Compounds in Universal Dependencies: A Survey in Five European Languages

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Abstract

In Universal Dependencies, compounds, which we understand as words containing two or more roots, are represented according to tokenization, which reflects the orthographic conventions of the language. A closed compound corresponds to a single word in Universal Dependencies (e.g. *waterfall*) while a hyphenated compound (*father-in-law*) and an open compound (*apple pie*) to multiple words. The aim of this paper is to open a discussion on how to move towards a more consistent annotation of compounds. The solution we argue for is to represent the internal structure of all compound types analogously to syntactic phrases, which would not only increase the comparability of compounding within and across languages, but also allow comparisons of compounds and syntactic phrases.

1 Introduction

Compounding, as a word-formation process in which two or more words (bases, roots, or stems) are combined to form a new word (Lieber, 2010, p. 43), is used across languages (Štekauer et al., 2012, pp. 51–100). However, the term compound is not only used to refer to words that result from the combination of two words (cf. *flowerpot*) or are outputs of recursive compounding (e.g. German *Jahresabschlussprüfung* 'end-of-the-year audit'), but also to words that are results of compounding happening in conjunction with derivation or conversion (e.g. the German adjective *blauäugig* 'blue-eyed'),[1] and to words that are both direct and indirect derivatives of these compounds (German *Blauäugigkeit* 'blue-eyedness/naiveté'); cf. Bauer et al. (2013, p. 442).

The criteria for defining compounds (and especially distinguishing them from syntactic phrases) vary from language to language, but features with cross-linguistic validity include, besides the requirement of at least two roots, syntactic and semantic compactness. What is not decisive, on the other hand, is spelling. Compounds are spelled as a single word (closed compounds; e.g. *waterfall*), or as several orthographic words joined by hyphens (hyphenated compounds; e.g. *cyan-magenta-yellow-key*) or separated by spaces (open compounds; e.g. *apple pie*).

The present paper surveys how compounds are treated in Universal Dependencies (UD; version 2.12, Zeman et al. 2023). Five languages, namely English, German, Czech, Latin, and Russian, have been chosen for this pilot survey based on the working criteria that for each of the languages (a) at least one treebank is available in UD, (b) a lexical database exists that contains a non-negligible number of compounds (and can be used to identify compounds in the treebanks), and (c) the authors have a sufficient command of it. We show that the current treatment of compounds in UD, which is determined by the languages' orthographic conventions and by UD's tokenization rules, renders compounds difficult to identify in the data, hindering their comparison within and across languages. However, this paper is not limited to the mere unification of compound annotation according to the existing guidelines. Our proposal is to annotate the relations between the compound's component parts by using the syntactic relations already implemented in UD, making the analogy between compounds and multi-word expressions and syntactic phrases explicit, which has already been pointed out in the literature.

The paper is structured as follows. Section 2 briefly summarizes those aspects of the linguistic discussion on compounding that are necessary for understanding the issues presented. An overview

[1] The compound cannot be traced back to *blau* 'blue' and **äugig* '*eyed', because the latter item does not exist in isolation. It is rather analysed as being formed by combining the adjective *blau* 'blue' and the noun *Auge* 'eye' and simultaneously adding the *-ed* suffix to get the compound adjective.

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of the language data resources that contain compounds and are used in the paper is also provided. In Section 3, we describe how compounds are currently handled in UD, exemplifying the general and language-specific problems of compounds. In Section 4, we discuss steps that can be taken to make the annotation of compounds more coherent and to bring it closer to the way syntactic relations are annotated, but without losing the difference between compounding and syntax. Future directions regarding the automation of compound identification and annotation are outlined to some extent. Section 5 concludes the paper.

2 Background

2.1 Compounds in the linguistic literature

Besides the spelling differences mentioned above, the debate over compounding and compounds has been centered around the following topics:

– boundary between compounding vs. derivation, with a special focus on neo-classical formations (cf. ten Hacken 1994, Bauer 2005, among others), and between compounds vs. syntactic phrases and multi-word expressions in particular (Olsen, 2001; Schlücker, 2019);

– part-of-speech (POS) category of the compound and its components: if the components obtained by splitting the compound do not correspond to independently existing words, the POS of the component is determined according to the closest word; if this applies to the head, the compound's POS is different from its head's POS (cf. the distinctions below; for examples, see Section 2.2);

– headedness: if one of the components plays a prominent role, it is considered the head; left-headed compounds and right-headed compounds are distinguished;

– endocentricity vs. exocentricity: the head determines the POS and meaning in endocentric compounds; an exocentric compound is headless or, as Bauer (2001, p. 70) puts it, it is "a compound which is not a hyponym of its own head element";

– relations between the compound's components: in the literature cited below, the compound's internal structure is indicated by brackets, in analogy to syntactic constituent trees;

– syntactic type of the relation between the compound parts: the crucial distinction is whether the components are independent of each other (coordinate, coordinative, additive or copulative are some of the terms used) or whether one depends on the other (subordinate, determinative, etc.).

These features, assigned varying degrees of importance and priority, have been employed to classify compounds. The classifications proposed by Bloomfield (1933), Bally (1944), Marchand (1969), Spencer (1991), Fabb (1998), Olsen (2001), Haspelmath (2002), Bauer (2001), and Booij (2005) are compared by Bisetto and Scalise (2005), who come up with yet another classification, where the relation between the components is used as the first-level criterion[2] and it is followed by the distinction between endocentric and exocentric compounds. Bisetto and Scalise's classification was implemented in annotation scheme of the MorboComp database, which is one of the resources reported on below.

2.2 Compounds in language data resources

The selective list presented here contains language data sources that include a substantial number of compounds along with annotations reflecting various features discussed in the literature.

MorboComp is a multilingual database of compounds covering 20 languages, including the ones in scope except for Czech (Guevara et al., 2006). In Table 1, the annotation provided in MorboComp is exemplified by three nominal Italian compounds composed of words from different POS categories (cf. 2nd and 3rd column). While the first compound (*madrelingua* 'mother tongue') is endocentric with the right component playing the role of head, the latter two are exocentric (and headless). The components are listed as they occur in the compound (8th and 9th column), they may not be existing words (cf. the third compound in the table). While potentially highly useful for the purposes of this paper, as of 2023 the project seems to have been discontinued and the data are not publicly available.

Compounds are also covered by CELEX2, which is a lexical database of English, German, and Dutch (Baayen et al., 2014). Out of all the linguistic annotations provided in this resource, delimitation of the components (and the linking element, interfix, if present), POS of the components, and annotation of the internal structure using nested brackets (cf. (1) to (3)) were the most important for our survey. In the bracketed structures in German, some

[2] The authors speak of grammatical relations: "The grammatical relations holding between the two constituents of a compound are basically the relations that hold in syntactic constructions: subordination, coordination and attribution".

Compound	POS	Struc	Class	End	Head-C	Head-S	1st-C	2nd-C	Gloss
madrelingua	N	[N+N]	SUB	Tru	right	right	madre	lingua	mother+tongue
mano lesta	N	[N+A]	ATT	Fal	none	none	mano	lesta	quick+hand = thief
dormiveglia	N	[V+V]	CRD	Fal	none	none	dormi	veglia	sleep+be awake = dozing

Table 1: Annotation of Italian compounds in the MorboComp database. The compound's lemma (1st column) is followed by its POS category (2nd column), the POS categories of the components (column Struct[ure]), syntactic relation between the components (Class: subordinate/attributive/coordinate), endocentricity (End[ocentric]: True/False), placement of the semantic head (Head-C), placement of the syntactic head (H-S), the form of the first component (1st-C) and of the second one (2nd-C), and the gloss.

morphs are replaced with a representative form (cf. *gang* substituted by *geh*, which occurs in the infinitive *gehen* 'to go' in (1); but in the English example (3) *woman* is not used instead of *women*). Based on these features, $19,304$ compounds were extracted from the German section of CELEX and $6,267$ compounds from the resource's English section.

(1) `Umgangssprache ... Umgang+s+Sprache NxN ... ((((um)[V|.V],(geh)[V])[V])[N], (s)[N|N.N],((sprech)[V])[N])[N] ...`

(2) `Grossmachtpolitik ... Grossmacht+Politik NN ... (((gross)[A],(Macht)[N])[N], ((polit)[R],(ik)[N|R.])[N])[N] ...`

(3) `womenfolk ... women+folk NN ((women)[N],(folk)[N])[N] ...`

The GermaNet compound list (Henrich and Hinrichs, 2011) contains more than 120,000 compounds in its 2023 edition. This source lists for each compound the lemmas of two immediate ancestors from which it was composed ((4) to (6)). The ancestors provided are existing words, not just strings occurring in the compound (cf. (5) where the verb *abbiegen* 'to turn' is given, because **Abbiege* is not a separate word in German). Compounds with more than two roots are split in succession; see (6) where the second ancestor is a compound which is analyzed in a separate entry in the resource. For the first component, two possibilities are given, if both are equally relevant (cf. the action noun *Umfrage* 'survey' and the verb *umfragen* 'to survey' in (6)).

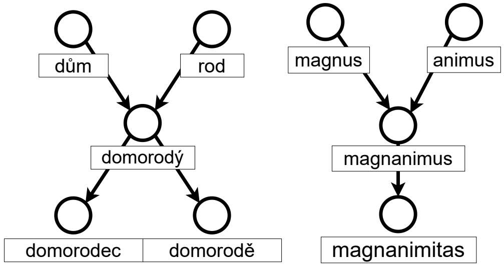
(4) `Umgangssprache Umgang Sprache`

(5) `Abbiegeassistent abbiegen Assistent`

(6) `Umfrageteilnehmer`
`Umfrage|umfragen Teilnehmer`

DeriNet is a lexical database of Czech where words that share a common root are arranged into tree-like graphs according to their morphological structure – from the morphologically simplest words (unmotivated words) to the most complex. The database contains over a million entries, of which less than a half are corpus-attested (432 thousand; only this subset is used in this study). While derivatives are linked to a single ancestor, compounds are connected to two or more ancestors. Additional compounds were identified based on heuristics and lexical lists of compound parts. When the compounds both with and without the links to their ancestors are counted (all of them having the explicit Boolean compoundhood flag set to `true`) together with the derivatives of all these compounds, the number totals to 45 thousand corpus-attested compounds available in DeriNet 2.1 (Vidra et al., 2021). The left graph in (7) shows the unmotivated nouns *dům* 'house' and *rod* 'kin' as ancestors of the adjectival compound *domorodý* 'native', from which the noun *domorodec* 'native man' and the adverb *domorodě* 'in a native way' are derived. All of *domorodý*, *domorodec* and *domorodě* are counted as compounds.

(7)



More than 3 thousand Latin compounds and their derivatives are part of the Word Formation Latin database (Litta et al., 2016). The database is organized in a way similar to DeriNet; cf. the right graph in (7) modeling the Latin adjective *magnan-*

Dataset	Language	Compounds	Total entries
CELEX (Baayen et al., 2014)	English	6,267	52,447
CELEX (Baayen et al., 2014)	German	19,304	51,728
GermaNet (Henrich and Hinrichs, 2011)	German	121,655	215,000
Derinet 2.1 (Vidra et al., 2021)	Czech	45,473	431,857
Word Formation Latin (Litta et al., 2016)	Latin	3,198	36,258
Golden Compound Analyses (Vodolazsky and Petrov, 2021)	Russian	1,699	1,699

Table 2: The databases employed in the present survey for identification of compounds in the Universal Dependencies treebanks of the five languages. The last two columns specify the number of lemmas (types).

imus 'high-spirited' as being formed by combining the adjective *magnus* 'high' and the noun *animus* 'spirit', and giving rise to the noun *magnanimitas* 'high-spiritedness'.

Golden Compound Analyses (Vodolazsky and Petrov, 2021) is a database of Russian compounds compiled for training of a compound splitter. It contains $1,699$ compounds that a re directly traced back to two or more ancestors. The annotation includes the POS category of each compound, the lemmas and POS of each of the components; cf. полувсерьёз 'half serious' in (8).

(8) полувсерьёз,adv,половина,noun,всерьёз,adv

The sources introduced in this section are, with the exception of MorboComp, further used in this survey to gain preliminary quantitative insights into how many compounds are found in the UD treebanks; cf. Table 2 for a summary.

3 Current annotation of compounds in Universal Dependencies

3.1 The annotation guidelines

We start by introducing how words considered as compounds in the literature are treated according to the UD annotation principles (de Marneffe et al., 2021).[3] The application of these rules to each of the languages under survey is described in the following subsections. Syntactic annotation in UD is based on tokenization, which in turn follows the spelling conventions of individual languages. Since the term compound covers words spelled in several ways, compounds are not annotated uniformly in UD:

– Closed compounds, appearing in the text as continuous orthographic words, are handled as discrete, internally unstructured (= atomic) items which enter into relations with other items of the sentence structure. Although the compound's components are linked by similar relations as the constituents of syntactic phrases, these intra-word relations are not captured in UD because "there is no attempt at segmenting words into morphemes".[4]

– Open compounds, which are spelled as two (or more) separate words, are treated as two (or more) items that are arranged into a subtree with the head component as the root and the less prominent item(s) as dependent node(s). The relation between the head and the other component is labeled with the dedicated syntactic relation compound. This relation is assigned to open compounds regardless of the semantic relation between the components (cf. *apple pie* = "pie made from apples" vs. *coffee cup* = "cup for coffee" vs. *water mill* = "mill powered by water", etc.). Besides the bare compound relation, there are 22 subtypes of this relation intended for language-specific phenomena,[5] of which only compound:prt is used in some languages under analysis, namely in English and German. The compound:prt is used for "[p]article verbs where the particle is realized as a separate word (which may alternate with affixed particles), for example Swedish *byta ut* ('exchange'; cf. *utbytt* 'exchanged')".

– Hyphenated compounds are treated in the same way as in open compounds. The hyphen is attached to the head, with the relation label punct.[6]

Annotation of compounds is explored for each language based on all treebanks available in the UD collection (i.e. ten treebanks for English with a total of 46K sentences, four German treebanks containing 208K sentences, six treebanks for Czech with 208K sentences, five Latin treebanks with

[3] See also https://universaldependencies.org/guidelines.html

[4] https://universaldependencies.org/u/overview/tokenization.html

[5] https://universaldependencies.org/ext-dep-index.html

[6] This is the case for the languages in scope, but the claim does not hold for all languages in UD. Swedish hyphenated compounds are for instance handled the same way as closed compounds.

Language	compound relations	Sentences with compound	compound:prt relations	Sentences with compound:prt	Total words	Total sent.
English	22,017 (3,03%)	13,459 (29.27%)	2,485 (0.34%)	2,313 (5.0%)	726K	46K
German	1,787 (0.05%)	1,418 (0.68%)	22,349 (0.59%)	21,897 (10.5%)	3,810K	208K
Czech	2,690 (0.12%)	1,356 (1.06%)	0 (0.00%)	0 (0.0%)	2,222K	128K
Latin	85 (0.01%)	82 (0.1%)	0 (0.00%)	0 (0.0%)	983K	59K
Russian	1,973 (0.11%)	1,812 (1.6%)	0 (0.00%)	0 (0,0%)	1,830K	111K

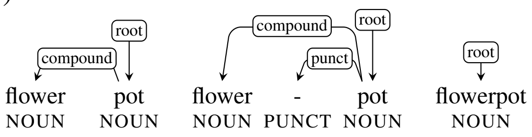
Table 3: The number of sentences containing a compound relation (assigned to open and hyphenated compounds) and sentences with the compound:prt label (with particle verbs) in the Universal Dependencies treebanks of the five languages. The percentage indicates the proportion of sentences with the labels in all sentences of the language's treebanks.

59K sentences, and five treebanks for Russian with 111K sentences). The number of sentences containing the compound relation in the languages' UD treebanks is listed in Table 3. The compound:prt relation is used only in English and German; it will not be further commented upon.

3.2 The UD treebanks for English

Out of the languages analyzed, English treebanks contain the highest number of compound relations, both in absolute numbers and in percentages, owing to the fact that in this language, NOUN+NOUN sequences are analyzed as compounds. English is also a language where these NOUN+NOUN compounds can alternatively be spelled with a hyphen or even without a space as a single graphical word (cf, Table 4), resulting in different tree structures; cf. the textbook example *flower pot* as an open compound with the hyphenated (*flower-pot*) and closed spelling alternative (*flowerpot*) annotated in line with the UD guidelines in (9).

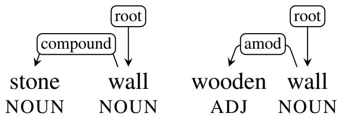
(9)



The compound relation is also assigned to NOUN+ADJ phrases (*emerald green*, *labour intensive*), as well as complex open numerals such as *twenty one*.

Even though the relationship between the components of the open compound *stone wall*, which can be paraphrased as "wall of stones", is the same as the relationship between the adjective *wooden* and the noun *wall* ("wall of wood"), the syntactic relations within these sequences are labeled differently, namely compound in the first sequence while amod in the second; cf. (10).

(10)



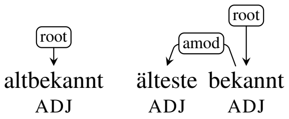
If there were an adjective to the noun *stone* (**stonen*) or if *stone* were considered also as an adjective in English, the annotation would have been no different from *wooden wall*. This is encountered in the phrase *west side*, where *west* is interpreted as an adjective (while the formally identical noun *west* and the formally different adjective *western* exist) and therefore handled as an adjectival modifier (amod) of the nominal governor.

3.3 The UD treebanks for German

German is a language where compounding is widely used, but compounds are typically spelled as compact strings. Nevertheless, both hyphenated compounds (cf. the Anglicism *Trackpad-Click*) and open compounds (NOUN+NOUN sequences, often with proper names; e.g. *Präsident Franjo* 'President Franjo') are documented in the treebanks, both types assigned the compound relation.

In German we also find cases of (here, closed) compounds with the components' relations analogous to those between words in syntactic phrases, but these analogies are not obvious in the current annotation; cf. the compound *altbekannt* 'well-known', which is represented by a single node, and the phrase *älteste bekannt* 'oldest known', which is represented as a tree headed by the second word with the first element linked by the amod relation in (11).

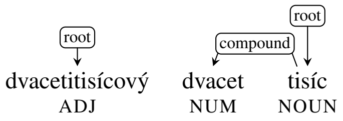
(11)



3.4 The UD treebanks for Czech

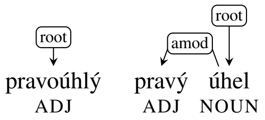
Also in Czech, compounds are commonly written as continuous strings, still a hyphen may connect the components in coordinate compounds. In the data, however, the compound relation appears not only with hyphenated compounds (*indo-australský* 'Indo-Australian'), but also with numeral expressions, which in Czech are separated by spaces.[7] The rightmost component is taken as the head and the other parts are depending on it as modifiers; cf. the right structure in (12). When a numeral construction enters derivation, the output is a closed compound and it is represented by a single node; cf. the adjective *dvacetitisícový* 'twenty-thousand' on the left in (12) which is traced back to the phrase *dvacet tisíc* 'twenty thousand'.

(12)



Similarly, nouns modified by adjectival modifiers can give rise to adjectives with two roots and closed spelling. Cf. the noun phrase *pravý úhel* 'right angle' and the adjectival compound *pravoúhlý* 'right-angled' in (13), which is close to the German adjective *blauäugig* 'blue-eyed' mentioned in the introductory section in that the right component does not exist as a separate adjective (**úhlý* 'angled' similar to **äugig* '*eyed').

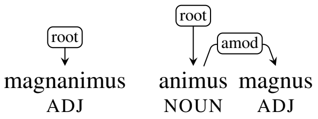
(13)



3.5 The UD treebanks for Latin

Latin treebanks contain the lowest number of compound relations, as documented in Table 3. Its current usage is limited to numeral expressions if they are spelled as separate words in a way described above for Czech, with the addendum that sometimes one of the words is *unus* 'one' labeled as a determiner and not a numeral. Example (14) is also analogous to Czech, documenting an adjectival compound (*magnanimus* 'high-spirited') that is based on a noun phrase (here, more specifically, on a phrase with the head noun preceding the adjectival modifier: *animus magnus* lit. 'spirit high' = 'high spirit').

(14)



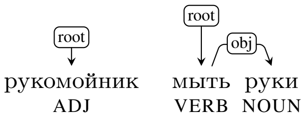
3.6 The UD treebanks for Russian

In the Russian treebanks, the compound relation is – unlike in Czech – applied to "noun compounds (e.g., стресс менеджмент 'stress management, Жар птица 'Fire bird'), but also adjective compounds (e.g., бэд блоки 'bad blocks', мини колонка 'mini speaker', Гранд отель 'Grand hotel') and some other types ("+ 1", "№ 1")".[8] Such NOUN+NOUN compounds and ADJ+NOUN compounds are often loanwords or direct translations of foreign expressions.

In addition, now similarly to Czech and also Latin, the compound relation appears also with numerals (две тысячи 'two thousand') and hyphenated constructions (город-государство; 'city-state').

Noteworthy are compounds which are analyzed as NOUN+VERB structures in the Golden Compound Analyses database. Since they are closed compounds, they are currently represented by a single node in the treebanks, but the relationship between the components resembles the obj relation of the object noun to its governing verb; cf. рукомойник 'washbasin' and the phrase мыть руки 'to wash hands' in (15), or короед 'bark beetle' traced back to есть кору 'to eat bark' and травосеяние 'grass sowing' related to сеять траву 'to sow grass'.

(15)



4 A proposal of a syntax-based annotation of compounds

4.1 Covering all types of compounds and annotating their internal structure

As we have tried to show, the current annotation does not allow to get a complex picture of compounds (as multi-root items) either within one language or across languages. On the one hand, the compound relation only applies to open and hyphenated compounds while closed compounds are

[7] The interpretation of numerals as compounds, though, does not conform to the Czech linguistic tradition.

[8] https://universaldependencies.org/ru/dep/compound.html

not marked in any way. On the other hand, the compound relation is underspecified, without capturing the different relations observed between the components in individual compounds – the exact same label is used for English NOUN+NOUN compounds, which themselves document a variety of internal relationships, and for relations between numerals in Czech, for example.

We now roughly outline a preliminary proposal for a new annotation of compounds in UD that should overcome these issues. Rather than offering an ultimate solution to each individual aspect of compound annotation, we present in our proposal one or more possible solutions based on what we have encountered in the literature or in existing language resources, with our primary goal being to initiate a discussion on this topic.

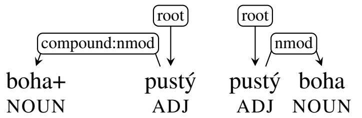
Compounds with all types of spelling should be approached as complex structures that consist of components which are linked by a relationship that is often similar to syntactic relations between words in syntactic phrases:

(a) Closed compounds should be split into their respective constituents for this purpose, and further handled in the same manner as open and hyphenated compounds. Compounds with three and more components will be divided into individual parts (e.g. the above German example *Umfrageteilnehmer* 'survey participant' into *Umfrage+ Teil+ Nehmer*) and their relationships will be captured by arranging them into a tree structure (see the next points). As illustrated, in closed compounds a "+" sign may be used on the first (or on all non-final) components to indicate the original morphological boundary, so that the information on their orthography is retained. An interfix, if contained in a compound, will be part of the preceding component (cf. *Umgangssprache* 'colloquial language' as *Umgangs+ Sprache*).

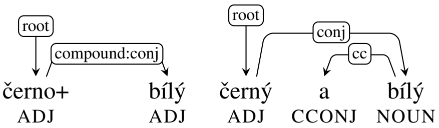
(b) Since such an approach would yield strings that do not exist as separate words (cf. **Abbiege* in *Abbiegeassistent*), we propose – in accordance with the fact that the words in syntactic phrases are treated in this way – to assign a lemma to each component. It can be a full word that is identical with the component (i.e. *Umgang* 'dealing' or *umgehen* 'to deal' and *Sprache* 'language' for *Umgangs+ Sprache*) or close to it (*abbiegen* 'to turn' and *Assistent* 'assistant' for *Abbiege+ Assistent*). Derivatives of compounds would share this lemmatization with their ancestors, e.g. *domorodec* 'native man' would be lemmatized as *domo+ rodý* 'native' (i.e. *dům* 'house' and *rod* 'kin').

(c) All types of compounds should be organized into subtrees in a way analogous to syntactic phrases in UD, making a distinction between subordinate compounds (with the compound's head as the governor and its modifier as its dependent; cf. *bohapustý* 'godless' in (16)) and coordinate compounds (with the first component as the root of the subtree and all the other conjuncts depending on it; cf. *černobílý* 'black-and-white' in (17)).

(16)



(17)



(d) Though the subtree modeling the syntactic structure of a compound's components is proposed to be as close an analogy as possible to the subtrees of syntactic phrases, the relation may retain the compound/phrase distinction. As bare compound relations are not informative, the relations within compounds could be tagged with a compound:<relation> label, where <relation> is an already-existing UD syntactic relation. This restriction regarding forcing compound subtypes into established relations should pertain solely to a) currently bare compound relations and b) closed compounds currently treated as atomic units, **not** to established, already-subtyped relations such as the compound:prt mentioned in Section 3.1. These should not be overwritten, their further usage is neither blocked nor discouraged by our proposal.

How these individual pieces of annotation could be brought into the data is discussed in the next section.

4.2 Steps towards the proposed annotation

Identification of closed compounds. To get a preliminary idea of which part of the treebank data for individual languages would be affected by the proposed annotation, the number of closed compounds in the UD treebanks needs to be estimated in addition to the number of the compound relations (which are in Table 3). In this study, we used the lists of compounds contained in the language resources discussed above in Section 2.2. The figures in Table 4 are heavily conditioned by the size of the resources used. The figures represent a lower

Language	Closed compounds	Total words	Sentences with closed compounds	Total sentences
English	5,934 (0.82%)	726K	5,286 (11.57%)	46K
German	156,629 (4.11%)	3,810K	87,104 (50.14%)	208K
Czech	47,103 (2.11%)	2,222K	34,775 (27.27%)	128K
Latin	26,271 (2.62%)	983K	18,353 (31.27%)	59K
Russian	4,803 (0.27%)	1,830K	4,460 (4.00%)	111K

Table 4: A lower bound estimate of the amount of closed compounds (tokens) in Universal Dependencies, based on searching for the known compounds (and their derivatives) extracted from the data sources listed in Table 2.

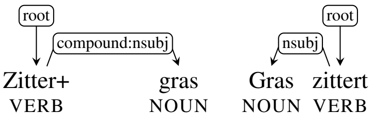
bound for the actual amount of closed compounds contained in UD, since none of the data sources list the compounds from their respective languages exhaustively.

With these limitations in mind, Table 4 suggests that the influence of such a change would be substantial, especially in German, where more than 156 thousand closed compounds were identified, which are part of 87 thousand sentences (i.e. 50% of all sentences). The least affected language by our current estimate would be Russian with less than 5 thousand closed compounds distributed over 4 thousand (4%) sentences; this is due to the relatively low coverage of the Golden Compound Analyses database used as the Russian compound data source in this study (see Table 2). The utilization of resources with higher coverage or another more sophisticated approach could render these numbers substantially higher.

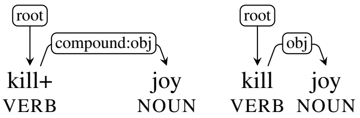
For **splitting of compounds and lemmatization of the components**, the language data sources reviewed above can be taken as a starting point, because they contain high-quality, linguistically adequate material. Whereas CELEX both divides the compounds into substrings and assigns representative forms to its individual parts (cf. *geh* for *gang* above), the other resources provide full-fledged ancestors for compounds that would fit our idea of components' lemmas. Even if the resources for some languages are limited, the existing data can – after unifying the annotation according to the proposal – be used for training automatic tools. A prototype of such a tool, *PaReNT* (Svoboda and Ševčíková, 2022), performs both compound splitting and component lemmatization with decent results on Czech.

Specifying the syntactic structure and assigning syntactic relation labels is another important step for which existing sources provide only very limited data (cf. the bracketed structure in CELEX). Since the pilot manual annotation was based around a mostly mechanical process of finding compound-associated phrases, feeding them into UDPipe (Straka et al., 2016), and observing the relation within the phrase, a semi-automatic procedure is being developed that follows this approach. For example, the German compound *Zittergras* 'quaking-grass' encodes the phrase *das Gras zittert*. The syntactic annotation provided for this phrase by UDPipe is then replicated in the compound, cf. the structures of the compound and of the underlying phrase both with *Gras* as `nsubj` in (18). The English example *killjoy* with the `obj` relation follows in (19).

(18)



(19)



In addition to the examples provided in this section ((16) through (19)), the envisioned annotation scheme is applied to the examples that were presented above in Section 3 – see the Appendix, where the annotation according to the current UD guidelines is shown on the left-hand side and the proposed annotation on the right.

5 Concluding remarks

In this paper, we explored the current treatment of compounds in UD in five languages. We observed that the handling of open and hyphenated compounds varies widely according to the particular language in question, and that closed compounds are taken into account in none of them. Based on these observations and also the long-standing tradition of describing compounds from a syntactic perspective present in the linguistic literature, the objective of the paper was to open a discussion on whether a multilingual annotation scheme for compounds in UD that employs the dependency relations already in use is useful and what features it should have.

The proposed scheme is currently being implemented in the data of the languages under study, and the aim is to extend it to other languages, which will inevitably result in modifications to individual aspects of the scheme.

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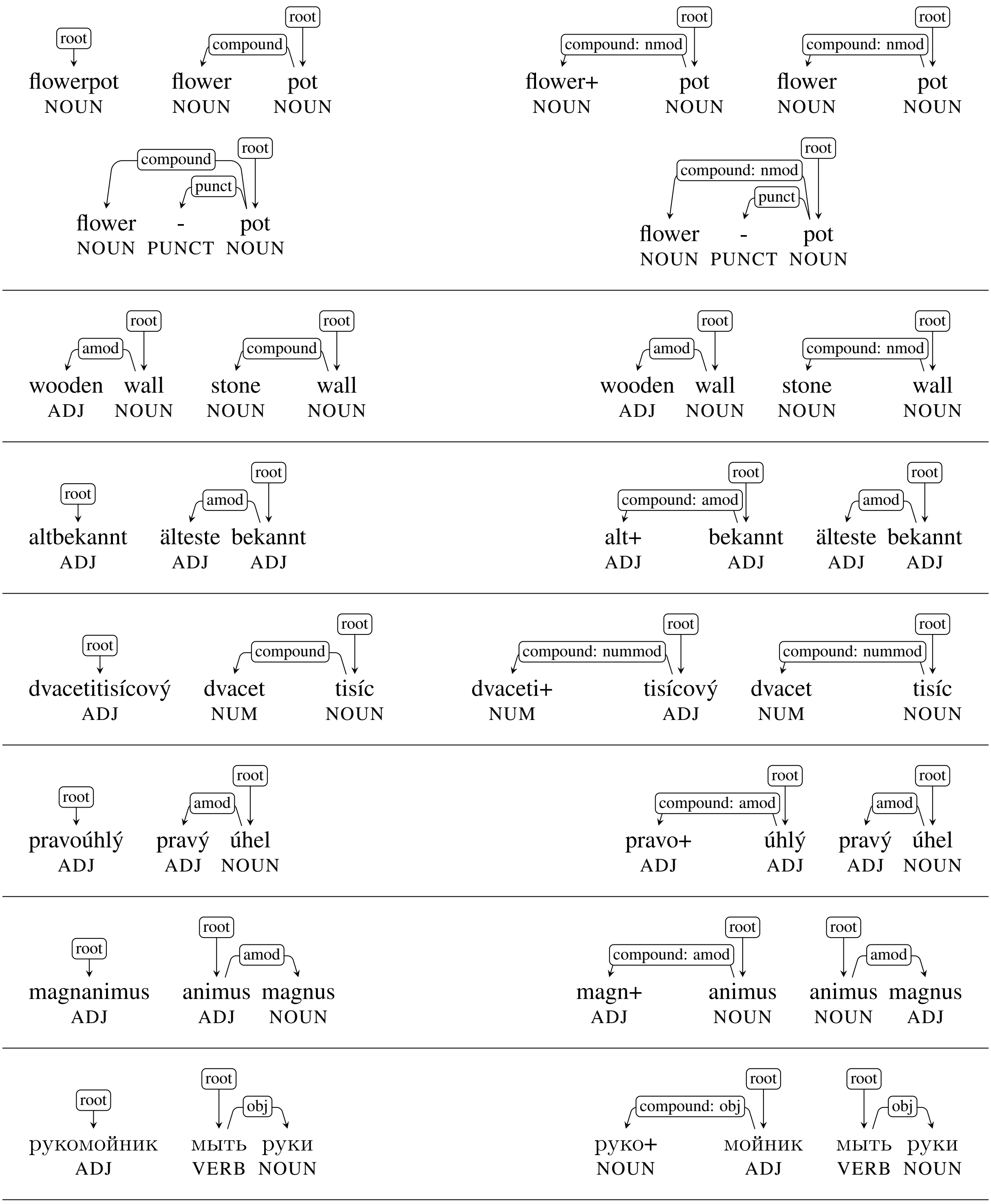
Appendix: Compounds annotated according to the current Universal Dependencies guidelines (left) vs. in line with the proposed annotation scheme (right)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compound
root
flower NOUN
pot NOUN
compound: nmod
root
flower+ NOUN
pot NOUN
compound: nmod
root
flower NOUN
pot NOUN
compound
punct
root
flower - pot
NOUN PUNCT NOUN
compound: nmod
punct
root
flower - pot
NOUN PUNCT NOUN
amod
root
wooden ADJ
wall NOUN
compound
root
stone NOUN
wall NOUN
amod
root
wooden ADJ
wall NOUN
compound: nmod
root
stone NOUN
wall NOUN
root
altbekannt ADJ
amod
root
älteste ADJ
bekannt ADJ
compound: amod
root
alt+ ADJ
bekannt ADJ
amod
root
älteste ADJ
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compound: nummod
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tisícový ADJ
compound: nummod
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amod
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úhel NOUN
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úhlý ADJ
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úhel NOUN
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magnanimus ADJ
root
amod
animus ADJ
magnus NOUN
compound: amod
root
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animus NOUN
root
amod
animus NOUN
magnus ADJ
root
рукомойник ADJ
root
obj
мыть VERB
руки NOUN
compound: obj
root
руко+ NOUN
мойник ADJ
root
obj
мыть VERB
руки NOUN