

Adapting GermaNet for the Semantic Web

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Abstract

GermaNet¹ (Hamp and Feldweg, 1997) is a lexical-semantic net that relates German nouns, verbs, and adjectives semantically. For this purpose, it groups lexical units that express the same concept into *synsets* and it defines semantic relations between them. GermaNet has been developed since 1997, and its most recent edition contains over 200,000 lexical units and about 160,000 synsets. The GermaNet resource is of high quality as all its entries have been manually entered with great care. GermaNet has been linked with the *InterLingual Index* and with *Wiktionary*, and it is our goal to increase such linkage with other resources such as the *Leipzig Corpora Collection* and the *DWDS-Wörterbuch*. For this purpose, GermaNet is converted to RDF, a format that facilitates the interlinking of data sources significantly.

1 Introduction

GermaNet is a rich lexical resource that describes German vocabulary as a light-weight ontology. While GermaNet has been inspired by the Princeton Wordnet, the German resource deviates from it by a number of design decisions aimed to better represent the German language, *e.g.*, by giving an adequate account of German compounds. The creation of GermaNet started in 1997 and it has been maintained and extended ever since. The latest version of GermaNet (release 17.0, April 2022) offers about 205,000 lexical units and nearly 160,000 synsets. It defines 173,742 conceptual relations between synsets, and 12,204 lexical relations between lexical units; the number of segmented compounds is 115,366. GermaNet already has some substantial linking to external data sources such as 28,564 pointers to the interlingual index and 29,546 links to Wiktionary.

¹<https://uni-tuebingen.de/en/142806>

GermaNet data is stored in a relational database from which an XML-based serialisation can be generated. Although the database is part of the yearly GermaNet releases, its main purpose is to serve as a reliable way to store and manage continuous and simultaneous updates by the GermaNet team. The XML representation, which is stored in several XML files, gives programmers easy access to the data, as Java and Python libraries are available to read and access all information. However, it is not practical, nor intended, to extract information about synsets and their lexical entries from the XML representation using a text editor. In this paper, we describe how we map GermaNet's XML-based format to RDF, the standard format for data interchange in the Semantic Web. The new format gives users a compact, human-readable representation, as all information about a synset (or a lexical unit) is directly attached to it. The RDF format also makes it possible to easily link such information with external knowledge sources such as Babelnet, Wikidata, DWDS, or the Leipzig Corpus Collection.

2 Background

2.1 GermaNet

In many ways, GermaNet's XML serialisation reflects its original database-centered representation of database tables. With 23 files for nouns, 15 files for verbs, and 16 files for adjectives, the information on synsets is spread over 54 synset files. The names of these 54 files encode the word category and the semantic class of the synsets they contain. For instance, all nouns related to humans are given in the XML file *nomen.Mensch.xml*.

In addition, there are three XML files to encode the wiktionary links for nouns, verbs, and adjectives, respectively. Also, there is an XML file to encode the entries for the interlingual index and

```

<synset id="s50724" category="nomen" class="Tier">
  <lexUnit id="l71792" sense="1" source="core" namedEntity="no" artificial="no" styleMarking="no">
    <orthForm>Eisbär</orthForm>
    <compound>
      <modifier category="Nomen">Eis</modifier>
      <head>Bär</head>
    </compound>
  </lexUnit>
  <lexUnit id="l199681" sense="1" source="core" namedEntity="no" artificial="no" styleMarking="no">
    <orthForm>Polarbär</orthForm>
    <compound>
      <modifier category="Adjektiv">polar</modifier>
      <head>Bär</head>
    </compound>
  </lexUnit>
</synset>

```

Figure 1: Lexical units *Eisbär* and *Polarbär* in XML

another file to encode the conceptual and lexical relations. Each type of XML file is accompanied by a DTD file that defines the syntactic validity of their content.

In the remainder of this section, we describe how each type of information is described in XML. Fig. 1 depicts the lexical entries *Eisbär* and *Polarbär* (taken from the file *nomen.Tier.xml*), both sharing the same meaning, and therefore, they are part of the same synset. Each synset has a unique identifier (here, *s50724*), a category (*nomen*), and a class (*Tier*), naming the part of speech (noun) and the semantic class (animal) of its members. A synset consists of one or more lexical units. Each unit has an orthographic form, and if applicable, a child tagged *compound*, which defines its head and its modifiers. A lexical unit also comes with a number of attributes, for instance, information about whether it represents a named entity or whether it is stylistically marked.²

A separate file (*gn_relations.xml*) specifies lexical relations between lexical units and conceptual relations between synsets. For our synset *s50724*, we find the following entry, a conceptual relation:

```

<con_rel name="has_hyponym"
  from="s50724"
  to="s50721"
  dir="revert"
  inv="has_hyponym" />

```

The representation reads as follows: the synset *s50724* is in a hyponym relationship with the synset *s50721* (which in turn has a single lexical unit with orthographic form *Bär*). The direction of

²Our description lacks some detail. For an in-depth description of the GermaNet data format, see Appendix B of Henrich’s dissertation (Henrich, 2015).

the semantic relation can be reverted, reading that the synset *s50721* is in a hyponym relationship to the synset *s50724*.

In the same file, we find an example of a lexical relation for our lexical entry *l71792*:

```

<lex_rel name="has_habitat"
  from="l71792"
  to="l69189"
  dir="one" />

```

It shows that it is in an *has_habitat* relationship with “l69189”, a lexical unit with the orthographic name *Eis* and class *Substanz*. The relationship is uni-directional.

The lexical entry “l71792” has also been linked with Wiktionary as the following entry from the file *wiktionaryParaphrases-nomen.xml* testifies:

```

<wiktionaryParaphrase
  lexUnitId="l71792"
  wiktionaryId="w19163"
  wiktionarySenseId="0"
  wiktionarySense="Bär mit weißem Fell,
  lebt in den nörd-
  lichen Polargebieten"
  edited="no" />

```

And the lexical unit for *Eisbär* is also part of the interlingual index³ (encoded in the file *interLingualIndex_DE-EN.xml*):

```

<iliRecord
  lexUnitId="l71792"
  ewnRelation="synonym"
  pwnWord="Thalarctos maritimus"
  pwn20Id="ENG20-02049886-n"
  pwn30Id="ENG30-02134084-n"
  pwn20paraphrase="white bear of arctic
  regions"
  source="initial" >

```

As the examples show, GermaNet provides extensive information about the German language,

³GermaNet’s interlingual index stems from the EuroWordNet project, for details see (Kunze and Lemnitzer, 2002).

and our resource has grown considerably in the last 25 years. Purpose-built software is used to update GermaNet’s database (Henrich and Hinrichs, 2010a), and we publish a new release of GermaNet on a yearly basis.

Users of GermaNet can query the lexical resource via Rover⁴, a web-based interface that gives users easy access to all of GermaNet’s content, and also allows users to calculate the semantic similarity between synsets.

2.2 Format Evolution of GermaNet

Since its beginning, GermaNet has undergone several format adaptations and conversions. A first version for an XML-based format of GermaNet was proposed by Lemnitzer and Kunze (2002). The current XML format of GermaNet is largely based on the work reported by Henrich and Hinrichs (2010b), with several extensions since then.

In (Henrich and Hinrichs, 2010b), a conversion from GermaNet’s XML format to WordNet-LMF (Lexical Markup Framework⁵) is given. The conversion helped identifying some representational shortcomings of WordNet-LMF (e.g., the lack of encoding for lexical relations; the lack of entailment relations for synsets; the omission of syntactic frames for word senses), and hence a number of DTD adaptations were proposed to deal with this issue. Note, however, that the WordNet-LMF format has evolved since then, and that the new version⁶ addresses some of these shortcomings.

2.3 Wordnets and their Move to Linked Data

The Princeton WordNet (Fellbaum, 1998) was the first wordnet that was given a representation in RDF.⁷ In 2006, two formalisations were created independently from each other. While Graves and Gutierrez (2006) insist on staying within pure RDF, van Assem et al. (2006) give a representation that makes use of RDF-Schema (RDFS)⁸ and OWL semantics.⁹ In the latter work, classes, sub-classes, and property definitions are explicitly encoded in RDFS, and there are also additional OWL-based restrictions on classes. In this representation it is hence possible to specify that, say, *isAntonym*

is a symmetrical relation, or that a fact such as *isAntonym(160336,1186616)* can be used to automatically derive *isAntonym(1186616, 160336)*.

Recently, the Princeton Wordnet has been forked into the Open English WordNet and given a public repository home on GitHub so that it can be further developed under an open source methodology.¹⁰ There exists a searchable web interface¹¹ and the wordnet can be downloaded in yet another RDF-based format, one which makes use of the OntoLex¹² conceptualisation. Other download formats include WordNet-LMF, a format advocated by the Global WordNet Association, and Princeton’s original format.

There exist linked data wordnets for a number of other languages such as the Danish WordNet¹³, the Dutch WordNet¹⁴, and the Polish Wordnet¹⁵, most of which are directly accessible on a central website.¹⁶ The wordnets are available in JSON-LD¹⁷, OntoLex-based RDF (both using the lemon vocabulary), but also in WordNet-LMF.¹⁸

The benefits of having all wordnets in a common and easily searchable format is demonstrated by a browser-based search interface to the Open Multilingual WordNet¹⁹, where a word can be searched in a selected language, and where the search result can then be used to find semantically equivalent words in the other available languages.

3 GermaNet in RDF

In this section we discuss the design choices of our RDF-based representation of GermaNet. Expressing GermaNet in RDF forces us to express all information in terms of subject-predicate-object triplets.

Clearly, synsets and their lexical entries must be first class citizens of the triple store. It is about these two classes of resources for which GermaNet has an abundance of information. Consequently, they must take the subject position in the triple

⁴<https://weblicht.sfs.uni-tuebingen.de/rover/>

⁵<http://www.lexicalmarkupframework.org>

⁶<https://github.com/globalwordnet/schemas/blob/master/WN-LMF-1.1.dtd>

⁷<https://www.w3.org/RDF/>

⁸<https://www.w3.org/TR/rdf-schema/>

⁹<https://www.w3.org/TR/owl-ref/>

¹⁰<https://github.com/globalwordnet/english-wordnet>

¹¹<https://en-word.net>

¹²<https://www.w3.org/2016/05/ontolex/>

¹³<https://github.com/kuhumcst/DanNet>

¹⁴<https://github.com/cltl1/OpenDutchWordnet>

¹⁵<http://plwordnet.pwr.wroc.pl/wordnet/>

¹⁶<http://compling.hss.ntu.edu.sg/omw/>

¹⁷<http://json-ld.org>

¹⁸<https://globalwordnet.github.io/schemas>

¹⁹<http://compling.hss.ntu.edu.sg/omw/cgi-bin/wn-gridx.cgi?gridmode=grid>

```

PREFIX gn_lex: <https://uni-tuebingen.de/germanet/v16/LexUnit/>
PREFIX gn_syn: <https://uni-tuebingen.de/germanet/v16/synset/>

### https://uni-tuebingen.de/germanet/v16/LexUnit/l71792
gn_lex:l71792 rdf:type owl:NamedIndividual ,
               <https://www.uni-tuebingen.de/germanet/v16/compound> ,
               <https://www.uni-tuebingen.de/germanet/v16/LexUnit> ;
dcterms:identfier "l71792"^^xsd:string ;
gn:artificial "no"^^xsd:string ;
gn:compoundHead "Bär"^^xsd:string ;
gn:compoundModifier "Eis"^^xsd:string ;
gn:compoundModifierCategory "Nomen"^^xsd:string ;
gn:hasEWNRelation "synonym"^^xsd:string ;
gn:hasPWN20Id "ENG20-02049886-n"^^xsd:string ;
gn:hasPWN20Paraphrase "white bear of arctic regions"^^xsd:string ;
gn:hasPWN20Synonym "Ursus Maritimus"^^xsd:string ,
                  "ice bear"^^xsd:string ,
                  "polar bear"^^xsd:string ;
gn:hasPWN30Id "ENG30-02134084-n"^^xsd:string ;
gn:hasPWNWord "Thalarctos maritimus"^^xsd:string ;
gn:hasSource "initial"^^xsd:string ;
gn:hasWiktionaryParaphrase "Bär mit weißem Fell, lebt in den nörd-
                           lichen Polargebieten"^^xsd:string ;
gn:has_habitat gn_lex:l69189 ;
gn:isMemberOf gn_syn:s50724 ;
gn:namedEntity "no"^^xsd:string ;
gn:orthForm "Eisbär"^^xsd:string ;
gn:sense "1"^^xsd:string ;
gn:source "core"^^xsd:string ;
gn:styleMarking "no"^^xsd:string .

### https://uni-tuebingen.de/germanet/v16/synset/s50724
gn_syn:s50724 rdf:type owl:NamedIndividual ,
                 <https://www.uni-tuebingen.de/germanet/v16/synset> ;
dcterms:identfier "s50724"^^xsd:string ;
gn:category "nomen"^^xsd:string ;
gn:class "Tier"^^xsd:string ;
gn:hasMember gn_lex:l199681 ,
            gn_lex:l71792 ;
gn:has_hypernym gn_syn:s50721 .

```

Figure 2: Lexical unit "Eisbär" and its synset in RDF

representation. Given that GermaNet encodes lexical relations between lexical units and conceptual relations between synsets, it is also clear that the two classes of resources can also take the object position. This also holds for expressing the facts that a lexical unit is part of a synset, or that a synset consists of lexical units.

Reconsider the definition of the synset *s50724* in Fig. 1 with its three attributes *id*, *category*, and *class* and its two children, the lexical units *l71792* and *l199681*. The RDF representation of the synset is given at the bottom of Fig. 2. The synset resource *s50724* is given an identifier with the same name (using Dublin Core terminology), and for the other two attributes (as for all others), we have chosen to keep the attribute name of the XML representation as predicate name in our RDF format. Similarly, the XML names for our lexical and conceptual relations are reused in our RDF representation.

The information that a synset has children, or that a lexical unit node has a synset parent node (in XML, this is encoded through hierarchical embedding) is expressed by introducing two newly defined predicates *hasMember* and *isMemberOf*.

Note that the RDF representation of the lexical unit *l71792* has a corresponding predicate *isMemberOf*, so each lemma has a direct link to the synset it is part of. Clearly, this duplicates information, but we wanted instances of *lexUnit* and *synset* to know about their interrelationship.

The information on compounds is directly encoded using the three relations *compoundHead*, *compoundModifier*, and *compoundModifierCategory*, flattening the tree structure in the XML representation accordingly.²⁰

Consider the following lexical relation:

```
<lex_rel name="has_antonym"
  from="l60336"
  to="l186616"
  dir="both"
  inv="has_antonym" />
```

It represents the fact that the lexical unit *l60336* (*Kunstschnee*, engl. *artificial snow*) is an antonym to the lexical unit *l186616* (*Naturschnee*, engl. *natural snow*). In GermaNet, antonymy is a symmetrical sense relation, which is encoded by the attribute value for the relation's direction (*both*). In our conversion to RDF, our algorithm generates two triples for this (only one is shown in Fig. 2).

²⁰Here, we could have chosen to introduce a blank node in RDF, and relating it both to the lexical unit it belongs to and the two relations for modifier and head, respectively, but we opted for the simpler, more readable representation.

Similarly, for the example conceptual relation given above two triples are asserted, namely that the synset *s50724* with the lexical units *Eisbär* and *Polarbär* is a hypernym to *S50721* (*Bär*), and that *vice versa*, the latter synset has as hyponym the former synset (only one direction is shown in Fig. 2).

As with the XML representation, all information is *explicitly* encoded. As a consequence, we have refrained from using RDF-Schema or OWL to define an ontology of classes and relations at all. We require no inference mechanism to infer new information as all information is already made explicit. This does not stop Protégé²¹, an open-source editor for RDF-based ontologies, to infer a number of RDF class statements or OWL-type statements when it is given our large set of triples (e.g., that *lexUnit*, *synset*, and also *compound* are classes and that, for instance, a lexical unit such as *l71792* is an instance of (*rdf:type*) class *lexUnit* (see Fig. 2).

In our RDF-based representation, the entire information relevant for a lexical unit is directly attached to it. The same holds for synsets. Where multiple database queries would be required to obtain the information (or where multiple XML documents need to be looked up), in SPARQL, a simple query with the subject position instantiated to the lexical unit or synset in question (with the predicate and object position kept variable) is needed.

Our conversion takes GermaNet's XML-based serialisation of its database content as a starting point. The conversion has been implemented in Prolog using SWI-Prolog, its built-in library `sgml` for XML parsing and its semantic web library `semweb/rdf11`. The conversion processes all main input files for nouns, verbs, and adjectives, the XML file that defines conceptual and lexical relations, and the ILI and wiktionary files. While those files are being parsed, RDF triples are being asserted. At the end of the process, the triple store is written into a file resulting in 4015172 RDF triples. We have loaded all triples into Protégé and used the software to export them in turtle format, an excerpt of which is shown in Fig. 2.

A SPARQL end-point for the triple store has been tested and deployed as part of the Text+²² research infrastructure.

²¹<https://protege.stanford.edu>

²²<https://www.text-plus.org>

4 Discussion

The Resource Description Framework (RDF) is a representational model that cannot get any more simple. In fact, it almost appears as if the field of knowledge representation with its many high-level representation languages has been given a common, low-level assembly language to which all knowledge can be compiled to. With RDF, each piece of data about some entity can be expressed as a simple statement. This statement consists of a subject (the entity that is talked about), a predicate (the property we would like to attribute to the entity), and an object (the property's value). In RDF, it is important that this information can be combined with information from other sources. For this, the subject must get a unique identifier, preferably a Uniform Resource Identifier that is web-resolvable.

The RDF platform makes it easy to realize the AAA slogan "Anyone can say Anything about Any topic". If two persons say something about the same resource, but they use different identifiers for it, one can combine the varying pieces of information once it is clear that the resource with identifier, say *id-1*, is identical to the resource with, say, identifier *id-2*.²³

As we have said earlier, we have abstained from defining an RDF schema or even OWL vocabulary that would restrict us to express lexical or semantic information about the German language. As a result, we cannot draw a line between valid and invalid RDF statements, but we do not need to draw that line either.

In the past, we have converted GermaNet also to the Lexical Markup Framework (Henrich and Hinrichs, 2010b). The conversion, however, comes with an information loss as the LMF DTD prevented us to express lexical information in a valid format. Where RDF actively promotes the AAA slogan, the LMF DTD imposes a representational straight-jacket that prevents us from encoding all the information we have.

Moreover, the LMF standard is not open but behind an ISO paywall. This makes it hard to access the currently active standard and update our LMF variant of GermaNet according to the new standard. Open standards such as RDF score much better on this aspect as its W3C specification is readable for anyone.

²³In OWL terms, the relation *owl:sameAs* relation between the two resources can be established: `ns1:id1 owl:sameAs ns2:id2`.

In contrast to LMF, RDF requires the use of URIs where synsets and lexical units are universally addressable. This makes it much easier to establish links across wordnets and other lexical resources, making it straightforward to incorporate those statements that others made about a particular entity.

5 Conclusion and Future Work

In this paper, we have described our conversion of GermaNet's XML format to a pure RDF representation. This makes it possible for GermaNet to be part of a linked data cloud that combines rich linguistic information from various, high-quality resources.

Future work includes linking GermaNet with other lexical resources. In part, this is already done, but not in an ideal way. Reconsider Fig. 2 where a lexical unit is also described with information stemming from its interlingual index, for instance, the relation *hasPWN20Id* and *hasPWN20Id*. Here, their literal string values *ENG20-02049886-n* and *ENG30-02134084-n* should be replaced by URIs pointing to the respective RDF representation of the Princeton Wordnet, or its new open source equivalent, the Open English WordNet.²⁴

At the time of writing, our GermaNet resource identifiers are not yet web-resolvable. In the future, an HTTP request to, say, <https://uni-tuebingen.de/germanet/v16/lexUnit/171792>, will return the top part of Fig. 2.

Rover, a web-based user interface for the exploration and visualization of GermaNet data (Hinrichs et al., 2020) is currently using the XML representation and the Java API in the back-end. In the future, we would like to experiment with using a back-end that executes SPARQL queries on the triple store.

The main reason for having an RDF-based representation of GermaNet, however, is to unleash its potential when properly linked to other high-quality lexical sources. In the context of the Text+ project, it is our aim to link GermaNet with the DWDS dictionary of the German language²⁵ and also with the Leipzig Corpora Collection²⁶. There are plans to convert both resources into RDF, which would allow the creation of a linked data cloud for the

²⁴<https://en-word.net/lemma/ice%20bear>

²⁵<https://www.dwds.de>

²⁶<https://corpora.uni-leipzig.de/>

German language. In addition, linkages to both Babelnet²⁷ and the lexicographical data of Wikidata²⁸ will be possible.

In a pilot study, we have started linking GermaNet synsets of type *Ort* (location) to a subset of the *Integrated Authority File* (GND)²⁹ of the German National Library, namely, the subset holding *Geographika* with approximately 4.5 million triples. In this exercise, for instance, the synset *s43887* with its lexical unit *l63714* and its orthographic form *Potsdam* was automatically linked to the entity <https://d-nb.info/gnd/4046948-7> of the GND dataset. The semantic linkage gives users access to a variety of information such as alternative names or lexicalisations (e.g., Bostanium, Potestampium, Pozdam), the geographical coordinates in terms of latitude and longitude, and other information (*Hauptstadt vom Bundesland Brandenburg, kreisfreie Stadt, 993 als Poztupimi urkundl. erwähnt, 1317 Stadt*), hence demonstrating the potential of linked data. In this initial study, 1764 links between GermaNet entries to entities in the subset of the GND dataset were established.

Mapping location entities of one dataset to the locations of another dataset is relatively straightforward. In general, the main task to properly link together nodes from different RDF graphs is – essentially – a word disambiguation task. Our work will build upon [Henrich et al. \(2014b\)](#), where GermaNet senses were linked to wiktionary senses, and [Henrich et al. \(2014a\)](#), where word senses in GermaNet were linked with those in the DWDS Dictionary of the German Language. The linking task will be supported by the WebCAGE corpus ([Henrich et al., 2012](#)).

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²⁷<https://babelnet.org>

²⁸<https://wikidata.org>

²⁹<https://gnd.network>