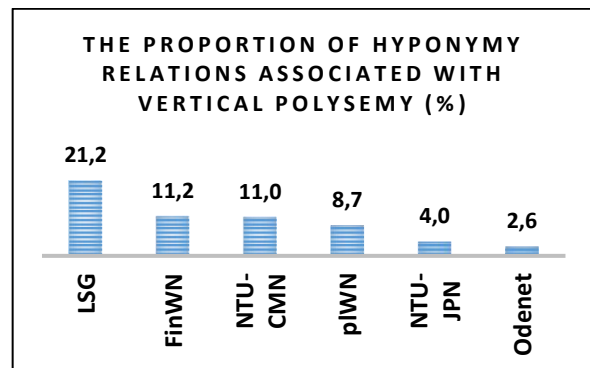

Figure 16: Proportions of hyponymy relations associated with vertical polysemy

Based on Table 1, two wordnet pairs show quite clearly how polysemic relations may vary in different languages. The first pair to consider is NTU-CMN, and the other is NTU-JPN. Both wordnets have exactly the same number of hyponymy relations, but at least in terms of vertical polysemy, NTU-CMN is represented by a much higher number. Their similarity is that they have been developed in parallel. Another pair of similar comparisons is FinWN and plWN-eng. FinWN has been compiled by translating PWN with the help of professional translators, however, FinWN is more diverse in terms of vertical polysemy.

Wordnet	Language	Nr of hyponymy relations	Nr of hyponymy rel.s related to VP[4]	Nr of vertical polysemy relations	Nr of polysemy structures	Unique synsets
Odenet	German	1 594	42	52	49	82
EstWN	Estonian	80 244	254	265	227	453
FinWN	Finnish	91 879	**10 281**	**11 529**	**7 478**	**15 664**
LSG	Irish	19 117	**4 062**	6 424	4 752	**6 094**
NTU-CMN	Chinese	89 376	**9 806**	**13 112**	9 314	**15 001**

---

[4] Vertical polysemy

Wordnet	Language	Nr of hyponymy relations	Nr of hyponymy rel.s related to VP[4]	Nr of vertical polysemy relations	Nr of polysemy structures	Unique synsets
NTU-JPN	Japanese	89 376	3 544	**8 463**	**6 704**	5 676
ODWN	Ducth	**102 789**	1 815	2 510	2 176	3 109
OWN-PT	Portuguese	8 577	4	4	4	8
plWN	Polish	**201 706**	1 743	1 854	1 696	3 252
plWN-eng	English	**97 597**	352	382	357	653
TrWN	Turkish	4 687	9	10	10	18

Table 1: Statistical indicators related to vertical polysemy and polysemy structures

In addition to Figure 16, we can also confirm the proportion of vertical polysemy in the second column of Table 2, which shows how many meanings a word may have among vertical polysemy relations.

Wordnet	Max nr of synsets for a term in vertical polysemy	Nr of **multiple inheritance** cases with vertical polysemy	Nr of **shortcuts** with vertical polysemy	Max nr of relations in a polysemy structure	Nr of nodes in the longest chain if any (nr > 2)
Odenet	4	2	0	3	−
EstWN	9	0	0	4	3
FinWN	**33**	4	**1**	**20**	**4**
LSG	**18**	6	**2**	17	**4**
NTU-CMN	**21**	**7**	**1**	16	**4**
NTU-JPN	16	3	0	7	**5**
ODWN	7	**31**	16	6	3
OWN-PT	2	0	0	1	−
plWN	11	**96**	0	7	3
plWN-eng	7	0	0	6	3
TrWN	2	0	0	1	−

Table 2: Statistical indicators related polysemy structures, multiple inheritance and shortcut structures

7   Conclusion

The study of polysemy in wordnet semantic hierarchies is essential because it is one of the central problems that needs to be considered in the case of distinctive NLP tasks that require semantic analysis. For this reason, we aimed to capture what polysemic structures occur in the wordnets uploaded to OMW.

In more detail, we studied the Estonian Wordnet, where polysemy has been kept under the spotlight for years. That is also the reason why its results were not as extreme as any other wordnets. However, we did find a couple of examples here, yet only one that needed correction. Thus in Estonian Wordnet polysemy structures of auto-hyponyms do not represent major problems of fine-grained senses, only few cases are present. Many of the structures of polysemy are caused by the economy principles of languages, i.e. general meaning is transferred to a more specific meaning or to a domain terminology. Some auto-hyponymy cases can be solved, if we introduced new semantic relations to Estonian Wordnet, for example the domain-relation.

By studying eleven wordnets, we discovered some unexpected polysemic structures. These are structures that by their nature are not new, but are not previously presented as closed chunks caused by vertical polysemy (as substructures in the semantic hierarchy). These polysemic structures are:

- Multiple inheritance
- Shortcut structure
- The longest chain (path)

These structures are unexpectedly frequent in many of the wordnets. The longest chain found

had five vertices, longer than the four that have been previously discussed.

The study of vertical polysemy relations in the 11 different wordnet networks reveals the impact of the individual choices, as it is a choice of the lexicographer, how to organize the polysemic senses in the wordnet hierarchy (e.g. as a configuration of a sister structure or as two children instead). This is the main reason behind the size of polysemic clusters in particular hierarchies.

The code to discover and visualize these structures will be incorporated into the Open Multilingual Wordnet, which can be accessed online or run on your own machine.

Acknowledgements

Reference

Aller, S., Orav, H., Vare, K., & Zupping, S. (2016). Playing Alias - efficiency for wordnet(s). *Global WordNet Conference, Bucharest, 27-30 January 2016* (pp. 16-21). Bucharest: Editura Universității "Alexandru Ioan Cuza" din Iași.

Fellbaum, D. C. (1998). *WordNet: An Electronic Lexical Database.* Cambridge: MIT Press.

Fellbaum, D. C. (2002). On the Semantics of Troponymy: R. Green, C. A. Bean, & S. H. Myaeng, *The Semantics of Relationships: An Interdisciplinary Perspective* (pp. 23-34). Springer.

Freihat, A. A., Giunchiglia, F., & Dutta, B. (2013). Approaching Regular Polysemy in WordNet. *eKNOW 2013, The Fifth International Conference on* (pp. 63-69). Nice, France: IARIA XPS Press.

Horn, L. (1984). Toward a new taxonomy for pragmatic inference. book: D. Schiffrin, *Meaning, form, and use in context* (pp. 11-42). Washington: Georgetown.

Jen-Yi, L., Yang, C.-H., Tseng, S.-C., & Chu-Ren, H. (2002). The Structure of Polysemy: A study of multi-sense words based on WordNet. *Proceedings of the 16th Pacific Asia Conference on Language, Information and Computation* (pp. 320-329). Jeju, Korea: The Korean Society for Language and Information.

Jia-Fei, H. (2015). Previous Researches on Lexical Ambiguity and Polysemy: *Verb Sense Discovery in Mandarin Chinese—A Corpus based Knowledge-Intensive Approach* (pp. 9-21). Springer.

Kahusk, N., & Vider, K. (2002). Estonian WordNet Benefits from Word Sense. *Proceedings of the 1t Global WordNet Conference*, (pp. 26-31). Mysore, India.

Koskela, A. (2011). Metonymy, category broadening and narrowing, and vertical polysemy. rmt: R. Benczes, A. Barcelona, & F. de Mendoza Ibáñez, *Defining Metonymy in Cognitive Linguistics: Towards a consensus view* (pp. 125-146). Amsterdan: John Benjamins Publishing Co.

Langemets, M. (2009). *Systematic Polysemy of Nouns in Estonian and Its Lexicographic Treatment in Estonian Language Resources: In Estonian.* Tallinn: Tallinn University.

Lohk, A. (2015). *A System of Test Patterns to Check and Validate the Semantic Hierarchies of Wordnet-type Dictionaries.* Tallinn, Estonia: TalTech Press.

Lohk, A., Norta, A., Orav, H., & Võhandu, L. (2014). New Test Patterns to Check the Hierarchical Structure of Wordnets. *Information and Software Technologies : 20th International Conference, ICIST 2014* (pp. 110–120). Druskininkai: Springer.

Mihalcea, R. (2003). Turning WordNet into an Information Retrieval Resource: Systematic Polysemy and Conversion to Hierarchical Codes. *International Journal of Pattern Recognition and Artificial Intelligence, Vol. 17, NO. 05*, 689–704.

Pedersen, B., Agirrezabal, M., Nimb, S., Olsen, S., & Rørmann, I. (2018). Towards a principled approach to senseclustering –a case study ofwordnet and dictionary sensesin Danish. *The 9th Global WordNet Conference* (pp. 183-190). Singapore: Global WordNet Accosiation.

Peters, W., Peters, I., & Vossen, P. (1998). Automatic Sense Clustering in EuroWordNet. *Proceedings of the 1st International Conference on* (pp. 409–416). Granada, Spain: European Language Resources.

Pociello, E., Agirre, E., & Aldezabal, I. (2011). Methodology and construction of the Basque WordNet. *Lang Resources & Evaluation*, pp. 121-142.

Snow, R., Prakash, S., Jurafsky, D., & Ng, A. (2007). Learning to Merge Word Senses. *Proceedings of the 2007 Joint Conference on Empirical Methods in Natural Language Processing and Computational Natural Language Learning* (pp. 1005-1014). Prague: Association for Computational Linguistics.

Verdezoto, N., & Vieu, L. (2011). Towards Semi-automatic Methods for Improving WordNet. *Proceedings of the Ninth International Conference on Computational Semantics* (pp. 275-284). Oxford, United Kingdom: Association for Computational Linguistics (ACL).

Weinreich, U. (1964). Webster's Third: A Critique of its Semantics American Linguistics, 4, Vol. 30. *International Journal of American Linguistics*, pp. 405-409.

Wordnets Used in This Paper

Open German Wordnet (Odenet). https://ikum.medien-campus.h-da.de/projekt/open-de-wordnet-initiative.

Estonian Wordnet. Orav, Heili; Vare, Kadri; Zupping, Sirli (2018). Estonian Wordnet: Current State and Future Prospects. Proceedings of the 9th Global WordNet Conference Singapore, January 8-12, 2018. Global Wordnet Association: Global Wordnet Association.

FinnWordNet. Lindén K., Carlson. L., (2010). FinnWordNet WordNet påfinska via översättning,LexicoNordica — Nordic Journal of Lexicography, 17 pp 119–140.

Chinese Open Wordnet. Shan Wang and Francis Bond (2013). Building the Chinese Open Wordnet (COW): Starting from Core Synsets. In Proceedings of the 11th Workshop on Asian Language Resources, a Workshop of The 6th International Joint Conference on Natural Language.

Japanese Open Wordnet. Hitoshi Isahara, Francis Bond, Kiyotaka Uchimoto, Masao Utiyama and Kyoko Kanzaki (2008). Development of Japanese WordNet. In LREC-2008, Marrakech.

Open Dutch Wordent. Marten Postma and Emiel van Miltenburg and Roxane Segers and Anneleen Schoen and Piek Vossen (2016). Open Dutch WordNet. In Proceedings of the Global WordNet Conference 2016

Brazilian Wordnet. Valeria de Paiva and Alexandre Rademaker (2012). Revisiting a Brazilian wordnet. In Proceedings of Global Wordnet Conference, Matsue.

Polish WordNet. Maciej Piasecki, Stanisław Szpakowicz and Bartosz Broda. (2009). A Wordnet from the Ground Up. Wroclaw: Oficyna Wydawnicza Politechniki Wroclawskiej, Poland.

enWordnet. Rudnicka, E., Witkowski, W., Kaliński M. (2015). Towards the Extension of Princeton WordNet. Cognitive Studies 15, 335-351.

Turkish Wordnet. R. Ehsani, E. Solak, O. T. Yildiz , Constructing a WordNet for Turkish Using Manual and Automatic Annotation, ACM Transactions on Asian and Low-Resource Language Information Processing, Vol. 17, No. 3, Article 24, 2018.