Citation: Dziob, A., & Piasecki, M. (2018). Dynamic verbs in the Wordnet of Polish. *Cognitive Studies / Études cognitives*, 2018(18). <https://doi.org/10.11649/cs.1718>

AGNIESZKA DZIOB^A & MACIEJ PIASECKI^B

Faculty of Computer Science and Management, Wrocław University of Science and Technology, Poland

^Aagnieszka.dziob@pwr.edu.pl ; ^Bmaciej.piasecki@pwr.edu.pl

DYNAMIC VERBS IN THE WORDNET OF POLISH

Abstract

The paper presents patterns of co-occurrences of wordnet relations involving verb lexical units in plWordNet — a large wordnet of Polish. The discovered patterns reveal tendencies of selected synset and lexical relations to form regular circular structures of clear semantic meanings. They involve several types of relations, e.g., presupposition, cause, processuality and antonymy, do not have a necessary character (there are exceptions), but can be used in wordnet diagnostics and guidelines for wordnet editors. The analysis is illustrated with numerous positive and negative examples, as well as statistics for verb relations in plWordNet 4.0 emo. Some attempts to a more general, linguistic explanation of the observed phenomena are also made. As a background, pl-WordNet model of linguistic character is briefly recollected. A special attention is given to the verb part. In addition the description of dynamic verbs by relations and features is discussed in details including relation definitions and substitution tests.

Keywords: plWordNet; Wordnet of Polish; lexico-semantic relations; Polish language; dynamic verbs; verbs in wordnet; natural language processing

1 Introduction

Wordnets describe words of the four basic Parts of Speech,¹ i.e. nouns, verbs, adjectives and adverbs. However, they do this in a very unbalanced way. Even in Princeton WordNet (Fellbaum, 1998) — one of the largest and richest wordnets — nouns are the most privileged category with rich structure of relations and good coverage, while the number of relations for adjectives is very small and the coverage is modest, not mentioning a very sparse description of adverbs. Verbs in WordNet are in the middle of the way with the significantly smaller number of relations and much more selective coverage than the one for nouns. The lower density of verb sub-networks of many wordnets, e.g. Princeton WordNet, plWordNet (Maziarz, Piasecki, Rudnicka, Szpakowicz, & Kędzia, 2016) means less information. Our general aim is to introduce a richer structure of verb relations into a wordnet and make it closer to the expectations of different applications.

¹Some wordnets also include the descriptions for other PoSs, e.g. prepositions and conjunctions in BulNet (Koeva, 2010).

In the paper we will discuss an expanded model for the description of verbs in plWordNet which originates from the general model of plWordNet and consists of: *features* (e.g. verb class, aspect) and *lexico-semantic relations*. We will also strive to formulate guidelines for linguists. The discussion will be confined to the Polish language and plWordNet, but set in a perspective enabling more general conclusions. Since this topic is still very broad, even if limited to verbs in plWordNet (e.g. the guidelines for verbs in plWordNet consists of 37 pages), here we will mainly focus on *dynamic verbs*.

2 plWordNet in brief

2.1 Linguistic model

The plWordNet model (cf Piasecki, Szpakowicz, & Broda, 2009 and Maziarz, Piasecki, & Szpakowicz, 2013) is based on *lexical units* (LUs, i.e. triples: lemma, Part of Speech, sense identifier) as basic building blocks. LUs are grouped into synsets on the basis of sharing constitutive relations and features, i.e. two LUs belong to one synset if and only if they share targets of *constitutive relations* and values of *constitutive features*.

Constitutive relations are selected lexico-semantic relations that are frequent enough and express relatively high sharing factor. They also originate from lexicography and wordnets and are relatively well-understood among linguists, e.g. hyper/hyponymy, holo/meronymy, iterativity, distributivity.

Constitutive features constrain the shape of the system of lexico-semantic relations (e.g. *aspect* or *adjective and verb classes*) or express some general pragmatic conditions on the use of lexical meanings (e.g. *stylistic register*). Constitutive features are often referred to in the definitions of lexico-semantic relations, e.g. hyper/hyponymy is defined only for adjectives of the same class or inter-register synonymy links LUs of non-compatible lexical registers (cf Maziarz et al., 2013).

All plWordNet relations are precisely described guidelines for wordnet editors (i.e. lexicographers) by textual *definitions*, *examples* and *substitution tests*. A substitution test for a relation or its subtype consists of up to several test sentence templates that include variables to be replaced by lemmas corresponding to LUs that are examined. Each test sentence template can be positive or negative. In the former case, we expect that the template filled with the analysed word forms is a semantically well-formed sentence, in the latter case, the created sentence is expected to be semantically odd. The whole test is passed by a pair of lemmas if and only if all answers conform to the expectations. Sentence templates in substitution tests can also be compared with use examples from corpora. They connect relation definitions with language data from the corpora. Substitution tests are also presented in the user interface of WordnetLoom (Piasecki, Marcińczuk, Ramocki, & Maziarz, 2013 and Naskręt, Dziob, Piasecki, Saedi, & Branco, 2018) prior to adding any new relation link. They are already instantiated with the forms of the lemmas under consideration.

In short, lexico-semantic relations are the main means of description. In plWordNet they can all be traced back to language data.

Synset relations are, in fact, abbreviations of sets of constitutive relations held between the synset members. The synonymy relation is to some extent derived from constitutive relations and features that define synsets. There is no ontological difference between synset relations and *lexical relations* (i.e., the relations that link LUs). Both types of relations are lexico-semantic relations of strictly linguistic character between lexical meanings. The synset relations are in fact relations linking LUs belonging to the two synsets. This is in contrast to the Princeton WordNet model in which synset relations are conceptual and link lexicalised concepts represented by synsets, not LUs — synset members.

In plWordNet, most of synset relations are constitutive relations. However, Dziob and Piasecki (2018) introduced *non-constitutive synset relations* as relations that help to expand semantic characteristics of a synset, but are not treated as the part of synset definition, because they are

more descriptive than discriminative, e.g. *subject* or *circumstance* relations.

plWordNet also includes also glosses (short meaning descriptions, similar to Princeton WordNet glosses) and use examples, but both are defined for LUs, not for synsets.

2.2 Construction

plWordNet is divided into four sub-databases of nouns, verbs, adjective and adverbs. However, there are many relations linking LUs of different Parts of Speech, called cross-categorial relations in EuroWordNet (Vossen, 2002).

Table 1: Basic statistics of plWordNet 4.0 emo (<http://plwordnet.pwr.edu.pl>)

Elements	Verbs	Nouns	Adv.	Adj.	All
Lemmas	19 941	133 843	8 010	29 228	191 022
Lexical Units	40 799	176 935	14 040	54 021	283 795
Synsets	29 650	132 623	11 260	46 705	220 238
Links to SUMO Pease (2002)					206 426
Links to Wikipedia²					44 432

3 Verb model in plWordNet

The model for the description of verbs in plWordNet 3.1 (Dziob, Piasecki, Maziarz, Wiczorek, & Dobrowolska-Pigoń, 2017) originated from the one of plWordNet 3.0 (Maziarz, Piasecki, Szpakowicz, Rabiega-Wisniewska, & Hojka, 2011). The introduced modifications resulted in the simplification of the system of verb semantic classes and lexico-semantic relations. The changes were aimed at limiting proliferation of verb senses triggered by too fine grained semantic classes and their interactions with relation definitions. In the case of the latter, some subtypes of relations were discarded, definitions rewritten, slightly simplified and made stricter, but also a few new relations were introduced. As observed in Dziob and Piasecki (2018), the modified model resulted in the significant increase of a number of instances of verb relations, especially in the case of relations expressing associations between situations on which we will concentrate in Sec. 4.

3.1 Semantic verb classes

Seven main semantic verb classes were introduced in plWordNet 2.0 capitalising on the classification of Vendler (1957) and its modification by Laskowski (1998), namely: processes, actions, acts, accidents, activities, events and states (Maziarz et al., 2011). The classes were organised into a complex hierarchy with many subtypes represented by additional artificial synsets. This complex system of verb classification found several interesting applications, e.g. Lis and Navarretta (2014). However, as noticed in Dziob et al. (2017) and Dziob and Piasecki (2018), it posed several problems to wordnet editors. Thus, we decided to simplify the system of classes following EWN (Vossen, 2002). Only two main classes were introduced (instead of 7): *static* and *dynamic* verbs. In this paper we will concentrate on the latter.

Static verbs were defined in Dziob et al. (2017) as imperfective atelic and durative verbs that represent situations which are stable and do not include any change during their time span, i.e. we cannot distinguish any change from a state X to Y in the situation represented by a static verb, cf detailed subclasses in Dziob and Piasecki (2018). As in Vendler (1957), only imperfective verbs are static verbs.

Dynamic verbs encompass all perfective and bi-aspectual verbs. Among them, Dziob and Piasecki (2018) identified several subgroups (subclasses) focusing on differences in paraphrasing the verb meanings:

1. *distributive* — representing situations in which something is done by many agents, in relation to many objects or affects many objects, e.g. *przebadać* ‘to examine many people’,
2. *accumulative* — situations that have lasted or been done to such an extent that it is enough (from some point of view) e.g. *ubawić się* ‘to amuse itself’,
3. *perdurative* — doing something during a particular or limited time, e.g. *przemieszkąć* ‘to live during some period in a place’,
4. *delimitative* — expressing doing something or happening of something for some time or to some extent, e.g. *pomieszkać* ‘to live for short time in a place’,
5. *action verbs* — a) all perfective and bi-aspectual, b) imperfective derivatives of accumulative, delimitative, perdurative, and distributive verbs (representing changing situations), c) imperfective derivatives of semelfactive verbs (i.e. representing punctual or instantaneous events), e.g. *mrugać_{imp}* (from *mrugnąć_{perf}*) ‘to flicker’, representing multiple changes, d) imperfective causative verbs (expressing occurrence of a new situation), e) processive (expressing gradual transition to a new state) (e.g. *starzeć się_{imp}*, *postarzeć się_{perf}* ‘to becoming (become) older’), f) inchoative, representing an introductory phase of a new situation, (e.g. *rozplakiwać się_{imp}*, *rozplakać się_{perf}* ‘to start crying’) and g) limitative (representing ending of some situation) (e.g. *wybarwiać się_{imp}*, *wybarwić się_{perf}* ‘to lose colour’), and also h) other imperfective verbs that represent a situation changing due to actions of entities or with respect to them, e.g. *iść* ‘to walk_{imp}’, *biegać* ‘to run_{imp}’, *plakać* ‘to cry_{imp}’.

Some plWordNet relations are restricted only to processive, causative and inchoative verbs, see Sec. 3.2. These relations facilitate defining verbs of these groups as verbs expressing a situation change.

3.2 Hyponymy and relationships between situations

Hyponymy and its reverse *hypernymy* are basic relations building the verb hierarchy in plWordNet. Hyponymy is defined with the help of the following substitution test (Maziarz et al., 2011):

X_{inf} to Y_{inf} w specjalny sposób, jakoś ‘To *X* is to *Y* in a special way, somehow’

plWordNet hyponymy corresponds to *troponymy* relation from Princeton WordNet, described by the substitution test (Fellbaum, 1998):

To V1 is to V2 in some particular manner

Troponymy is also characterised as a specific kind of entailment, restricted to verbs representing temporarily coexistent situations. The same aspect of temporal co-existence is expressed in plWordNet in *hyponymy/hyperonymy*, *meronymy/holonymy*, cf Dziob and Piasecki (2018).

Meronymy for verbs in plWordNet is a relation expressing that there are two situations co-occurring in the same time in such a way that a situation represented by the verb *X* is the part of the one represented by *Y* or *X* is accompanying *Y*.

Holonymy is a reverse relation to meronymy, but it is not obligatory, i.e. not every meronymy link entails a reverse holonymy link (cf Dziob et al. 2017). The definition of meronymy is a complex issue, often discussed in literature (e.g. Murphy, 2006; Brown, 2004) and also in Dziob and Piasecki (2018), so we will omit the details in this paper.

In addition to the above four relations, in plWordNet there are several more relations that describe associations between situations. They form a rich system of verb meanings.

Presupposition and **preceding** — both express an association of a situation represented by the source verb, with a situation that occurred earlier, represented by the target. *Presupposition*

is close to logical presupposition and informs about the necessity of an earlier occurrence of some situation, while *preceding* does not include such an aspect of necessity, but only expresses a possibility that one situation happens before the other one. Both relations connect a verb (perfective or imperfective) representing a situation *X* with the representation of an earlier situation *Y* characterised by a verb, noun, adjective or adverb. Neither can be established between verb synsets that include LUs associated derivationally (including *pure aspectuality*), possessing very close meaning and linked by *inter-register synonymy* or representing situations co-existing temporarily (i.e. those linked by hyponymy, meronymy or holonymy).

There are two subtypes of presupposition and preceding in plWordNet (Dziob & Piasecki, 2018):

- *subject identity* (SI), in which the semantic subjects of both linked situations — *X* and *Y* — must be identical (henceforth, subject will be understood as a semantic subject),
- *no subject identity* (NSI) without the above condition.

1. variant: V-V

Presupposition-SI *Jeżeli stwierdzamy, że X-ował(o), oznacza to, że musiał(o) wcześniej Y-ować.* ‘If one says that sth/sb X-ed, then it means that it/he earlier had to Y’

Jeśli nie X-ował(o), to też musiał wcześniej Y-ować lub Y-kuje do tej pory. ‘If sth/sb did not X, then it also means that it/he had to earlier Y or it/he has been Y-ed.’

Prawdziwość stwierdzenia, że wcześniej Y-ował(o) jest warunkiem koniecznym, aby sensownie stwierdzić, że X-ował(o). ‘The truth of the statement that someone or something Y-ed earlier is a necessary condition for saying that X.’

Preceding-SI: *Jeśli ktoś/coś X-ował(o), to wcześniej mógł Y-ować; istnieje przynajmniej jeszcze jeden czasownik Z taki, że może zastąpić czasownik Y w tym teście.* ‘If sb/sth X-ed, it means that he/it could earlier Y; there is at least one more verb Z such that it can replace Y in this test.’

Presupposition-NSI *Jeżeli stwierdzamy, że X-ował(o), oznacza to, że wcześniej ktoś inny lub coś innego musiał(o) Y-ować.* ‘If one says that sth/sb X-ed, then it means that sth/sb else had to earlier Y’

Jeśli nie X-ował(o), to ktoś inny lub coś innego też musiał(o) wcześniej Y-ować lub Y-kuje do tej pory. ‘If sth/sb did not X, then it also means that sth/sb else had to earlier Y or sth/sb else has been Y.’

Prawdziwość stwierdzenia, że wcześniej Y-ował(o) jest warunkiem koniecznym, aby sensownie stwierdzić, że X-ował(o). ‘The truth of the statement that someone or something Y-ed earlier is a necessary condition for saying that X.’

Preceding-NSI: *Jeśli ktoś/coś X-ował, to wcześniej ktoś/coś inny/innego mógł/mogło Y-ować; istnieje przynajmniej jeszcze jeden czasownik Z taki, że może zastąpić czasownik Y w tym teście.* ‘If sb/sth X-ed, it means that sb/sth else could earlier Y; there is at least one more verb Z such that it can replace Y in this test.’

2. variant: V-N

Presupposition-SI: *Jeżeli stwierdzamy, że X-ował(o), oznacza to, że musiał(o) wcześniej być Y-kiem.* ‘If one says that sth/sb X-ed, it means that it/he had to earlier be Y.’

Jeśli nie X-ował(o), to też musiał(o) wcześniej być Y-kiem lub jest Y-kiem do tej pory. ‘If sth/sb did not X, it also means that it/he had to earlier be Y or it/he has been Y.’

Prawdziwość stwierdzenia, że wcześniej był(o) Y-kiem jest warunkiem koniecznym, aby sensownie stwierdzić, że X-ował. ‘The truth of the statement that sth/sb was earlier Y is a necessary condition for saying meaningfully that it/he X-ed.’

Preceding-SI: *Jeśli ktoś lub coś X-ował(o), to wcześniej mógł/mogło być Y-kiem; istnieje przynajmniej jeszcze jeden rzeczownik Z taki, że może zastąpić rzeczownik Y w tym teście.*

‘If sb/sth *X*-ed, it means that he/it could earlier be *Y*; there is at least one more noun *Z* such that it can replace *Y* in this test.’

Presupposition-NSI: *Jeśli ktoś lub coś X-ował(o), to wcześniej musiał(o) być jakieś Y.*

‘If sb/sth *X*-ed, then there had to be earlier some *Y*’

Jeśli nie X-ował(o), to też musiał(o) wcześniej być jakieś Y lub jest jakieś Y do tej pory.

‘If sth/sb did not *X*, it also means that there had to be earlier some *Y* or it has been some *Y*.’

Prawdziwość stwierdzenia, że wcześniej był(o) jakieś Y jest warunkiem koniecznym, aby sensownie stwierdzić, że X-ował(o).

‘The truth of the statement that there was earlier some *Y* is a necessary condition for saying meaningfully that sb/sth *X*-ed.’

Preceding-NSI: *Jeśli ktoś lub coś X-ował(o), to wcześniej mógł/mogło być jakieś Y; istnieje przynajmniej jeszcze jeden rzeczownik Z taki, że może zastąpić rzeczownik Y w tym teście.*

‘If sb/sth *X*-ed, it means that there could be earlier some *Y*; there is at least one more noun *Z* such that it can replace *Y* in this test.’

3. variant: V-Adj

Presupposition-SI: *Jeśli ktoś lub coś X-ował(o), to musiał(o) wcześniej być Y-kowy/e, gdzie Y jest w stopniu równym.* ‘If sth/sb *X*-ed, then it/he had to earlier be *Y*, where *Y* is in positive or comparative grade (degree).’

Jeśli nie X-ował(o), to też musiał(o) wcześniej być Y-kowy/e lub jest Y-kowy/e do tej pory.

‘If sth/sb did not *X*, then it/he also had to earlier be *Y* or it/he has been *Y*.’

Prawdziwość stwierdzenia, że wcześniej był(o) Y-kowy/e jest warunkiem koniecznym, aby sensownie stwierdzić, że X-ował(o). ‘The truth of the statement that sth/sb was earlier *Y* is a necessary condition for saying meaningfully that it/he *X*-ed.’

Preceding-SI: *Jeśli ktoś lub coś X-ował(o), to wcześniej mógł/mogło być Y-kowy/e; istnieje przynajmniej jeszcze jeden przymiotnik Z taki, że może zastąpić przymiotnik Y w tym teście.*

‘If sb/sth *X*-ed, it means that he/it could earlier be *Y*; there is at least one more adjective *Z* such that it can replace *Y* in this test.’

Presupposition-NSI: *Jeśli ktoś lub coś X-ował(o), to wcześniej ktoś inny lub coś innego musiało być Y-owy/e, gdzie Y jest w stopniu równym.* ‘If sth/sb *X*-ed, then sth/sb else had to earlier be *Y*, where *Y* is in positive grade (degree).’

Jeśli ktoś lub coś nie X-ował(o), to ktoś inny lub coś innego też musiał(o) wcześniej być Y-kowy/e lub jest Y-kowy/e do tej pory. ‘If sth/sb did not *X*, then it/he also had to earlier be *Y* or it/he has been *Y*.’

Prawdziwość stwierdzenia, że wcześniej był(o) Y-kowy/e jest warunkiem koniecznym, aby sensownie stwierdzić, że X-ował(o). ‘The truth of the statement that sth/sb was earlier *Y* is a necessary condition for saying meaningfully that sth/sb *X*-ed.’

Preceding-NSI: *Jeśli ktoś lub coś X-ował(o), to wcześniej ktoś inny lub coś innego mógł/mogło być Y-owy/e; istnieje przynajmniej jeszcze jeden przymiotnik Z taki, że może zastąpić przymiotnik Y w tym teście.* ‘If sb/sth *X*-ed, it means that sb/sth else could earlier be *Y*; there is at least one more adjective *Z* such that it can replace *Y* in this test.’

4. variant: V-Adv

SI Presupposition/Preceding: *Jeśli ktoś lub coś X-ował(o), to wcześniej* ‘If sb/sth *X*-ed, it means that earlier’

- (a) **Presupposition** *musiało być Y-owo, gdzie Y jest w stopniu równym.* ‘it/he had to be *Y*, where *Y* is in the positive grade (degree).’

Preceding *mogło być Y-owo, gdzie Y jest w stopniu równym.* ‘it could be *Y*, where *Y* is in the positive grade (degree).’

- (b) **Presupposition** *musiało dziać się Y-owo, gdzie Y jest w stopniu równym.* ‘it had to Y happen, where Y is in the positive grade (degree).’

Preceding *mogło dziać się Y-owo, gdzie Y jest w stopniu równym.* ‘he/it could happen Y, where Y is in the positive grade (degree).’

- (c) **Presupposition** *ktoś lub coś musiał(o) robić coś Y-owo, gdzie Y jest w stopniu równym.* ‘he/it had to Y do, where Y is in the positive grade (degree).’

Preceding *ktoś lub coś mógł/mogło robić coś Y-owo, gdzie Y jest w stopniu równym.* ‘he/it could Y do, where Y is in the positive grade (degree).’

Jeśli ktoś lub coś nie X-ował(o), to też

- (a) **Presupposition** *musiało być wcześniej Y-owo lub jest Y-owo do tej pory.* ‘it/he had to be Y or it has Y been.’

Preceding *mogło być wcześniej Y-owo lub jest Y-owo do tej pory.* ‘it could be Y or it has been Y.’

- (b) **Presupposition** *musiało dziać się Y-owo lub dzieje się Y-owo do tej pory.* ‘it had to Y happen or it has Y happened.’

Preceding *mogło dziać się wcześniej Y-owo lub dzieje się Y-owo do tej pory.* ‘he/it could Y happen or it is possible that it has Y happened.’

- (c) **Presupposition** *ktoś lub coś musiał(o) robić coś Y-owo lub robi Y-owo do tej pory.* ‘he/it had to Y do or he/it has to have Y done.’

Preceding *mógł/mogło robić coś wcześniej Y-owo lub robi Y-owo do tej pory.* ‘he/it could Y do or it is possible that he/it has Y done.’

Presupposition *Prawdziwość stwierdzenia, że wcześniej był(o) Y-kowo/dział(o) się Y-kowo/ktoś lub coś robił(o) coś Y-owo jest warunkiem koniecznym, aby sensownie stwierdzić, że X-ował.* ‘The truth of the statement that it was Y / Y happened, sb/sth did Y is a necessary condition for saying meaningfully that sth/sb X-ed.’

Preceding *Istnieje przynajmniej jeszcze jeden przysłówek Z taki, że może zastąpić przysłówek Y w tym teście.* ‘There is at least one more adverb Z such that it can replace Y in this test.’

NSI Presupposition/Preceding: *Jeśli ktoś lub coś X-ował(o), to wcześniej w innych okolicznościach dotyczących kogoś lub czegoś innego* ‘If sb/sth X-ed, it means that earlier in some other circumstances involving somebody or something else’

- (a) **Presupposition** *musiało być Y-owo, gdzie Y jest w stopniu równym.* ‘It was Y, where Y in the positive grade.’

Preceding *mogło być Y-owo.* ‘it could be Y’

- (b) **Presupposition** *musiało się coś dziać Y-owo, gdzie Y jest w stopniu równym.* ‘It had to Y happen, where Y in the positive grade.’

Preceding *coś mogło dziać się Y-owo.* ‘it could Y happen’

- (c) **Presupposition** *ktoś lub coś musiał(o) robić coś Y-owo, gdzie Y jest w stopniu równym.* ‘sb/sth had to do Y sth, where Y in the positive grade.’

Preceding *ktoś lub coś mógł/mogło robić coś Y-owo.* ‘sb/sth could Y do’

Jeśli ktoś lub coś nie X-ował(o), to w innych okolicznościach dotyczących kogoś lub czegoś innego ‘If sb/sth did X, it means that earlier in some other circumstances involving somebody or something else’

- (a) **Presupposition** *też musiało być wcześniej Y-owo lub jest Y-owo do tej pory.*
 ‘it also had to be earlier Y or it has been Y till now.’
Preceding *też mogło być wcześniej Y-owo lub jest Y-owo do tej pory.*
 ‘it also could earlier be Y or it has been Y’
- (b) **Presupposition** *też musiało dziać się wcześniej Y-owo lub dzieje się Y-owo do tej pory.*
 ‘also it had to earlier Y happen or it has Y happened till now.’
Preceding *też mogło dziać się wcześniej Y-owo lub dzieje się Y-owo do tej pory.* ‘it also could earlier Y happen or it has Y happened till now.’
- (c) **Presupposition** *ktoś lub coś musiał(o) wcześniej też robić coś Y-owo lub robi Y-owo do tej pory.* ‘sb/sth had to Y do or it is necessary that he/it has Y done till now.’
Preceding *ktoś lub coś mógł/mogło wcześniej też robić coś Y-owo lub robi Y-owo do tej pory.* ‘sb/sth could earlier Y do or he/it has Y done till now.’

Presupposition *Prawdziwość stwierdzenia, że wcześniej był(o) Y-kowo/dział(o) się Y-kowo/ktoś lub coś robił(o) coś Y-owo jest warunkiem koniecznym, aby sensownie stwierdzić, że X-ował.*

‘The truth of the statement that it was Y / happened Y / sb/sth did Y is a necessary condition for saying meaningfully that sth/sb X-ed.’

Preceding *Istnieje przynajmniej jeszcze jeden przysłówek Z taki, że może zastąpić przysłówek Y w tym teście.* ‘There is at least one more adverb Z such that it can replace Y in this test.’

Inchoativity express an initial phase of a situation represented by the target element:

1. **variant V-V:**

X-ować to zaczynać/zacząć Y-ować. ‘ X_{inf} is to begin $_{impinf}$ Y_{inf} ’ (e.g. *ruszyć* ‘to move’ → *poruszać się* ‘’);

2. **variant V-N:**

Jeśli zaczynał/zaczął się Y, to znaczy, że ktoś/coś X-ował(o) (coś). ‘If Y began $_{impinf}$ /has begun, that means, that sb/sth. $X_{Verb-past}$ (sth)’ (e.g. *rozpłakać się* ‘to start cry’ → *placz* ‘cry’)

In plWordNet *cause* and *inchoativity* are distinguished as two different relations, in a way similar to Levin and Hovav (1995) and Haspelmath (1993). However, this distinction is not so clear in other works, e.g. Koontz-Garboden (2009) or Olszewska (1986) and Malicka-Kleparska (2013) in the case of Polish.

Both relations — *cause* and *inchoativity* — express temporal sequence of situations (represented by the linked verbs) such that the later is the result of the former. However, in the case of *cause* there are two distinct subjects: the first one causes a new situation involving the second one, e.g. *karmić* ‘to feed’ → *jeść* ‘to eat’. In contrast, in *inchoativity*, the former situation describes an initial phase of the following situation which is its continuation and includes all important aspects of the former, e.g. *rozmarzyć się* ‘to start dreaming’ → *marzyć* ‘to dream’ — both subjects are identical.

Inchoativity is often signalled by derivational associations, but not always, and it has been expanded to the level of synsets, beyond the derivational signal, due to its clear semantic content, see Maziarz et al. (2011), i.e. also in plWordNet it links LUs that are not derivationally associated.

Cause and **processuality** both express a change from an earlier situation represented by the source *X* to a new situation represented by the target *Y*, which results from or is caused by *X*. *Cause* emphasises that the resulting situation is caused/brought about the next situation of *Y*,

while *processuality* informs that the change happened inside the situation represented by *X*, which is gaining some new features and transformed.

Cause only links verbs of the same aspect. Both relations can link a verb with a noun (non-gerunds), an adjective or an adverb. *Processuality* cannot link a verb to a verb, that can be partially explained by the condition of having the same subject. Both relations are often signalled by derivational associations, but both were expanded beyond derivationally linked LUs up to the level of synsets and sharing among LUs.

1. **variant: V-V**

Cause *Jeżeli ktoś lub coś X-ował(o), to (s)powodował(o), że ktoś lub coś Y-ował(o).* ‘If sb/sth X-ed, then it caused that sb/sth Y-ed.’

2. **variant: V-N**

Cause *Jeżeli ktoś lub coś X-ował(o), to (s)powodował(o), że ktoś lub coś sta(wa)ł(o) się Y-em.* ‘If sb/sth X-ed, then it caused that sb/sth has been becoming Y’
OR *X-ować to (s)powodować Y.* ‘to X is to cause Y.’

Processuality *X-ować to sta(wa)ć się Y-em.* ‘to X is to become Y’

3. **variant: V-Adj**

Cause *Jeżeli ktoś lub coś X-ował(o), to (s)powodował(o), że ktoś lub coś sta(wa)ł(o) się Y-owy(e), gdzie Y jest w stopniu równym lub wyższym.* ‘If sb/sth X-ed, then it caused that sb/sth Y, where Y is in the positive or comparative grade (degree).’

Processuality *X-ować to sta(wa)ć się Y-owym, gdzie Y jest w stopniu równym lub wyższym.* ‘To X is to become Y, where Yadj is in the positive or comparative grade.’

4. **variant: V-Adv**

Cause *Jeżeli ktoś lub coś X-ował(o), to (s)powodował(o), że* ‘If sb/sth X-ed, then it caused that’

Processuality *X-ować means* ‘To X is’

- (a) **Cause** *było Y-owo gdzie Y jest w stopniu równym lub wyższym.* ‘it happened Y, where Y is in the positive or comparative grade.’

Processuality –

- (b) **Cause** *(z)robiło się Y-owo, gdzie Y jest w stopniu równym lub wyższym.* ‘it became Y, where Y is in the positive or comparative grade.’

Processuality *(z)robić coś Y-owo, gdzie Y jest w stopniu równym lub wyższym.* ‘it did Y something, where Y is in the positive or comparative grade.’

- (c) **Cause** *ktoś lub coś (z)robił(o) coś Y-owo, gdzie Y jest w stopniu równym lub wyższym.* ‘sb/sth did sth Y, where Y is in the positive or comparative grade.’

Processuality *(z)robić się Y-owo, gdzie Y jest w stopniu równym lub wyższym.* ‘it became Y itself/by itself, where Y is in the positive or comparative grade.’

Anti-causative and auto-causative verbs that render similar semantic differences are distinguished in linguistic works for English (e.g. Levin & Hovav, 1995; Koontz-Garboden, 2009; Horvath & Siloni, 2011). Anti-causative verbs express a change that happened in the object, but caused by an external agent (e.g. *zatonąć* ‘to sink’), while auto-causatives are verbs that represent such a change in which object and subject are identical (e.g. *zmienić się* ‘to change’). In Polish such situations are often indistinguishable, because the information about an external agent must be overtly defined. For instance, a ship may sink because it has been sunk by pirates or because a hole appeared in her side. Thus, a synonym for *zatonąć* ‘to sink’ is a reflexive verb *zatopić się* ‘≈to sink itself’. Taking this into account, similar changes in situations are described in plWordNet by means of *processuality* relation:

(e.g. *zmienić się* ‘to change itself’ → *inny* ‘different’)

and *cause*

(e.g. *zatopić* ‘to sink something’ → *zatonąć/zatopić się* ‘to sink/ $\approx$ to sink itself’)

on the basis of the semantic substitution test, without referring to the valency of these verbs.

Classes of intentional and non-intentional verbs (Laskowski, 1998) were distinguished in pl-WordNet 2.0 (Maziarz et al., 2011). However, problems with the consistent recognition of the intentionality of the subject’s actions caused that this distinction was abandoned in Dziob et al. (2017); Dziob and Piasecki (2018).

As mentioned, the main difference in the verb hierarchy between plWordNet and Princeton WordNet is in different hierarchical relations, respectively: hyponymy vs troponymy. *Troponymy* has been defined Fellbaum (1998) as a subtype of *entailment*:

“the relation between two verbs V1 and V2 that holds when the sentence Someone V1 logically entails the sentence Someone V2”

where V1 and V2 are verbs representing situations. Troponymy restricts this association to verbs representing temporarily co-existing situations.

The hyponymy substitution test of plWordNet resembles the test for troponymy in Princeton WordNet — both require that the situation *X* is a sub-kind of the situation *Y*, but differ in a specific way in which the situation represented by *X* happens or is performed. The troponymy test adds “in some particular manner” that is covered in different aspects by several other relations of plWordNet. We can find many more such similarities in both wordnets. The comparison of relations corresponding to entailment in Princeton WordNet Fellbaum (1998) and plWordNet (Dziob & Piasecki, 2018) is presented in Table 2.

Table 2: Relationships between Situations

PWN entailment	+Temporal inclusion		-Temporal inclusion	
	co-extensiveness (troponymy)	proper inclusion	backward pressupposition	Cause
plWN	hyponymy, meronymy	meronymy	presupposition, preceding	Cause, inchoativity, processivity

The two sub-kinds of entailment are distinguished in Princeton WordNet by the criterion of temporal co-existence of the two situations represented by the linked verbs. In plWordNet, verbs representing co-existing situations are linked by *hyponymy* and *meronymy*. In the latter case, there is no requirements for subtype-like similarity.

The rich system of verb relations, especially more fine-grained forms of entailment in plWordNet allows for more elaborated description of temporal relations between situations represented by verbs. In the case of referring to situations previously occurring *presupposition* and *preceding* can be used. In the case of situations from the future, somehow resulting from the contemporary situation of *X*, plWordNet enables to use three synset relations: *cause*, *processuality* and *inchoativity*.

Processuality and *cause* have a lot in common — both relations inform that a situation represented by the target verb *Y* appears as a result of the source *X*. However, the former is limited to cases in which there is the same subject of both situations, while *cause* signals that subjects of both situations are different.

3.3 Other verb relations in plWordNet

Multiplicativity is a relation which describes repetition of some state or activity, and performance an activity by many agents or on many objects. It has two subtypes: 1) **distributivity** restricted to perfective distributive verbs, e.g. *wytluc* ‘to break all things’ → *stluc* ‘to break_{perf}’

and 2) **iterativity** for imperfective iterative verbs, e.g. *czytywać* ‘to read_{imp} many times’ → *czytać* ‘to read_{imp}’.

State is restricted to static verbs and describes an association between a verb *X* with a noun, an adjective or an adverb that represents a state in which the subject of *X* is, e.g. *zielenieć* ‘to be green’ → *zielony* ‘green’.

Four new relations were introduced in plWordNet 3.1 (Dziob et al., 2017). Three of them are related to the verb predicate-argument structure, but only with respect to its semantic properties:

1. **subject** (e.g. *rżeć* ‘to neigh’ → *koniowate* ‘equine’),
2. **object** (e.g. *wzuwać* ‘to put on shoes’ → *but* ‘a shoe’),
3. **circumstance** linking a verb with a noun, which is an element of the prepositional phrase that can function as an adjunct to the verb (e.g. *dobijać do brzegu* ‘to reach a shore’ → *brzeg* ‘a shore’).

The fourth relation, namely **manner**, is motivated by a component of the substitution test for hyponymy (and a similar test for troponymy in Princeton WordNet). This component represents a manner in which the given situation proceeds (or an activity is performed). It influences the sense of a given verb in a significant way and helps to distinguish between verb senses, e.g. *podsmążyć* ‘to fry a little’ → *trochę* ‘a little’.

Besides synset relations, plWordNet includes many verb lexical relations.

Pure aspectuality and **secondary aspectuality** link verbs of different aspects, but derivationally associated. The first one links pure aspectual verb pairs, i.e. pairs in which the change of the aspect exhausts the meaning difference³, e.g.

czytać_{imp} ‘to read_{imp}’ ↔ *przeczytać_{perf}* ‘to read_{perf}’.

The *secondary aspectuality* relation provides information about the meaning change going beyond the aspect difference, e.g.

trzymać ‘to hold_{imp}’ ↔ *potrzymać* ‘to hold_{perf} a little’.

Verbs linked by *secondary aspectuality* often belong to synsets linked by some other relation, e.g.

rozkochać_{perf} ‘to cause somebody fall in love’ -cause→ *kochać* ‘to love_{imp}’.

Proper antonymy and **complementary antonymy** both signal an opposition resulting from antonymic association and both link verbs of the same aspect. However, the first one links LUs *X* and *Y*, such that both *X* and *Y* cannot happen at the same time with the same subject, but if *X* does not take place, then it is not necessary that *Y* takes place e.g.

zwiększać ‘to increase_{imp}’ ↔ *zmniejszać* ‘to reduce_{imp}’.

Complementary antonymy excludes any third possibility, if *X* does not take place, then *Y* must happen — there is no other option (see also Sec. 4) e.g. *zatrzymywać* ‘to keep_{imp}’ ↔ *oddawać* ‘to give_{imp} back’.

Converseness is similar to antonymy (it is often considered to be a kind of antonymy, e.g. see Fellbaum (1998)) links verbs of the same aspect, and also expresses a kind of semantic opposition. However, it links verb LUs describing the same situation, but from two different, opposite perspectives (e.g. agent and patient, see also Sec. 4), e.g.

sprzedać ‘to sell_{perf}’ ↔ *kupić* ‘to buy_{perf}’

In addition to the verb lexical relations discussed above, plWordNet includes other lexico-semantic relations motivated derivationally and defined on the level of LUs: **role inclusion** and **derivationality**. The former links verbs derived from nouns with their noun derivational bases. It is further subdivided into seven subtypes that express different semantic associations between a derivative and its basis (Maziarz et al., 2011; Dziob et al., 2017): *subject*, *instrument*, *result*, *location*, *object*, *time* and *indefinite subtype* (for less clearly identified roles).

³ In Polish, the verb aspect is not only a morphological or grammatical category, because verbs of different aspects participate in different lexico-semantic relations, see the elaborate discussion in Dziob et al. (2017).

Derivationality represents semantically less regular or frequent links signalled by a derivational association. It very often links LUs that belong to synsets participating in some other relation, e.g. *wznioślić* ‘to get exalted’ → *wzniosły* ‘exalted’, where the synsets including these LUs are linked by the *cause* relation.

Statistic data concerning verb relations in plWordNet 4.0 emo are presented in Table 3. We can notice that the relations of dynamic verbs, namely: *presupposition*, *preceding*, *cause* and *processuality* are relatively frequent. Thus, they are important from the point of view of language description.

Relation	Example	Statistics
hyponymy	<i>iść</i> ‘to go’ → <i>poruszać się</i> ‘to move’	34 362
inter-register synonymy	<i>gadać</i> ‘to talk’ → <i>pieprzyć</i> ‘to speak nonsense’	2 623
state	<i>ograniczać</i> ‘to border’ → <i>granica</i> ‘a border’	198
processuality	<i>starzeć się</i> ‘to be becoming old’ → <i>stary</i> ‘old’	1 269
cause	<i>bielić</i> ‘to whiten’ → <i>biały</i> ‘white’	3 964
presupposition	<i>umrzeć</i> ‘to have died’ ← <i>żywy</i> ‘alive’	312
preceding	<i>siadać</i> ‘to sit’ ← <i>leżeć</i> ‘to lie’	763
inchoativity	<i>rozpalić się</i> ‘to start burning’ → <i>płonąć</i> ‘to burn’	550
iterativity	<i>siadywać</i> ‘to sit down from time to time’ → <i>siadać</i> ‘to sit down’	153
distributivity	<i>pokraść</i> ‘to steal much’ → <i>ukraść</i> ‘to steal’	979
meronymy	<i>przełykać</i> ‘to swallow’ → <i>jeść</i> ‘to eat’	1 391
holonymy	<i>jeść</i> ‘to eat’ → <i>przełykać</i> ‘to swallow’	3 526
manner	<i>otoczyć</i> ‘to surround’ → <i>wokół</i> ‘around’	887
circumstance	<i>werbować</i> ‘to recruit’ → <i>wojsko</i> ‘army’	108
subject	<i>żyć</i> ‘to live’ → <i>istota</i> ‘living being’	263
object	<i>palić</i> ‘to smoke’ → <i>papieros</i> ‘cigarette’	256
aspect. — pure	<i>pisać</i> ‘to write _{perf} ’ ↔ <i>napisać</i> ‘to write _{imp} ’	28 171
aspect. — secondary	<i>pisać</i> ‘to write _{perf} ’ ↔ <i>popisać</i> ‘to write _{imp} a little’	8 785
ant. — compl.	<i>odzywać się</i> ‘to speak’ ↔ <i>milczeć</i> ‘to keep silent’	32
ant. — proper	<i>biednieć</i> ‘to become poor’ ↔ <i>bogacić się</i> ‘to become rich’	2 948
converseness	<i>pożyczać</i> ‘to lend’ ↔ <i>pożyczać</i> ‘to borrow’	88
role inclusion	<i>solić</i> ‘to salt’ → <i>sól</i> ‘salt’	1 916
derivationality	<i>zagęszczać</i> ‘to make thicker’ → <i>gęsty</i> ‘thick’	420

Table 3: Statistics of verb relations in plWordNet 4.0 emo

4 Co-occurrence of relations

As it was mentioned in Sec. 2, plWordNet editors check substitution tests while making decisions about linking LUs or synsets by relation links. Their work is supported by a network based system for wordnet editing called *WordnetLoom* (Naskręt et al., 2018). The system automatically presents

substitution tests for any action aimed at adding a new relation link. This facility is meant to increase the consistency of annotators' decisions and prevent the most frequent errors made by lexicographers. In addition, the systems automatically checks several other basic constraints on relations like compatibility of PoS of elements to be connected, e.g. *role inclusion* links a noun with a verb, or aspect (every LU has an aspect value assigned: perfect, imperfect, bi-aspectual), e.g. *pure aspectuality* can be only defined for verbs of different aspect and *antonymy* only for verbs of the same aspect. We will try to show below that similar tests can be performed on the semantic level taking into account *co-occurrence of relations*.

We are now going to present substitution tests for relations that will be discussed in the following subsections.

Antonymy links LUs of opposite meanings and is divided into the two subtypes: *complementary antonymy* (CA) and *proper antonymy* (PA), see Sec. 3.3. Both subtypes link verbs of the same aspect and are defined also for LUs of other PoS (i.e. nouns, adjectives and adverbs) (Maziarz, Piasecki, & Szpakowicz, 2012):

1. variant: V-V

- *Ktoś lub coś X-ował(o)?* ‘– Did sb/sth X-ed?’
- *Wręcz przeciwnie, Y-ował(o)! – Just the contrary, he/it Y-ed!*

CA: *Jeżeli X-ował(o), to nie Y-ował(o) i jeżeli nie X-ował(o), to Y-ował(o).* ‘If sb/sth X-ed, then he/it did not Y, and if sb/sth did not X, then he/it Y-ed’

PA: *Jeżeli X-ował(o), to nie Y-ował(o), ale jeśli nie X-ował(o), to niekoniecznie Y-ował(o).* ‘If sb/sth X-ed, then he/it did not Y, but if sb/sth did not X, then it is not necessary that he/it Y-ed’

2. variant: N-N

X i Y to kohiponimy, albo też komeronimy lub hiponimy antonimów (konwersów). ‘X and Y are co-hyponyms or co-meronyms, or they are both hyponyms of some semantically opposite LUs: antonyms or converses’

- *To jest X?* ‘– Is this an X?’

CA: – *Nie, wręcz przeciwnie, to musi być Y!* ‘– No, just the opposite, this must be Y!’
Jeśli ktoś/coś nie jest X-em, to musi być Y-em. ‘If sb/sth is not X, then it must be Y’
Jeśli ktoś/coś nie jest Y-em, to musi być X-em. ‘If sb/sth is not Y, then it must be X.’

PA: – *Nie, wręcz przeciwnie, to jest Y!* ‘– No, just the opposite, this is Y!’
Jeśli ktoś/coś jest X-em, to nie może być Y-em. ‘If sb/sth is X, then it cannot be Y.’
Jeśli ktoś/coś jest Y-em, to nie może być X-em. ‘If sb/sth is Y, he/it cannot be X’

3. variant: Adj-Adj

Ktoś/coś jest X-owy(e). ‘Sb/sth is X.’

- *Wręcz przeciwnie! Jest Y-owy(e).* ‘– Just the opposite! He/it is Y.’
- Jeżeli ktoś/coś jest X-owy(e), to nie jest Y-owy(e).* ‘If sb/sth is X, then it is not Y.’

CA: *Jeżeli ktoś/coś nie jest X-owy(e), to jest Y-owy(e).* ‘If sb/sth is not X, then it is Y.’

PA: *Jeżeli ktoś/coś nie jest X-owy(e), to niekoniecznie jest Y-owy(e).* ‘If sb/sth is not X, then it is not necessary that it is Y.’

4. variant: Adv-Adv

- (a) – *Ktoś/coś robi coś X-owo?* ‘– Does sb/sth do sth X?’
- *Wręcz przeciwnie: robi to Y-owo.* ‘– Just the opposite: he/it does it Y.’
- Jeżeli ktoś/coś robi coś X-owo, to nie robi tego Y-owo.* ‘If sb/sth does sth X, then he/it does not do this Y’

- CA:** *Jeżeli ktoś/coś nie robi czegoś X-owo, to robi to Y-owo.* ‘If sb/sth does not do sth X, then he/it does this Y.’
- PA:** *Jeżeli ktoś/coś nie robi czegoś X-owo, to niekoniecznie robi to Y-owo.* ‘If sb/sth does not do sth X, then it is not necessary that he/it does this Y.’
- (b) – *Coś dzieje się X-owo?* ‘– Does something happen X?’
 – *Wręcz przeciwnie: dzieje się Y-owo.* ‘– Just the opposite: this happens Y.’
Jeżeli coś dzieje się X-owo, to nie dzieje się Y-owo. ‘If sth happens X, then it does not happen Y.’
- CA:** *Jeżeli coś nie dzieje się X-owo, to dzieje się Y-owo.* ‘If sth does not happen X, then it does not happen Y.’
- PA:** *Jeżeli coś nie dzieje się X-owo, to niekoniecznie dzieje się Y-owo.* ‘If sth does not happen X, then it is not necessary that it happens Y.’
- (c) – *Ktoś/coś jest X-owo jakiś?* ‘– Is sb/sth somehow X?’
 – *Wręcz przeciwnie: jest Y-owo jakiś.* ‘– Just the opposite: he/it is somehow Y.’
Jeżeli ktoś/coś jest X-owo jakiś, to nie jest Y-owo jakiś. ‘If sb/sth is somehow X, then it is not somehow Y.’
- CA:** *Jeżeli ktoś/coś nie jest X-owo jakiś, to jest Y-owo jakiś.* ‘If sb/sth is not somehow X, then he/it is somehow Y.’
- PA:** *Jeżeli ktoś/coś nie jest X-owo jakiś, to niekoniecznie jest Y-owo jakiś.* ‘If sb/sth is not somehow X, then it is not necessary that he/it is somehow Y.’
- (d) – *Jest X-owo?* ‘– Is it X?’
 – *Wręcz przeciwnie: jest Y-owo.* ‘– Just the opposite: it is Y.’
Jeżeli jest X-owo, to nie jest Y-owo. ‘If it is X, then it is not Y.’
- CA:** *Jeżeli nie jest X-owo, to jest Y-owo.* ‘If it is not X, then it is Y.’
- PA:** *Jeżeli nie jest X-owo, to niekoniecznie jest Y-owo.* ‘If it is not X, then it is not necessary that it is Y.’

Converseness, similarly to antonymy, expresses a kind of semantic opposition and is defined for verbs of the same aspect (see Sec. 3.3), but also for LUs of all other PoS (Maziarz, Piasecki, & Szpakowicz, 2012).

1. **variant: V-V**

Jeśli A X-ował(o) [Prep] B, to B Y-ował(o) [prep] A. ‘If A X [Prep] B, then B Y [Prep] A.’

2. **variant: N-N**

X i Y to kohiponimy, albo też komeronimy lub hiponimy antonimów (konwersów). ‘X and Y are co-hyponyms or co-meronyms, or they are both hyponyms of some semantically opposite LUs: antonyms or converses’
Jeśli A jest dla B X-em, to B jest dla A Y-em. ‘If A is a X for B, that B is a Y for A.’

3. **variant: Adj-Adj**

Jeżeli X i Y to przymiotniki w stopniu wyższym, to ich podstawy słowotwórcze wchodzą w relację antonimii. ‘If X and Y are adjectives in the comparative grade, then their derivational bases are linked by antonymy.’
Jeżeli A jest X-owe względem B, to B jest Y-owe względem A. ‘If A is X in relation to B, then B is Y in relation to A.’

4. **variant: Adv-Adv** *X i Y to przysłówki w stopniu wyższym* ‘X and Y are adverbs in the comparative grade.’

- (a) *Jeżeli A robi coś X-owiej niż B, to B robi to Y-owiej niż a.* ‘If A does sth X-er than B, then B does this Y-er than A.’

- (b) *Jeżeli A dzieje się X-owiej niż B, to B dzieje się Y-owiej niż A.* ‘If A happens X-er than B, then B happens Y-er than A.’
- (c) *Jeżeli A jest X-owiej jakiegoś niż B, to B jest Y-owiej jakiegoś niż A.* ‘If A is somehow X-er than B, then B is somehow Y-er than A.’
- (d) *Jeżeli w pierwszej sytuacji jest X-owiej niż w drugiej, to w drugiej jest Y-owiej niż w pierwszej.* ‘If it is X-er in the first situation than in the second, than in the second situation it is Y-er than in the first.’

One of the characteristic features of plWordNet is its rich set of lexico-semantic relations including a large number of relations motivated by derivational associations⁴ of Polish (cf Maziarz, Piasecki, & Szpakowicz, 2012; Piasecki, Szpakowicz, & Broda, 2010). Derivationally signalled relations are defined not only for verbs, but also for other PoS. For the needs of the discussion of the co-occurrences of verb relations in this section, it is worth to take a closer look into three non-verb relations, namely: *characteristic*, *feature bearer* and its reverse *state*.

Characteristic is a relation linking *qualitative adjectives* derived from nouns⁵ with their derivational bases. Such adjectives are mostly formed by the suffixes: *-asty*, *-aty*, *-isty*, *-ny*, and can be paraphrased by the expressions *pełen ...* ‘full of ...’, *ma charakterystyczne ...* ‘has characteristic ...’, *ma ...* ‘has ...’ (Maziarz, Szpakowicz, & Piasecki, 2012).

1. **Adj-N** *X jest przymiotnikiem jakościowym derywowanym od rzeczownika N* ‘X is an qualitative adjective derived from the noun N’
X nie wchodzi w relację podobieństwa z N ‘X is not linked with N by the *similarity* relation’
Jeśli ktoś/coś jest X, to jest [pełen/pełne N] / [ma charakterystyczne N] / [ma N] ‘If sb/sth is X, then he/is is [full of N] / [has characteristic N] / [has N]’

Feature bearer is a relation linking nouns derived from adjectives with their derivational bases (Maziarz, Piasecki, & Szpakowicz, 2012). It is used for connecting nouns that name somebody or something being in some state or possessing some characteristic features with adjectives that name this state or feature. Nouns that name states or bearers of features have usually broad denotation and can be used to name any feature or person that is characterised by the given state or feature e.g. *brzydota* ‘sb/sth who/what is ugly’ (Maziarz, Szpakowicz, & Piasecki, 2012).

State relation is the obligatory reverse to *feature bearer* in plWordNet. Initially, *feature bearer* was meant to be used for defining the names of feature bearers in a broad sense, i.e. such LUs for which the core of their definition is that someone or something has some intrinsic feature or is characterised by some intrinsic state (e.g. *głupota* ‘a stupidity’ representing anything that is *głupi* ‘stupid’ or *ślepotą* ‘a blindness’, representing anyone or anything that is not able to see, i.e. is *ślepy(-e)* ‘blind’). However, there is a set of words in Polish used for naming entities on the basis of some characteristic feature, but which do not conform to the above rule as they do not describe bearers of this feature in a more general way. For instance, *pstrokaczka* ‘a freckled duck’ — is a bird that was named in this way as it is *pstry* ‘guady’, but it is only one particular species, not a subclass of entities in a more general way.

1. N-Adj

- X to rzeczownik, Y to przymiotnik* ‘X is a noun, Y is an adjective’
- X jest kimś/czymś, do kogo/czego odnosi się stan wyrażony przez Y.* ‘X is sb/sth for which the state expressed by Y is relevant to’
- X jest kimś/czymś, kto/co jest Y.* ‘X is sb/sth, who/which is Y’

⁴ Many of them have been expanded to synsets relations i.e. beyond derivational connections and linking not only derivatives and their bases.

⁵ *Qualitative adjectives* describe properties of entities, tell about their features, in contrast to *material adjectives* that describe materials and substances from which entities are built, and also to *relational adjectives* (or transpositional adjectives) which express a relation between entities.

plWordNet is a lexico-semantic network in which every element (LUs and synsets) is linked to a vast majority of other elements:⁶ with some directly (by different relations), with others indirectly by chains of relation links, i.e. paths in the wordnet graph. Between many elements one can find more than one path linking them. This shows the richness of such a relational semantic dictionary as the wordnet is. In the rest of the section we will investigate examples of interconnections and co-occurrences of different relations from the linguistic point of view.

4.1 Presupposition

We can observe co-occurrences of *presupposition* (of both subtypes) and *antonymy* (to both subtypes) links. *Presupposition* describes a relation to the representation of an earlier situation or its element, in the latter case represented by an adjective. Thus, when *presupposition* co-occurs with *antonymy* of the members of the target synset, then the source of the *presupposition* link is also connected by:

1. *processuality* to the synsets including these antonyms in the case of the *subject identity* subtype,
2. and *cause* to such synsets in the case of the *no subject identity* subtype.

Example 1. *{kwaśny 2, kwasowy 1}* ‘acid’ ← presupposition SI– *{odkwaszać się 1}* ‘≈ to get rid of acid by itself’

kwasowy 1 ← proper antonymy → *zasadowy 1* ‘alkaline’

kwasowy 1 ← proper antonymy → *obojętny 6* ‘neutral’

{odkwaszać się 1} –processuality→ *{zasadowy 1, alkaliczny 1}*

{odkwaszać się 1} –processuality→ *{obojętny 6, neutralny 2}*

Example 2. *{fizyczny 5, materialny 1}* ‘physical, material’ ←presupposition NSI–*{dematerializować 1}* ‘to dematerialise’

materialny 1 ←complementary antonymy→ *niematerialny 1* ‘nonmaterial’

{dematerializować 1} –cause→ *{niematerialny 1, pozamaterialny 2, niefizyczny 1}* ‘nonmaterial, nonphysical’

Example 3. *{żyć 1}* ‘to live_{imp}’ ←presupposition NSI– *{uśmiercać 1}* ‘to kill_{imp}’

żyć 1 ←proper antonymy→ *umierać 1* ‘to die_{imp}’

{uśmiercać 1} –cause→ *{umierać 1, odchodzić 1, gasnąć 2, zasypiać 6, żegnać się ze światem 1, usypiać 9}* ‘to die_{imp}, to pass_{imp} away’

In spite of plenty of evidence found in plWordNet that support these relation co-occurrence patterns, we can also find cases in which these relations fail to meet each other. So, these patterns can be used only as a suggestion for a lexicographer to look for potentially missing links, not as a strict rule.

Example 4. (negative) *{dojrzały 5 ‘mature’}* ← presupposition SI– *{zarodnikować 1 ‘to produce spores’}*

dojrzały 5 ‘mature’ ←contemporary antonymy→ *niedojrzały 5* ‘immature’

4.2 Preceding

Preceding, which is similar to *presupposition* in many respects, occurs in similar coincidence patterns with other relations.

⁶In plWordNet nouns do not form a single rooted graph, as the description of hypernymy stops on the linguistic boundaries of this relation, see e.g. Piasecki et al. (2009). There are about 100 top synsets for nouns, but they are all linked to the external SUMO hierarchy Pease (2011).

Preceding with *no subject identity* and both subtypes of *antonymy* (i.e. *proper* and *complementary*) co-occur in such a way that *cause* closes the circle going to the verb being the source of *preceding*.

Example 5. {*różnica 1*, *rozbieżność 1*, *rozdźwięk 1*, *dywergencja 1*, *dyferencja 1*} ‘a difference, a divergence’ ←preceding without SI– {*uzgadniać 2*} ‘to negotiate’

różnica 1 ←proper antonymy→ *podobieństwo 1* ‘similarity’

{*uzgadniać 2*} –cause→ {*podobieństwo 1*}

Example 6. {*realnie 4*, *prawdziwie 4*} ‘realistically, truly’ ←preceding NSI– {*odrealniać 1*} ‘to make unreal’

prawdziwie 4 ‘truly’ ←complementary antonymy→ *nieprawdziwie 2* ‘untruly’

{*odrealniać 1*} –cause→ {*nieprawdziwie 2*} ‘untruly’

Example 7. {*funkcjonować 1*, *działać 3*, *chodzić 4*, *być na chodzie 1*, *iść 9*, *pracować 3*} ‘to function, to work’ ←preceding SI– {*zepsuć*, *popsuć 2*} ‘to break’

działać 3 ←proper antonymy→ *stać 2* ‘to stop’

{*zepsuć 3*, *popsuć 2*} –cause→ {*stać 2*}

As in the previous case, the above pattern is not always accurate. Our analysis has shown that these co-occurrence tendencies can be weakened especially in the case of nouns. It seems that antonymy between nouns is more influenced by the cultural background, than in the case of antonymy for other PoS, e.g.:

Example 8. (negative) {*niepowodzenie 1*, *klapa 2*, *fiasko 1*, *klęska 3*, *katastrofa 1*, *koniec 5*, *obsuwa 1*} ‘a failure, a disaster, a catastrophe’ ←preceding NSI– {*stawiać na nogi 2*} ‘to put sb back on his feet’

katastrofa 1 ‘a catastrophe’ ←proper antonymy→ *sukces 1* ‘a success’

where, we cannot say that *stawiać na nogi 2* means ‘to cause’ *sukces 1*.

An analogical co-incidence happens in the case of *preceding* with *subject identity*, but here *cause* is exchanged with *processuality*. The subjects stay the same, so the change expressed by *preceding* must undergo inside them. That results in a process of ‘becoming’ which is represented by *processuality*. This pattern is not applicable to two verbs linked by *preceding*, because *processuality* is not defined for verb synset pairs.

Example 9. {*mokry 1*} ‘wet’ ←preceding SI– {*schnąć 1*, *suszyć się 1*} ‘to dry’

mokry 1 ←proper antonymy→ *suchy 1* ‘dry’

{*schnąć 1*, *suszyć się 1*} –processuality→ {*suchy 1*}

The above combination of synset relations is illustrated in Figure 1, which presents a fragment of a screen-shot made in WordnetLoom. The picture does not include the lexical relation of *proper antonymy*.

Example 10. {*nierealnie 1*, *nierzeczywiście 3*, *irrealnie 2*} ‘unrealistically’ ←preceding SI– {*urealniać się 1*} ‘to become realistic, possible’

nierealnie 1 ←complementary antonymy→ *realnie 3* ‘realistically’

{*urealniać się 1*} –processuality→ {*realnie 3*}

In the case of *preceding* co-occurring with *converseness* both LUs linked by it to the source synset of *preceding* belong to the synsets linked by *preceding* (where both subtypes are possible).

Example 11. {*mąż 2*, *małżonek 1*} ‘a husband’ ←preceding SI– {*rozwieść się 1*, *rozejść się 8*} ‘to get divorced’

mąż 2 ←converseness→ *żona 1* ‘a wife’

{*żona 1*, *małżonka 1*, *współmałżonka 1*} ←preceding SI– {*rozwieść się 1*, *rozejść się 8*}

Example 12. {*pożyczać 2*} ‘to borrow’ ←preceding SI– {*odnosić 4*} ‘to bring back’

pożyczać 2 ←converseness→ *pożyczać 1* ‘to lend’

{*pożyczać 1*} ←preceding NSI– {*odnosić 4*}

Figure 1: Example of a pattern of synset relations for *preceding* and *processuality*, where “kauz”=*cause*, “proc”=*processuality*, and “uprz+t”=*preceding SI* (a screen-shot from Wordnet-Loom). Some synset relations are hidden. Lexical relation of *mokry 1* ←proper antonymy→ *suchy 1* ‘dry’ is not presented in this perspective.

4.3 Cause

Cause tells us about bringing about some other situations by the former one. It is very close to *processuality* with respect to the described logical construction of a cause-consequence chain. We can observe that both relations co-occur quite often among synset relations in such a way, that a verb LU which is the source of the *cause* link, and a verb with the *processuality* link, which is its target, should have the links of, respectively: *cause* and *processuality* to the same adjective or adverb. In the case of nouns, we cannot observe a similar co-occurrence of relations. For instance, in the case of *gniewać* ‘to anger’ it is linked by *cause* to *złość* ‘anger’, but a non-existing *processuality* link would have to connect *gniewać się* ‘to become angry_{reflex}. (by himself)’ to **stawać się złością* ‘anger’, that does not take place.

Example 13. {zabielać 1} ‘to whiten’ –cause→ {zabielać się 1} ‘to whiten oneself’
 {zabielać 1} –cause→ {biały 1} ‘white’
 {zabielać się 1} –processuality→ {biały 1}

Cause also often co-occurs with both subtypes of antonymy. A target synset of the *cause* link: $X\text{--}cause\rightarrow Y$ often includes also a LU $z \in Y$ connected by *complementary antonymy* to a LU q representing a situation which is earlier than the situation represented by the source of the cause link, i.e. q is earlier than X . Because *complementary antonymy* introduces a necessary condition, we should add a *presupposition* link between the following and the earlier situation, as *presupposition* also excludes alternatives, i.e. $q \in Q \leftarrow presupposition\text{--} X$, where Q is the synset of q .

Example 14. {wyswobadzać 2, wyswabdzać 2, wyzwalać 1, uwalniać 4, oswobadzać 3, oswabadzać 2} ‘to free [sb or sth]’ –cause→ {niepodległy 1, **niezawisły 1**} ‘independent’
niezawisły 1 ‘independent’ ←complementary antonymy→ **zawisły 1** ‘dependent’
 {podległy 1, **zawisły 1**} ←presupposition- {wyswobadzać 2, wyswabdzać 2, wyzwalać 1, uwalniać 4, oswobadzać 3, oswabadzać 2}

The relations of *cause* and *proper antonymy* also express a similar pattern of co-occurrence. If the target of *cause*: $X\text{--}cause\rightarrow Y$ includes an LU $z \in Y$ linked by *proper antonymy* to q , then q represents a situation which is earlier than X . However, in the case of *proper antonymy* there is no necessity aspect in the definition and we can connect X to $q \in Q$ only by a weaker *preceding* relation which does not introduce an aspect of necessity, too.

Example 15. {zagrzać 1, ogrzać 1, rozgrzać 1} ‘to warm’ –cause→ ciepły 1 ‘warm’
 ciepły 1 ←proper antonymy→ chłodny 1 ‘cool’
 ciepły 1 ←proper antonymy→ zimny 1 ‘cold’

{chłodny 1} ←preceding– {zagrzać 1, ogrzać 1, rozgrzać 1}

{zimny 1} ←preceding– {zagrzać 1, ogrzać 1, rozgrzać 1}

Example 16. {położyć 1} ‘to lay’ –cause→ {leżeć 1, spoczywać 1} ‘to lie’

leżeć 1 ←proper antonymy→ **stać 4** ‘to stay’

{stać 4} ←preceding SI– {położyć 1}

Example 17. {brukać 1, kalać 1, plamić 2, plugawić 1, brudzić 3} ‘to shame’ –cause→ {hańba 1, niesława 1, infamia 1, pohańbienie 2, zmaza 1} ‘a shame’

hańba 1 ←proper antonymy→ **zaszczyt 1** ‘a honour’

{zaszczyt 1, splendor 1, honor 1, chwala 2, chluba 2} ←preceding– {brukać 1, kalać 1, plamić 2, plugawić 1, brudzić 3}

All the examples given above conform to these co-occurrence patterns for *cause*. However, the picture is more complicated, and these patterns can be only treated as suggestions to lexicographers to look for possible links, not as automated procedures, because we can observe exceptions. As an example we can consider other verbs linked by *cause*:

Example 18. (negative) {urealniać 2} ‘to make real’ –cause→ {urealniać się 1} ‘to become real’

urealniać się 1 ←proper antonymy→ **odrealniać się 1** ‘to become unreal’

It is true that if something has *się urealniło* ‘≈made real itself’, then should *odrealnić się* ‘≈become unreal’ according to the pattern. In fact there is an association in the opposite direction. If something has *odrealnić się* ‘≈become unreal’, then it had to earlier *się urealnić* ‘become real’, so this pair does not fulfil the test for *processuality*.

Cause also co-occurs with *converseness* for adjectives and adverbs – if a verb synset *X* is linked by *cause* to *Y* which includes an LU *z* connected by *converseness* to an LU *q*, then *q* represents an earlier situation and the synset *q* ∈ *Q* should be presupposed by *X* (i.e. to be the target of *presupposition* from *X*), as *converseness* due to its definition imposes the comparative or superlative grade in the case of adjectives and adverbs.

Example 19. {podkręcić 3, przyśrubować 3} ‘to force sb to do sth better’ –cause→ {lepiej 1} ‘better’

lepiej 1 ←converseness→ **gorzej 1** ‘worse’

{gorzej 1} ←presupposition– {podkręcić 3, przyśrubować 3}

We can notice that synsets including verbs linked by *converseness* express a tendency for participating in the cause relation:

Example 20. {uderzyć 2, zadać cios 2, zadać raz 1, dać 13, wymierzyć 3, dać łupnia 1, dograć 6} ‘to hit’ –cause→ {dostać 4, oberwać 1, dostać łupnia 1} ‘≈ to get a hit/beaten’

dostać 4 ←converseness→ **dać 13**

This observation is not also a rule in a proper sense, as it is not free from exceptions and is relevant only for those verb pairs in which one of the elements is non-intentional. For instance, a negative example is: *wychodzić za mąż* ‘to get married (woman)’ i *żeńić się* ‘to get married (man)’, whose synsets are not linked by *cause*.

We can also notice that double *cause* relations: from a verb to both an adjective and a noun often co-occur with a *characteristic* relation between the adjective and noun.

Example 21. {barwić 1, ubarwiać 1, zabarwiać 1} ‘to colour’ –cause→ {barwny 1, kolorowy 2} ‘colourful’

barwny 1 –characteristic→ **barwa 2** ‘colour’

{barwić 1, ubarwiać 1, zabarwiać 1} –cause→ {kolor 1, barwa 2}

Figure 2: Example of a pattern of synset relations for *cause* and *characteristic*, where “kauz”=*cause*, “proc”=*processuality*, and “uprz+t”=*preceding SI* (a screen-shot from WordnetLoom). Some synset relations are hidden. Lexical relation of *szczęśliwy 2*-characteristic→*szczęście 1* ‘happiness’ is not presented in this perspective.

Example 22. $\{uszcześnieśliwiać\ 1\}$ ‘to make sb happy’ –cause→ $\{szczęśliwy\ 2\}$ ‘happy’
 $szczęśliwy\ 2$ -characteristic→ *szczęście 1* ‘happiness’
 $\{uszcześnieśliwiać\ 1\}$ –cause→ $\{szczęście\ 1, szczęśliwość\ 1\}$

This combination of synset relations is also illustrated in Figure 2 a screen-shot made in WordnetLoom. The picture does not include the lexical relation of *characteristic*.

The above pattern does not work well in all cases, so it should be only a suggestion for a lexicographer and its applicability should be always verified.

The next observed dependency refers to *cause* and *feature bearer* and its obligatory reverse relation, i.e. *state*. As already mentioned, in spite of the intention to make *feature bearer*/*state* describing LUs of broad denotation (see Sec. 4), some connections appeared to be quite narrow and conventional, cf the example of *pstrokaczka* ‘a freckled duck’. Because of this, we should not expect unconditional co-occurrence between *cause* and *feature bearer* links. Every potential new relation instance must be verified by a lexicographer.

Example 23. $\{łączyć\ 1, złączyć\ 1\}$ ‘to join’ –cause→ $\{całość\ 1, ogół\ 1\}$ ‘a whole’
 $całość\ 1$ –feature bearer→ *cały 8* ‘whole’
 $\{łączyć\ 1, złączyć\ 1\}$ –cause→ $\{cały\ 8, calutki\ 6, caluteniki\ 6, caluški\ 6, calusieniki\ 6\}$

Example 24. $\{przeciwstawić\ 1\}$ ‘to opposite’ –cause→ $\{odwrotny\ 3, przeciwny\ 6\}$ ‘opposite’
 $odwrotny\ 3$ –state→ *odwrotność 1* ‘a opposite’
 $\{przeciwstawić\ 1\}$ –cause→ $\{odwrotność\ 1, przeciwnieństwo\ 3, przeciwstawienie\ 3\}$

4.4 Processuality

Because, *processuality* resembles *cause* to a large extent, for the former we can expect to observe similar co-occurrence patterns with other relations like for the latter. In the case of a verb synset X (source) linked to an adjective synset Y (target) by *processuality*, such that Y includes an LU z with *proper antonymy* link to an LU q it is often observed that the synset $q \in Q$ is the target of *preceding* relation from X .

Example 25. $\{zbieleć\ 2, pobieleć\ 2\}$ ‘to become white’ –processuality→ $\{biały\ 1\}$ ‘white’
 $biały\ 1$ ←proper antonymy→ *czarny 2* ‘black’
 $biały\ 1$ ←proper antonymy→ *kolorowy 2* ‘colourful’
 $\{czarny\ 2\}$ ←preceding- $\{zbieleć\ 2, pobieleć\ 2\}$ $\{barwny\ 1, kolorowy\ 2\}$ ←preceding- $\{zbieleć\ 2, pobieleć\ 2\}$

Example 26. $\{zabarwić\ się\ 1, ubarwić\ się\ 1\}$ ‘to become colourful’ –processuality→ $\{barwnie\ 1, kolorowo\ 7\}$ ‘colourfully’
 $barwnie\ 1$ ←proper antonymy→ *bezbawnie 3*
 $\{bezbawnie\ 3\}$ ‘colourlessly’ ←preceding- $\{zabarwić\ się\ 1, ubarwić\ się\ 1\}$

Example 27. $\{zaprzyjaźniać\} 1$ ‘to make friends’ –processuality→ $\{przyjaciół\} 1$ ‘a friend’
 $\{przyjaciół\} 1$ ←proper antonymy→ $\{wrog\} 1$ ‘an enemy’
 $\{wrog\} 1, \{nieprzyjaciół\} 1$ ←preceding- $\{zaprzyjaźniać\} 1$

A similar co-occurrence can be observed between *processuality* and *complementary antonymy*. In this case, we can also expect that a *complementary antonym* is a member of the source synset of *processuality*. However, as *complementary antonym* includes an aspect of necessity in the lack of an alternative, it should be *presupposition* that points to the representation of an earlier situation, not *preceding*.

Example 28. $\{łysiec\} 1$ ‘to be getting bald’ –processuality→ $\{łysy\} 1$ ‘bald’
 $\{łysy\} 1$ ←contemporary antonymy→ $\{owłosiony\} 3$ ‘hairy’
 $\{owłosiony\} 3$ ←presupposition- $\{łysiec\} 1$

Example 29. $\{rozpowszechniać\} 1, \{szerzyć\} 1$ ‘to spread’ –processuality→ $\{powszechnie\} 3$ ‘frequently, comonly’
 $\{powszechnie\} 3$ ←contemporary antonymy→ $\{niepowszechnie\} 1$ ‘rarely, uncommonly’
 $\{niepowszechnie\} 1$ ←presupposition- $\{rozpowszechniać\} 1, \{szerzyć\} 1$

In the case of *processuality* and *converseness* we can expect two more co-occurrence patterns:

- with *presupposition* for adjectives and adverbs in the comparative grade, but both are not systematically introduced into plWordNet and their descriptions are infrequent — this issue requires further research,
- *presupposition: no subject identity* for nouns.

Example 30. $\{przedłużyć\} 2, \{wydłużyć\} 1$ ‘to become longer’ –processuality→ $\{dłuższy\} 1$ ‘longer’
 $\{dłuższy\} 1$ ←converseness→ $\{krótszy\} 1$ ‘shorter’
 $\{krótszy\} 1$ ←presupposition- $\{przedłużyć\} 2, \{wydłużyć\} 1$

Example 31. $\{otrzymywać\} 4$ ‘to receive’ –processuality→ $\{odbiorca\} 2$ ‘a receiver’
 $\{odbiorca\} 2$ ←converseness→ $\{nadawca\} 2$ ‘sender’
 $\{nadawca\} 2$ ←presupposition NSI- $\{otrzymywać\} 4$

5 Conclusions

We have shown that there is a kind of dependency or correlation between verb lexico-semantic relations that express associations between situations and several other lexico-semantic relations. We tried to identify the main co-occurrence patterns of relations. Such dependencies are rarely discussed in literature, and have not been investigated in relation to plWordNet. In spite of the quite substantial lexical material examined (i.e. the description of ≈10,000 verbs in plWordNet), this analysis is not yet statistically valid, and should be treated as the first step towards a more systematic overview. It will be used as a basis for the further development of plWordNet, see Sec. 6, especially towards increasing the completeness of the verb meaning descriptions and the density of the verb sub-network.

We could notice that lexical relations of *antonymy* and *converseness* can be very useful in the description of the cause-consequence chains with the help of relations for the dynamic verbs. Both lexical relations point to a state which could (in the case of *proper antonymy*) or had to (for *complementary antonymy*) appear before the situation that is a temporal reference point. This generalisation fails to work for nouns, which can be explained by a more culturally constrained antonymy in the case of Polish nouns, in contrast to other PoS.

Relations originating from the derivational associations express lower participation in co-occurrence patterns. We tried to consider all derivationally motivated relations in a broad overview

of the material from plWordNet, but some regularities could be observed only for *characterising*, *feature bearer/state* and *state/property*. This does not exclude existence of other types of dependencies between such relations, so this is still an open issue for further research.

The presented analysis has been solely performed on plWordNet and illustrated by Polish examples. plWordNet model introduces a rich system of linguistically motivated relations and Polish is an inflectional language with a complex derivational system. Thus, the analysis, especially the relation co-occurrence patterns cannot be directly mapped to the other wordnets for other languages. However, all Slavic languages have derivational systems of similar character (Šojat & Srebačić, 2014), BulNet (Koeva, 2008) or CzechWordnet (Pala & Hlaváčková, 2007). Their wordnet models show many differences in comparison to the plWordNet's one, but such differences are not very significant, e.g. a comparison between plWordNet and BultNet presented in Piasecki and Koeva (2017). Thus, the system of verb relations proposed by us and the idea of the relation co-occurrence patterns can be applied to other Slavic wordnets, and, e.g., used in language comparison.

The application of our model to non-inflectional languages seems to be more problematic. However, it is worth-noticing that, firstly, richer systems of verb relations based on more fine grained partitioning of entailment has been considered for Princeton WordNet several times, secondly, the idea of morpho-semantic relation was proposed and applied initially to Princeton WordNet and next transferred to several other wordnets, even to Slavic ones, e.g. ButNet (Dimitrova, Tarpomanova, & Rizov, 2014). For instance, if we take a look into English glosses in Table 3, we can discover that several derivationally-motivated relations from plWordNet can be transferred to WordNet of English and this number would be much increased if zero derivation is taken into account, too. Only the minority of relations, e.g. including *multiplicativity*, would be very hard to be transferred, as such distinctions are expressed in many languages, including English, on the syntactic-semantic level. Moreover, all derivationally motivated relations for verbs in plWordNet have been lifted to the level of synset relation. Thus, they also link LUs that are not derivationally associated and their definitions are not based on the requirement of the existence of the derivational association. The only two problems left are verb classes and verb aspect. The first one is simple, as the system of verb classes of plWordNet originated from the systems proposed for other languages. Aspect is not lexicalised in many languages, e.g. English, contrary to the Slavic ones. However, as a result, LUs in such languages would participate in larger number of relations, or in some cases more fine grained distinctions of senses can be considered.

6 Applications

Co-occurrence patterns presented in Sec. 4 are more a generalisation than a complete model. It shows possibly existing correlations among groups of lexico-semantic relations. Moreover, the formulated generalisations suggest that there are missing connections in plWordNet that are predicted by them. Paradoxically, the imperfect accuracy makes the patterns a diagnostic tool: the generalisations do not determine, but predict highly likely existence of relation links. Thus, one of the results of our analysis is a set of additional markers for relations that enrich the definitions of relation and the lexicographic procedure applied.

The identified co-occurrence patterns will be used as a basis for the expansion of a diagnostic tool supporting linguist in maintaining high agreement between their decisions. plWordNet is built by a team of lexicographers and is not free of inconsistencies or even mistakes. Diagnostic tools utilising also language technology allows for minimising the risk of errors. However, the interpretation of a specific language phenomenon or lexical meaning is always preserved for lexicographers. Awareness of regular tendencies in relation co-occurrences may help in formalising lexicographic procedures leaving less space for intuitive interpretation, especially in relation to the identification of lexical meanings.

We have also found several cases in which it was not possible to formulate co-occurrence patterns (e.g. 8 examples for *antonymy* between nouns), and a higher probability of a relation is

only a signal for a lexicographer. However such weaker signals should be also included into the guidelines for wordnet editors.

The observed exceptions from the noticed co-occurrence patterns are an intriguing starting point for further research, e.g. in the area of relations between linguistics and cultural studies, as well as contrastive studies between plWordNet and Princeton WordNet.

References

- Brown, C. H. (2004). Paradigmatic relations of inclusion and identity II: Meronymy. In D. A. Cruse, F. Hundsnurscher, & P. R. Lutzeier (Eds.), *Lexicology: An international handbook on the nature and structure of words and vocabularies* (Vol. 1, pp. 480–485). Berlin: Walter de Gruyter.
- Dimitrova, T., Tarpomanova, E., & Rizov, B. (2014). Coping with derivation in the Bulgarian WordNet. In *Proceedings of the Seventh Global WordNet Conference* (pp. 109–117). Tartu: University of Tartu Press.
- Dziob, A., & Piasecki, M. (2018). Implementation of the verb model in plWordNet 4.0. In F. Bond, C. Fellbaum, & P. Vossen (Eds.), *Proceedings of the 9th Global Wordnet Conference, Singapore, 8–12 January 2018*. Global Wordnet Association.
- Dziob, A., Piasecki, M., Maziarz, M., Wieczorek, J., & Dobrowolska-Pigoń, M. (2017). Towards revised system of verb wordnet relations for Polish. In J. P. McCrae, F. Bond, P. Buitelaar, P. Cimiano, T. Declerck, J. Gracia, I. Kernerman, E. Montiel Ponsoda, N. Ordan, & M. Piasecki (Eds.), *Proceedings of the LDK 2017 Workshops: 1st Workshop on the OntoLex Model (OntoLex-2017), Shared Task on Translation Inference Across Dictionaries & Challenges for Wordnets co-located with 1st Conference on Language, Data and Knowledge (LDK 2017)* (pp. 174–187). Retrieved August 31, 2017, from <http://ceur-ws.org/Vol-1899/>
- Fellbaum, C. (Ed.). (1998). *WordNet: An electronic lexical database*. Cambridge, MA: MIT Press.
- Haspelmath, M. (1993). More on the typology of inchoative/causative verb alternations. In B. Comrie & M. Polinsky (Eds.), *Causatives and transitivity* (pp. 87–121). Amsterdam: John Benjamins Publishing Company. (Studies in Language Companion Series, 23). <https://doi.org/10.1075/slcs.23.05has>
- Horvath, J., & Siloni, T. (2011). Anticausatives: Against reflexivization. *Lingua*, 121(15), 2176–2186. <https://doi.org/10.1016/j.lingua.2011.09.006>
- Koeva, S. (2008). Derivational and morphosemantic relations in Bulgarian Wordnet. In M. A. Kłopotek (Ed.), *Intelligent information systems XVI: Proceedings of the International IIS '08 Conference, held in Zakopane, Poland, June 16–18, 2008* (pp. 359–368). Warszawa: Institute of Computer Science, Polish Academy of Sciences.
- Koeva, S. (2010). Bulgarian wordnet — current state, applications and prospects. In M. Drinov (Ed.), *Bulgarian-American dialogues* (pp. 120–132). Sofia: Academic Publishing House.
- Koontz-Garboden, A. (2009). Anticausativization. *Natural Language & Linguistic Theory*, 27(1), 77–138. <https://doi.org/10.1007/s11049-008-9058-9>
- Laskowski, R. (1998). Kategorie morfologiczne języka polskiego — charakterystyka funkcjonalna. In R. Grzegorzczkowska, R. Laskowski, & H. Wróbel (Eds.), *Gramatyka współczesnego języka polskiego: Morfologia* (2nd ed., Vol. 1). Warszawa: PWN.
- Levin, B., & Hovav, M. R. (1995). *Unaccusativity: At the syntax-lexical semantics interface*. Cambridge, MA: MIT Press. (Linguistic Inquiry Monographs, 26).
- Lis, M., & Navarretta, C. (2014). Classifying the form of iconic hand gestures from the linguistic categorization of co-occurring verbs. In *Proceedings 1st European Symposium on Multimodal Communication University of Malta; Valletta; October 17–18; 2013* (pp. 41–50). Linköping University Electronic Press. (Linköping Electronic Conference Proceedings, 101).
- Malicka-Kleparska, A. (2013). In search of causative structures in the root-based morphology: The case of polish roz-/roze-causatives. *Studies in Polish Linguistics*, 8(2), 75–102.
- Maziarz, M., Piasecki, M., & Szpakowicz, S. (2012). Approaching plWordNet 2.0. In C. Fellbaum & P. Vossen (Eds.), *Proceedings of the 6th Global WordNet Conference, Matsue, Japan* (pp. 189–196). Global WordNet Association.
- Maziarz, M., Piasecki, M., & Szpakowicz, S. (2013). The chicken-and-egg problem in wordnet design: Synonymy, synsets and constitutive relations. *Language Resources and Evaluation*, 47(3), 769–796. <https://doi.org/10.1007/s10579-012-9209-9>

- Maziarz, M., Piasecki, M., Rudnicka, E., Szpakowicz, S., & Kędzia, P. (2016). plWordNet 3.0 — a comprehensive lexical-semantic resource. In N. Calzolari, Y. Matsumoto, & R. Prasad (Eds.), *COLING 2016, 26th International Conference on Computational Linguistics, Proceedings of the Conference: Technical Papers, December 11–16, 2016, Osaka, Japan* (pp. 2259–2268). ACL.
- Maziarz, M., Piasecki, M., Szpakowicz, S., Rabiega-Wiśniewska, J., & Hojka, B. (2011). Semantic relations between verbs in Polish WordNet 2.0. *Cognitive Studies / Études cognitives*, 2011(11), 183–200. <https://doi.org/10.11649/cs.2011.011>
- Maziarz, M., Szpakowicz, S., & Piasecki, M. (2012). Semantic relations among adjectives in Polish WordNet 2.0: A new relation set, discussion and evaluation. *Cognitive Studies / Études cognitives*, 2012(12), 149–179. <https://doi.org/10.11649/cs.2012.011>
- Murphy, L. M. (2006). Meronymy. In K. Brown (Ed.), *Encyclopedia of language & linguistics* (2nd ed., pp. 13–15). Amsterdam: Elsevier. <https://doi.org/10.1016/B0-08-044854-2/04838-0>
- Naskręt, T., Dziob, A., Piasecki, M., Saedi, C., & Branco, A. (2018). WordnetLoom — a multilingual wordnet editing system focused on graph-based presentation. In F. Bond, C. Fellbaum, & P. Vossen (Eds.), *Proceedings of the 9th Global Wordnet Conference, Singapore, 8–12 January 2018*. Global Wordnet Association.
- Olszewska, T. (1986). *Causativity as a linguistic phenomenon: A study based on English and Polish*. Lublin: Uniwersytet Marii Curie-Skłodowskiej.
- Pala, K., & Hlaváčková, D. (2007). Derivational relations in Czech WordNet. In *Proceedings of the Workshop on Balto-Slavonic Natural Language Processing: Information Extraction and Enabling Technologies* (pp. 75–81). Stroudsburg, PA: Association for Computational Linguistics.
- Pease, A. (2011). *Ontology: A practical guide*. Angwin, CA: Articulate Software Press.
- Piasecki M., & Koeva, S. (2017). WordNet relations in the Bulgarian-Polish bilingual perspective. In T. Aleksandrova & D. Blagoeva (Eds.), *Proceedings of the International Jubilee Conference of the Institute for Bulgarian Language, (Sofia, 15–16 May 2017)* (Vol. 1, pp. 285–296). Sofia: Institute for Bulgarian Language Prof. Lyubomir Andreychin, Bulgarian Academy of Sciences.
- Piasecki, M., Szpakowicz, S., & Broda, B. (2009). *A Wordnet from the Ground Up*. Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej. Retrieved from http://www.dbc.wroc.pl/Content/4220/Piasecki_Wordnet.pdf
- Piasecki, M., Szpakowicz, S., & Broda, B. (2010). Toward plWordNet 2.0. In P. Bhattacharyya, C. Fellbaum, & P. Vossen (Eds.), *Principles, construction and application of Multilingual Wordnets: Proceedings of the Fifth Global WordNet* (pp. 263–270). Mumbai: Narosa Publishing House.
- Piasecki, M., Marcińczuk, M., Ramocki, R., & Maziarz, M. (2013). WordNetLoom: A WordNet development system integrating form-based and graph-based perspectives. *International Journal of Data Mining, Modelling and Management*, 5(3), 210–232. <https://doi.org/10.1504/IJDM.2013.055861>
- Piasecki, M., Burdka, Ł., Maziarz, M., & Kaliński, M. (2016). Diagnostic tools in plWordNet development process. In Z. Vetulani, H. Uszkoreit, & M. Kubis (Eds.), *Lecture Notes in Computer Science: Vol. 9561. Human Language Technology: Challenges for Computer Science and Linguistics: 6th Language and Technology Conference, LTC 2013, Poznań, Poland, December 7–9, 2013: Revised selected papers* (pp. 255–273). Cham: Springer. https://doi.org/10.1007/978-3-319-43808-5_20
- Šojat, K., & Srebačić, M. (2014). Morphosemantic relations between verbs in croatian wordnet. In *Proceedings of the Seventh Global Wordnet Conference* (pp. 262–267). Tartu: University of Tartu Press.
- Vendler, Z. (1957). Verbs and times. *The Philosophical Review*, 66(2), 143–160. <https://doi.org/10.2307/2182371>
- Vossen, V. (2002). *EuroWordNet general document Version 3* (Technical report). University of Amsterdam.

Acknowledgment

Works funded by the Polish Ministry of Science and Higher Education within CLARIN-PL Research Infrastructure.

The authors declare that they have no competing interests.

The authors' contribution was as follows: concept of the study: Agnieszka Dziób (70%), Maciej Piasecki (30%); background overview: Agnieszka Dziób (75%), Maciej Piasecki (25%) data analyses: Agnieszka Dziób (90%), Maciej Piasecki (10%) the writing: Agnieszka Dziób (50%), Maciej Piasecki (50%).

This is an Open Access article distributed under the terms of the Creative Commons Attribution 3.0 PL License (<http://creativecommons.org/licenses/by/3.0/pl/>), which permits redistribution, commercial and non-commercial, provided that the article is properly cited.

© The Authors 2018

Publisher: Institute of Slavic Studies, Polish Academy of Sciences, University of Silesia & The Slavic Foundation