# Wordnet – a Basic Resource for Natural Language Processing: the Case of plWordNet

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**Abstract.** This paper presents a wide scope of wordnet applications on the example of applications of plWordNet – a wordnet of Polish. Wordnets are large lexical-semantic databases functioning as primary resources for language technology. They are machine-readable dictionaries. Thus, they are indispensible for tasks such as basic flow of text processing, text mining, word sense disambiguation, information extraction and retrieval. On a larger scale, wordnets are used in research, education and business. In this paper a few examples of specific plWordNet applications are described in detail.

**Keywords:** wordnet · plWordNet · language technology. · NLP

## 1 Introduction

Wordnet is a hierarchically organised lexical-semantic database in which nouns, verbs, adjectives and adverbs are grouped into sets of cognitive synonyms (synsets), each expressing a distinct concept. Synsets are interlinked by means of conceptual-semantic and lexical relations. The first wordnet in the world was Princeton WordNet (henceforth, PWN) created for the English language at Princeton University and developed since the mid 1980s [31]. The main element of PWN structure is synset, defined as a set of synonyms. Single words as well as synsets are linked with each other by lexical (at word level) and conceptual-semantic (at synset level) relations. Fundamental synset-level relations are hyponymy (hierarchy building), meronymy, and troponymy (the latter for verbs only). Basic word-level relations are derivational relations.

Unfortunately, since 2006, when version 3.1 was released, PWN has no longer been actively developed. Currently, works are continued within the English WordNet project [30]. Version 3.1 of PWN is available, containing 146,533 nouns, 25,061 verbs, 30,072 adjectives and 5,592 adverbs [8]. PWN is the core on which many wordnets for other languages have been based. These have been created by various methods such as automatic or semi-automatic translation of PWN synsets and lexical units or complete manual projection.

PWN is available under an open license. Although WordNet originates from psycholinguistic research on language acquisition by children, it has demonstrated its full potential in the NLP [31]. In 2004, J. Morato and others [32]

carried out a statistical analysis of the use of PWN based on publications available in databases such as: LISA [6], INSPEC [3], IEEE [5], ResearchIndex (now CiteSeerX) [1] and The Library of the University of Carlos III of Madrid [7] for the period 1994-2003. The bibliographic databases used by them include publications mainly from the area of engineering, especially computer and information science. They focus less on the use of PWN in Humanities and Social Sciences and in non-academic applications.

Since the analysis of Morato et al., we can observe the increase of interest in the use of wordnets in the field of natural language processing. The aim of this paper is to present the applications of a wordnet for the Polish language – plWordNet (henceforth, plWN), developed at the Wrocław University of Science and Technology since 2005 [39], with its latest official 4.1 version published in 2019 [14]. plWN is equally oriented towards applications in computer and information science, as well as in humanities and social sciences and in business. This is largely motivated by the fact that since 2013 plWN has become an element of the Polish part of CLARIN (Common Language Resources and Technology Infrastructure) [2], providing tools and resources for natural language processing outside the field of engineering sciences. It focuses on their popularization in the field of Humanities and Social Sciences.

The aim of this paper is to present plWN from the perspective of its versatile applications. To this end, we use the broadest possible data of plWN citations, collected from Google Scholar [4], for the period between 2005-2019, which allowed for manual verification of its usage in the last 15 years. Of 407 works that cite plWN we have chosen those that described its usage in research or existing applications. The second source of data are questionnaires filled in by users while downloading the plWN database. They have been collected since 2015, yet they do not give the full picture of applications, but rather indicate the potential of usage of national wordnets. We will strive to show how the range of applications of wordnets has changed in relation to the ones described in [32], and to present them in the perspective of Polish language processing.

## 2 WordNet implementation

The following areas of application of PWN emerge from [32]: wordnet-internal and wordnet-external ones. The former refer to building wordnet editing systems and multilingual resources. The latter cover information extraction and retrieval, document structuring and categorisation, audio and video retrieval. The authors also point out developmental trends which include: development of systems that allow to determine the degree of inter-lingual equivalence, the use of wordnets in information extraction systems (e.g. semantic search engines) to improve their efficiency, creating and categorising semantic ontologies[1], and other knowledge resources in the Internet as well as audiovisual and multi-media systems.

[1] As early as 2004, as Morato et al. mentioned, ontologies and semantic web were one of the most dynamically developing areas of wordnet applications.

Morato et al. see WordNet's success as mainly due to its open licence and big potential of use in NLP. While in 2004 there was potential, in 2019 the multitude of applications in NLP became a reality. The CiteSeerX database alone shows almost 29,000 results for 'wordnet'. Although plWN did not receive such a large number of citations, we will try to present on its example a cross-section of applications of wordnet type databases – actual, confirmed by citations, and potential, indicating trends in NLP development using wordnets.

## 3 plWordNet in brief

Similarly to Princeton WordNet, plWN defines meanings using lexical-semantic relations [39], but the central element is lexical unit [28] (henceforth, LU). This stems from the specificity of the Polish language, whose very rich morphology results in the fact that derivational relations (of formal and semantic character) are as significant as purely semantic relations between synsets. Compared to PWN , plWN is also characterized by a greater number of different relations at the level of lexical units and synsets.

In addition to LUs, synsets and relations, plWN has, like PWN , additional areas of description: glosses (abbreviated definitions) and examples of use (currently not for all lexical units, successively completed). Moreover, plWN has a very rich network of connections with external resources (see 4.1.). Since 2012 the mapping of Polish synsets on the English ones [45] has been carried out, and since 2018 it has been experimentally extended to the level of LUs [46]. These are pioneering works on a global scale.

Tab. 1 contains abbreviated statistics of the version 4.1 of plWN [14] published in 2019, covering Polish lemmas (words), LUs, synsets, as well as their mapping on PWN , which includes the number of inter-lingual synonyms for synsets and strong equivalence for LUs, relations particularly useful in applications related to translation. The table also covers the statistics on connections to external sources.

| Elements | **Verbs** | **Nouns** | **Adv.** | **Adj.** | **All** |
|---|---|---|---|---|---|
| **plWN 4.1 Lemmas** | 20 430 | 134 674 | 8 042 | 29 349 | **192 495** |
| **plWN 4.1 Lexical Units** | 43 701 | 178 167 | 14 088 | 54 410 | **290 366** |
| **plWN 4.1 Synsets** | 32 102 | 133 747 | 11 295 | 47 035 | **224 179** |
| **Links to PWN (Synsets):** | **280 502** | | | | |
| Inter-lingual synonymy: | 46 883 | | | | |
| **Links to PWN (LUs):** | **10 244** | | | | |
| Strong equivalence | **9 860** | | | | |
| **Links to SUMO** | **206 426** | | | | |
| **Links to Wikipedia** | **44 432** | | | | |

**Table 1.** Basic statistics of plWN 4.1 (`http://plwordnet.pwr.edu.pl`)

Unlike many wordnets created by the translation of PWN, plWN has been built manually, with the support of NLP tools and based on large corpora of text [39], so it gives an excellent picture of the Polish language vocabulary. Moreover, it is currently the largest electronic dictionary for Polish language. The initial set of lexical-semantic relations, taken mostly from PWN , was extended in terms of typical elements of dictionary description in Polish and potential applications in NLP. The authors were also guided in the choice of relations by other principles, according to which they were supposed to be established in the Polish lexicographic tradition and be frequent in the Polish lexical system [28].

In the current version of plWN there are about 200 types and subtypes of relations between synsets, LUs and external lexicons. Among them one can mention universal relations for this type of relational lexicons, e.g. hyponymy (*jamnik* 'dachshund' → *pies* 'dog'), antonymy (*zmniejszać* 'to decrease' ↔ *zwiększać* 'to increase'), meronymy (*rodzynka* 'a raisin' → *bakalie* 'dried fruit and nuts'), cause (for verbs) (*powodować* 'to cause' → *stawać się* 'to become'). However, plWN also contains many Polish-specific relationships, especially between LUs: feminity (*lekarka* 'a woman-doctor' ← *lekarz* 'a doctor'), markedness, which says that the unit has some emotional load (*guziczek* 'a little button' ← *guzik* 'a button') or role and role inclusion typical for nouns derived from verbs and verbs derived from nouns (e.g. role: *drukować* 'to print' ← *drukarka* 'a printer'; role inclusion: *nocować* 'spend a night' ← *noc* 'a night').

## 4 Applications of plWordNet

### 4.1 plWordNet development

**Wordnet editing system** The plWN graph-based editing system (WordnetLoom) [35] has three editing perspectives – units, synsets, and synset relations, which allow linguists to work on both levels in an integrated way. It has been recently enriched with a graphical presentation module (Wordnet Viewer) and an integrated linguist support module, which allows to preview changes made to the database, and presents language material from text corpora. In addition, the WordNet Weaver module has been implemented, allowing for partial automation of the plWN expansion process [39]. At the same time, a separate diagnostic module was developed, which allows to correct typical errors in plWN structure [40].

Since 2012, due to the linking of plWN with PWN by inter-lingual relations [45], it has become necessary to adapt the existing system to the requirements of linking with other language resources and the requirements of increasingly large teams working in an integrated way. In 2018, WordnetLoom 2.0 was presented with an extensive graphical module and limited remaining editing perspectives, linking to a modified [35] design database. WordnetLoom is currently used, in addition to the Polish team, also by teams building wordnets for languages: Portuguese [35], Danish [38] and African languages [17].

This system has been developed with a module for tracking changes in the plWN database integrated with the developed diagnostic system, based on formal

cohesion determinants of plWN and, partly also, content-related ones [34]. In 2018, a method of content-related evaluation of relationship cohesion for plWN was presented on the example of verbs [13]. Works on content-related and formal diagnostics are currently underway.

**Extension of resources** The mapping of plWN onto PWN has been carried out since 2012 [45]. Throughout the mapping, there has been observed a stable tendency for inter-lingual hyponymy to outgrow inter-lingual synonymy in terms of its frequency for all parts of speech. Lexicographers noted that in many cases inter-lingual hyponymy was introduced due to coverage gaps in Princeton WordNet. This observation motivated an experimental extension of PWN. Eventually, the size of this extension, called enWordNet, reached 11 294 LUs [47]. plWN is currently the part of the Open Multilingual Wordnet [9], compiled using inter-lingual relations (mainly inter-lingual synonymy) between individual wordnets and PWN .

Multi-word Expression (henceforth, MWE) units have been included in plWN, whose definition and selection from language material are presented in [29]. Semantically described in plWN , MWE are syntactically described using WCCL syntax adapted to the description of the common language in MWELexicon, currently containing over 50k units belonging to all parts of speech described in plWN in different structural types. The work on MWE was the motivation to develop the description of terminology in plWN [29]. However, from 2016 to 2019 works were carried out to combine plWN with external terminological resources and ontologies, including Wikipedia, DBPedia, SUMO and YAGO ontologies and thesauri, conducted semi-automatically, i.e. on automatic propagation of manual connections, based on plWN structure and gloss. They were based, apart from the mentioned description of MWE, also on previous studies on automatic linking of plWN with the SUMO ontology and many works on linking plWN and Wikipedia [41].

Since 2015, plWN has been supplemented with the emotive annotation for LUs [53], conducted manually by two annotators (a psychologist and a linguist), supervised by a superannotator, decisive of discrepancies in the annotation. The set of 100,000 manual annotations was extended by means of automatic propagation using the Classifier-based Polarity Propagation method [20]. The plWN emotive annotation became the basis for a sense-tagged sentiment resource comparison [10], aimed at developing methods of assessing the quality of emotive annotation in wordnets.

Walenty, a comprehensive valency dictionary of Polish developed at the Institute of Computer Science, Polish Academy of Sciences, containing currently over 18,000 units, is built from two levels: syntactic, describing syntactic schemes of units for the Polish language, and semantic, assigning meaning to units. These meanings correspond to the meanings of LUs from plWN [18]. In 2019, a semi-automatic projection of Walenty semantic layer on the plWN structure was carried out in such a way that relations corresponding to Walenty selection prefer-

ences were introduced into plWN , connecting synsets containing units that are described in Walenty with the use of these preferences [18].

The multitude of different sources by which plWN was extended makes it a valuable component of combined resources, such as the above mentioned Open Multilingual Wordnet, but also created for the Polish language: Lexical Platform [42] and Multisłownik [37].

### 4.2 plWordNet for systems of Natural Language Processing

**Text Mining** At the text analysis level, plWN is used to recognize and classify elements of text, such as MWEs [43], named entities [16], events [21], temporal expressions [22], spatial expressions [25], and terminology [33]. Many applications are related to word sense disambiguation. Among them we can mention the research [19], in which at first the method for Polish language based on Page Rank was used, and then plWN combined with SUMO ontology was used to improve its effectiveness. In another solution, cf. [48], to improve the results was used a combination of models trained on text corpora and information extracted from plWN, including relations and glosses.

Development trends in NLP indicate growing interest in using wordnets to build intelligent e-commerce and opinion mining tools. The article [49] presents a sample analysis of sentiment in the discourse of Polish politicians conducted using plWN. The system of opinion analysis applicable to texts on different fields was presented in the article [24]. The article [36] presents an approach combining the extraction of key words from the Polish text with the analysis of sentiment. The article [50] presents a comprehensive system for features extraction and opinion mining, allowing for the analysis of Internet comments, to which the synonyms and antonyms of plWN were used. plWN was also used in many cases as a basis or one of the main sources to build other text mining tools. These include tools for comprehensive text analysis such as Cluo [23] and LEM [26], for stylometric analysis [15] and for the analysis of text complexity [12].

**Knowledge extraction and building Semantic Web** The analysis of structure at the sentence and text level is applicable to the construction of semantic search engines. In 2016 plWN became one of the main sources for building the first such search engine for Polish language NEKST [11]. The real challenge are Question Answering systems, which are used in semantic search engines showing results for questions asked in natural language, as well as for building intelligent assistants (including voice). The use of plWN in QA systems is shown in [44]. The RAFAEL system described by the author, based on the Deep Entity Recognition (DeepER) procedure, alternative to Named Entity Recognition (NER). The operation of DeepER is based on combining knowledge resources the information available for Named Entities in plWN and Wikipedia.

Intelligent systems of the semantic search and answer to questions in natural language are, besides e-commerce, a branch of NLP, for which we can find great interest in the use of plWN (see Tab. 2) and predict that it will grow. New

possibilities are created by combining plWN with Linked Open Data resources, saved in SKOS format, which is described in [27]. Building such a system in the SKOS/LMF standard, using data contained in plWordNet, is described in [52].

**Multi-modal data** Another area, where growing interest in wordnets can be indicated, is multi-modal data analysis. So far plWN has been used to describe and classify visual data [51] and to the semantic annotation of indicating gestures. Table 2 shows the development of this range of uses, especially in the area related to speech analysis.

**Other applications** Since 2015, users downloading the plWN database are asked to fill in a short form, in which they indicate what they plan to use it for. They are specific, practic applications, not described in the scientific publications. The data collected so far indicate the following applications, declared by representatives of science, commercial companies and individuals interested in technological development. They are presented in Tab. 2.

At the text mining level, plWordNet's application is used by its users to analyse groups of texts such as customer service reports, software requirements, design requirements, CVs, e-mails, inquiries, economic documents, debates, job offers, transcriptions of telephone conversations, technical texts translation, analysis of intentions in dialogues, analysis of press releases, research on communication in social networks (very often devoted to sentiment research) and analysis of changes taking place in the labour market on the basis of e.g. job advertisements.

Another category are works of users declaring the application of plWordNet, devoted to varieties of language or discourse, among which one can mention analyses of parliamentary data, public debate and opinion, or political or religious discourse, research on changes in business language or media information.

As already mentioned, there is a growing interest in using NLP tools and resources in the e-commerce market in Poland. The results of text mining research with the use of plWN and the plWN database itself are, according to the declarations, used for analyzing opinions about products, automatic categorization of purchase and sale announcements, for describing products and their grouping (classification) in an online store, creating advanced product search engine (the quality of which is improved by the ability to recognize synonyms in user queries), as well as creating SEO texts, indexing and searching, creating material indexes. One of the more advanced applications are recommendation systems, based on opinion mining research.

## 5 Conclusions and Further Works

As predicted by Morato et al., our data indicate the greatest interest in plWN in areas such as combining data for many languages and creating a database of combined data with non-dictionary resources, including the expansive development of links with ontologies, especially domain-specific ones, the use of text

**Table 2.** plWordNet implementations declared in user's forms.

| Field | Example |
|---|---|
| text analysis | tagging, parsing, stemming, normalization of texts, control of correctness and error detection (also automatic, in real time) |
| text mining | sentiment analysis, opinion mining, semantic features analysis, paraphrases of texts, stylometry, automatic classification and categorisation of texts and theirs parts, similarity of texts, analysis of social nets, anty-plagiarism system, automatic summaries, personalizing texts, keywords and phrases extraction, word sense disambiguation, content analysis, named entity recognition |
| knowledge and information extraction | semantic nets, mapping onto Linked Open Data, ontology extracting, generating and interlinking, semantic search, intelligent search for products in e-commerce (e.g. synonyms recognition), automatic generation and classification of questions and answers, Question Answering systems, anonymization, full-text search, digital shadow analysis, automatic learning of knowledge bases, query expansion, analysis of links between persons (so-called PEP: politically exposed person) Knowledge Graph constructing, fake news detection |
| multilingual data and language learning | translation and building systems of machine translation, building multi-lingual resources, linking of wordnets, tools for native and second language learning, multi-lingual research, automatic generation of tasks and language games for language learners, translation of artificial languages |
| speech recognition and intelligent systems | chat boots, intelligent assistants, intelligent systems of remote control, machine learning, language modelling, communication in natural language with robots, systems for blocking undesirable content |
| data visualisation | building clouds of words and graphs |
| linguistic research | regular polysemy, semantic nests (semantic nodes), semantic classes, lexicology and lexicography, metaphores in language, psycholinguistics, corpus linguistics, valency, predicate-argument structures, semantic roles, multiword lexical units, terminology, proper names, semantic relations in language, derivational morphology, verbal aspect in Polish |
| clinical research | neurolinguistics, research on mental disabilities (including autism and dementia) and aging, building medical databases, analysis of medical patients autodescriptions, psychological research on trauma |
| other research in NLP field | building and training language models and semantic similarity measures, SPAM and phishing detection |
| others | on field of experimental philosophy, crosswords generator, creating UUID abbreviations, mnemonic password generator |

mining documents for semantic search, as well as the development of multi-modal systems (especially in the area related to speech processing). Other areas that we can point out are the interest in describing and processing terminology (single and multi-word) and the analysis of sentiment, both in applications related to commercial activities and for the analysis of various areas of social life (e.g. by associations working for the benefit of societies). The above summary shows that plWN has numerous applications covering both research and development of tools and systems used in non-academic applications. Aware of the potential and limitations of the resource, as well as trends in the application of NLP tools, we anticipate developments in the following areas:

1. further diagnostics with the use of WordnetLoom diagnostic model and numerical data extracted from text corpora (for Polish and English), which will significantly improve the quality of data contained in plWN ;
2. extending plWN with other relations, typical for the Polish language, which are well-established in lexicography and at the same time useful in commercial applications (e.g. for building intelligent e-commerce search engines);
3. expanding the coverage of terminological units and their relations, especially in the area of law and medicine
4. linking plWN to low-level ontologies will increase the use of grouping and classification of domain-specific texts.

At the same time, it should also be noted that the importance of national languages is growing, and that the future expansion of both plWN and wordnets for many other languages other than English can also be seen.

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